

Nuclear Physics Practicum Module Based on PhET Simulation Virtual Laboratory to Explore the Abilities of Senior High School/Islamic Senior High School Students

Pretty Oktianti Menur Kusuma Putri¹, Ika Kartika²

¹Departement of Theoretical and Computational Physics, Collage of Physics, Guizhou University, China

²Departement of Physics Education, Faculty of Tarbiyah and Teacher Training, State Islamic University Sunan Kalijaga
Yogyakarta, Indonesia

Email: gs.pretty24@gzu.edu.cn

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Abstract. Research on the exploration of the use of the PhET Simulation virtual laboratory in improving the science process skills of high school students in the second semester of class XII as research subjects. This study aims to examine the results of high school students' science process skills in using Virtual Laboratories due to the absence of facilities and infrastructure that support practicums that were carried out directly before and how they were implemented in the classroom. This research method is a qualitative research using descriptive data analysis. The research begins by analyzing the content of physics material in PhET Simulation to assess its suitability with the high school curriculum and how the simulation stages are available to estimate the type of critical thinking skills developed. With a specially designed virtual practicum module, students conduct virtual practicum on Alpha and Beta Decay according to the procedure and fill in the experimental analysis results into the data analysis results table and then compare them with the theory of alpha decay and beta decay. Based on the results of the researcher's data analysis and previous research reviews, the PhET simulation can be empowered in developing observing, interpreting, predicting, and communicating skills. This shows that PhET Simulation with the help and direction of the virtual practicum module has the potential to be used in improving science process skills for high school students.

Keywords: *PhET Simulation, science process skills, virtual laboratory*

INTRODUCTION

Education is an essential component of life that cannot be separated from it. In the era of globalization and modernization, continuous improvements in the field of education are inevitable. These efforts aim to address the challenges that arise along with the progress of the times. The challenges faced by today's education system include issues of equity, quality, relevance, and effectiveness [1]. To overcome these challenges, Hartono, in the 2020 National Seminar on Educational Technology, emphasized that efforts to boost and enhance the quality of education include ensuring equitable access to education across all regions and aligning the curriculum to effectively support the educational process wherever it takes place [2].

Several factors can influence the effectiveness of a learning process. To enhance both teaching and independent learning, instructional strategies should be engaging and varied. In addition, a supportive learning environment and the optimal use of available learning materials must also be utilized [3]. This is supported by previous research conducted by Risma, which highlights that one option for addressing issues in implementing instruction is the use of learning tools or instructional media [4]. This is further supported by research conducted by Hartawan et al., which found that providing learning materials tailored to students' current needs and characteristics—especially technology-based materials—enables learning to take place more effectively and efficiently [5].

The goal of physics is to understand the laws of nature that are mathematically elegant and beautifully expressed [6]. Very little understanding is gained when physics is taught merely to deliver facts and information to students, and true intellectual freedom is not fostered. Yet it is also of little value to teach the scientific method as a set of procedures detached from the actual content of scientific inquiry [7]. Simply put, physics serves as a universal language for all branches of science. When it is taught merely to deliver facts and information—without cultivating genuine intellectual freedom—very little true understanding is achieved. Broadly speaking, studying physics is more closely related to the process of deriving ideas through the scientific method than to the mere memorization of theories [8].

One learning resource that can be used to complement classroom activities is the module. This printed teaching material can be accessed by students anywhere. A module can also be considered a form of self-learning media because it provides comprehensive, self-directed learning instructions [9]. A module is a

type of teaching resource that is packaged and organized in a comprehensive and systematic manner. It contains a series of planned and tailored learning instructions designed to help students achieve specific learning objectives. Learning goals, instructional content, and evaluation components are all structured and integrated within the module [10].

This is further supported by the fact that laboratory activities are crucial in physics classes because they provide insight into students' outcomes, processes, and scientific attitudes. The ability to grasp the meaning of the material studied—such as summarizing key points from a text or transforming data—is an example of conceptual understanding. Conceptual understanding refers to the capacity to comprehend or explain something after it has been studied or learned [11]. Indeed, experimental activities carried out during the learning process—such as the use of simulations and interactive virtual laboratories—are among the most influential factors in developing conceptual understanding. Students' comprehension of the concepts and laws presented in the simulations has, for the most part, improved as a result of their use [12].

However, the limited availability of equipment and the time required often become constraining factors. When experimental instruments are not feasible for traditional laboratory practice—due to constraints of space, time, or potential hazards—PhET simulations serve as one of the most efficient learning tools [13]. Therefore, the use of PhET simulation media serves as a complementary solution to the inadequacy of actual laboratory facilities and equipment in schools, and can even substitute for the role of a physical laboratory. This is supported by field observation data showing that comprehensive internet access is available at the school, both inside and outside the classroom.

Based on several references and issues identified in previous studies, the researcher selected a topic from Nuclear Physics, in which conducting everyday experiments is relatively difficult due to the involvement of atomic elements in the practicum. This aligns with Sulastris's findings, which indicate that the use of virtual laboratories is most effective when applied to material that is difficult to project or observe in daily life [14].

In relation to the previous research discussed above, several learning difficulties have been identified. Based on a survey of 12th-grade students at MAN 1 Yogyakarta, 79% of students reported that physics is difficult to understand due to the large number of concepts and equations. This situation requires improvement because one aspect of assessing students' learning outcomes is their understanding of the fundamentals of physics. Physics, being an abstract subject, often presents challenges for educators. This is further reinforced by Asrizal's research, which emphasizes that students who achieve quality physics learning will develop strong skills, critical thinking patterns, and systematic analytical methods [15]. In addition, physics education must meet the demands of the times, particularly those of the emerging 22nd century. In line with this, the physics curriculum, in particular, should prioritize the development of general competencies such as teamwork, creativity, communication, character building, literacy, and skill development [15].

According to Putranta, one solution proposed to help students understand physics concepts is the use of PhET Simulation media [16]. This is further reinforced by previous research, which explains that students' ability to demonstrate scientific work in the classroom can be enhanced through learning with PhET Simulations. PhET Simulations are considered more engaging for students and more efficient [17].

This statement can be slightly refined for clarity and flow and is further supported by previous research, which shows that students' ability to perform and demonstrate scientific work in the classroom can be enhanced through the use of PhET Simulations. PhET Simulations are considered more engaging for students and offer a more efficient learning experience [18]. The issues mentioned above represent a fundamental aspect related to teaching materials, namely that they must align with the content being taught. Materials used in previous studies generally fall into the category of content that can be practically applied in everyday life (real-life), meaning that the tools and materials needed for experiments at school or at home are still feasible to use.

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According to field data collected at MAN 1 Yogyakarta through teacher observations and interviews, the use of physics learning media is highly beneficial, particularly in delivering abstract physics topics, such as Nuclear Physics. Nuclear Physics is a subject that is abstract, empirical, and mathematical in nature. Due to these characteristics, virtual tools play an important role in teaching physics, especially Nuclear Physics. Year after year, student achievement in Nuclear Physics remains very low compared to

other physics topics, with only about 35% of students scoring above the minimum competency criteria (KKM).

METHODS

Study area

The research subjects in this study were 12th-grade students (second semester) at MAN 1 Yogyakarta. A limited trial was conducted involving 10 students, followed by a broader trial involving 33 students. The study was carried out to examine the feasibility and effectiveness of a Nuclear Physics practicum module based on the PhET simulation virtual laboratory.

Procedure

This study is a Research and Development (R&D) project that follows the 4D development procedure, which was limited to the Develop stage. The development model consists of several stages: Define, Design, and Develop.

The first development stage is Define, which includes Front-end Analysis, Learner Analysis, Concept Analysis, and Specifying Instructional Objectives. The next stage is Design, which involves Media Selection, Format Selection, and Initial Design. The final stage is Develop, which covers the validation of the physics practicum module, assessment of the module, and student response trials.

During the Develop stage, validation was conducted by material experts and media experts. In addition, feasibility assessments were carried out by material experts, media experts, and physics teachers before the module was tested on students.

Data analysis

The instruments used in this study included observation sheets, interview sheets, validation sheets, assessment sheets, and student response sheets. These instruments were used to collect qualitative and quantitative data regarding the feasibility and effectiveness of the developed module.

The collected data were analyzed descriptively to determine the validity and feasibility of the developed physics practicum module based on expert assessments and student responses.

RESULTS AND DISCUSSION

Results

1. Define

1.1 Front-end analysis

This analysis was conducted through interviews and observations at MAN 1 Yogyakarta. The process began with an interview with one of the 12th-grade physics teachers. Many students experienced learning difficulties in understanding physics material, as evidenced by student achievement: only 43% reached the expected competency level, with an average daily test score (UH) of 73.9, a Mid-Semester Assessment (PTS) score of 60.3, and a Final Semester Assessment (PAS) score of 69.6.

The next step was a material analysis. The researcher conducted two analyses of the material to be developed. First, an analysis was carried out on the curriculum adapted to MAN 1 Yogyakarta. Second, an analysis was conducted on the tools to be used in developing the physics module. The primary tool chosen was the PhET Simulation. Based on this analysis, the researcher selected specific PhET simulations for module development, namely Alpha Decay and Beta Decay.

1.2 Learner analysis

Based on the survey results, 38.2% of students rely on explanations from the teacher, while 61.8% obtain information through the internet. This indicates that students tend to adopt a learning style that utilizes and maximizes digital technology. Furthermore, the use of learning resources such as textbooks, student worksheets (LKPD), or modules is still limited, supported by the availability of learning materials at a ratio of 1:3 per class.

1.3 Concept analysis

The concept analysis conducted by the researcher was based on interviews with the physics teacher at MAN 1 Yogyakarta, observations of the curriculum, and the availability of materials in the PhET Simulations, specifically focusing on Alpha Decay and Beta Decay.

1.4 Specifying instructional objectives

The learning objectives set by the researcher are for students to be able to understand the concepts of alpha decay and beta decay, as well as to comprehend and observe the changes in alpha/beta decay under both single and multiple decay conditions.

2. Design

During the design stage, the researcher developed a basic design to create the product draft. The module's content and format (draft module) were included in the initial design preparation.

2.1 Media selection

Media should be selected in a way that maximizes the use of teaching resources when creating instructional materials for the learning process. The media developed by the researcher is a physics practicum module based on a virtual laboratory using PhET Simulation.

2.2 Format selection

The format for creating this module was chosen using Corel Draw 2020 and Microsoft Word 365, as Microsoft Word 365 is fully capable of supporting module preparation. Its features include typing, text editing, displaying images, image editing, designing the layout, and arranging the overall format.

2.3 Initial design

Based on the previous stage, namely format selection, an initial product was created in the form of the Physics I Practicum Module, along with the preparation of research instruments that were subsequently validated by instrument experts.

3. Develop

3.1 Validation of the physics practicum module

The validation process by the validators was carried out by completing suggestion and feedback sheets, as well as statements of validity, resulting in instruments that were deemed valid for measuring the intended criteria.

Material experts validated the physics module for the accuracy of the physics content presented. The researcher made improvements regarding the use and selection of words that are easy for students to understand.

Revisions based on feedback from the media expert included improvements in color consistency and the placement of image credits.

3.2 Assessment of the physics practicum module

The assessment data were initially qualitative and then converted into quantitative data. The results of the physics module quality assessment by the material experts are shown in Table 1.

Table 1. Results of the Feasibility Assessment of the Physics Practicum Module

Aspects	Material Expert	Media Expert	Physics Teacher
Material Feasibility	3.70	0	4
Presentation Aspect	3.90	0	4
Graphic Aspect	0	3.78	4

Note: The score scale ranges from 1 (very poor) to 4 (very good).

The average score for the module's material feasibility aspect was 3.85, classified as Very Good. In the presentation aspect, the average score was 3.95, also classified as Very Good. In the graphic aspect, the analysis yielded an average score of 3.89.

3.3 Student response test

The student response test was conducted in two stages: a limited trial and a broader trial. The questionnaire covered aspects such as appearance, user-friendliness, and module content.

Table 2. Results of Student Responses to the Physics Practicum Module

Aspects	Limited Trial	Broad Trial
Appearance	0.94	0.99
User-Friendliness	1.00	0.99
Module Content	1.00	0.97

Note: The values represent the average student response scores obtained from limited and broad trials.

Overall, the combined average score for all aspects in both the limited and broad trials was 0.98, categorized as Agree (A).

Discussion

The results of this study indicate that the development of a nuclear physics practicum module based on the PhET Simulation virtual laboratory is feasible for use in physics learning at the senior high school level.

The validation results from material experts, media experts, and physics teachers show that the module meets the criteria of being very good in terms of material feasibility, presentation, and graphic aspects.

The integration of PhET Simulation into the practicum module provides students with opportunities to explore abstract nuclear physics concepts through interactive visualization. This approach helps students better understand alpha decay and beta decay processes.

Furthermore, the positive responses obtained from students during both the limited and broad trials indicate that the module is easy to use, visually appealing, and helpful in supporting the learning process. These findings suggest that virtual laboratory-based learning modules can serve as effective learning resources, particularly in situations where access to real laboratory equipment is limited.

CONCLUSION

This study produced a teaching material in the form of a Physics Practicum Module based on the PhET Simulation virtual laboratory for Nuclear Physics, which can be used as a self-learning resource. The developed product was based on a needs analysis, which included analyses of the school, students, and curriculum at MAN 1 Yogyakarta. The results of this analysis then guided the selection of the teaching material, resulting in the development of a physics practicum module utilizing the PhET Simulation virtual laboratory.

REFERENCES

- [1] Mukminan, "Tantangan pendidikan di abad 21," *Jurnal Pendidikan dan Pembelajaran*, vol. 4, no. 1, 2020.
- [2] M. R. Hartono, "Kesenjangan lembaga pendidikan wilayah perkotaan dengan wilayah terpencil," *Jurnal Pendidikan dan Kebudayaan*, vol. 3, no. 2, 2022.
- [3] Astuti and Y. Bhakti, "Developing adobe flash based mathematics learning media for 7th grade students of junior high school," *Journal of Physics: Conference Series*, vol. 1188, no. 1, pp. 134–156, 2021.
- [4] Risma, "Pengembangan bahan ajar interaktif dengan pendekatan saintifik bermuatan nilai-nilai karakter pada materi hukum newton kelas x sma ma," *Jurnal Pendidikan Fisika*, vol. 12, no. 1, pp. 81–88, 2019.
- [5] I. M. Hartawan, I. D. K. Tastra, and I. M. Pudjawan, "Pengembangan portal e learning berbasis moodle pada mata pelajaran fisika kelas x di sma dwijendra denpasar," *Jurnal Teknologi Pembelajaran Indonesia*, vol. 2, no. 1, 2022.
- [6] P. Razi, "Hubungan motivasi dengan kerja ilmiah siswa dalam pembelajaran fisika menggunakan virtual laboratorium kelas x sman kota padang," *Jurnal Pendidikan Fisika Indonesia*, vol. 6, no. 2, 2022.
- [7] N. E. Agusti and B. Jatmiko, "Keefektifan pembelajaran fisika dengan model inkuiri terbimbing berbantuan PhET interactive simulations untuk meningkatkan kemampuan berfikir kritis siswa sma," *Jurnal Inovasi Pendidikan Fisika*, vol. 6, no. 2, 2022.
- [8] Irwandani, "Multi representasi sebagai alternatif pembelajaran dalam fisika," *Jurnal Pendidikan Fisika*, vol. 3, no. 1, 2020.
- [9] Direktorat Pembinaan Sekolah Menengah Atas, *Panduan Pengembangan Bahan Ajar*. Jakarta, Indonesia: Direktorat Jenderal Manajemen Pendidikan Dasar dan Menengah, Departemen Pendidikan Nasional, 2008.
- [10] P. A. Cansraningrum, "Development of physics learning module with simulation PhET on gravitation material for class 11st senior high school in sma negeri 1 mlati," 2019, undergraduate Thesis, UIN Sunan Kalijaga Yogyakarta.
- [11] A. H. Maksum and Y. Saragih, "Analisis penerapan virtual laboratorium versus reality laboratorium," *Jurnal Pendidikan Fisika*, vol. 17, no. 2, pp. 47–52, 2020.
- [12] S. R. Muzana and D. Astuti, "Penerapan pembelajaran berbasis simulasi PhET untuk meningkatkan pemahaman konsep fisika inti pada siswa sma," *Seminar Nasional Pendidikan Fisika*, pp. 409–417, 2019.
- [13] R. Haryadi and H. Pujiastuti, "PhET simulation software based learning to improve science process skills," *International Journal of Scientific and Technology Research*, pp. 1–6, 2019.
- [14] Sulastri, "The use of virtual laboratory in physics learning," *Jurnal Pendidikan Fisika*, vol. 8, no. 2, pp. 100–108, 2020.
- [15] Asrizal, A. Ananda, and Khairani, "Effectiveness of integrated science instructional material on pressure in daily life theme to improve digital age literacy of students," *Journal of Physics: Conference Series*, vol. 1006, p. 012031, 2018.
- [16] H. Putranta, "Physics learning by PhET simulation assisted using problem based learning model to improve students critical thinking skills in work and energy chapters in man 3 sleman," *Momentum: Physics Education Journal*, vol. 20, no. 1, pp. 1–44, 2019.
- [17] Dolokasribu, "The reconstruction model of science learning based PhET problem solving," *Journal of Physics Learning Research*, vol. 3, no. 1, pp. 37–47, 2021.
- [18] H. Hamid, *Pengembangan Sistem Pendidikan Di Indonesia*, 1st ed. Bandung: Pustaka Setia, 2013.