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Digital-Based Photoelectric Effect Practicum Toolkit: Curriculum and Student Analysis

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Abstract: Physics education study programs at several private universities in South Sulawesi are still limited in implementing Modern Physics practicum. The implementation of Modern Physics practicum at College A is limited to three practicum units, while College B has never held a Modern Physics practicum. This is because college B does not yet have a modern physics laboratory and practicum unit. Therefore, researchers developed modern physics practical tools. The Modern Physics practicum device is designed using Arduino Uno which is equipped with a digital practicum module. The aim of this research is to describe the stages of definition in aspects of curriculum analysis, beginning and end, and student needs. This research is research and development using the 4D-Thiagarajan model. Research data was analyzed descriptively. The results of the research show that one of the important Modern Physics practicum contents according to course achievements is the Photoelectric Effect. It is hoped that the development of the Photoelectric Effects practicum equipment can become a learning medium for students and a precursor to the development of other Modern Physics practicum units at the two universities.

Keywords: Arduino uno; Curriculum analysis; Modern physics; Photoelectric effect; Practicum tools

Introduction

For students studying physics education, a modern physics course is required. The Modern Physics course has a weight of 3 theoretical credits. Modern physics is a bridge course for studying microscopic systems in physics for atomic nuclei, atoms, molecules, solids, nuclear physics, and laser theory (Park et al., 2019). Particles moving at speeds similar to the speed of light, $3x10^8$ m/s, are also studied in modern physics. (Balta & Eryılmaz, 2020). Students need to understand Modern Physics material properly and correctly, as a first step to understanding advanced Physics courses, such as quantum physics, statistical physics, introductory solid state physics, and introductory core physics (Aksakalli et al., 2021; Saehana et al., 2018).

Abstract and microscopic concepts like the idea of the photoelectric effect, represent most of the information of modern physics. (Levrini & Fantini, 2013; Yeşildağ Hasançevi & Günel, 2013). The photoelectric effect examines the Planck constant in determining standards for measuring electricity and mass. The photoelectric effect is a phenomenon when electrons are released because the frequency of the photons is greater than the frequency of the metal that is exposed to light (Maria Umma & Sucahyo, 2017). It was further explained that in the event of the photoelectric effect, light is not only considered as an electromagnetic wave, but also as an energy carrier (Hamzah et al., 2022). Therefore, modern physics courses must be supported by practicum Darmaji et al. (2019), in order to be able to cover abstract and microscopic concepts from modern physics content (Rianti et al., 2020). Practicum activities have a very big role in building an understanding of concepts Khasanah et al. (2017), verification of the correctness of the concept, growing student process

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skills, growing motivation to learn and training psychomotor abilities (Riskawati & Marisda, 2020).

Preliminary research found that college A had carried out modern physics practicum, but was limited to three practicum units. Meanwhile, Higher Education B, which is a research partner, has never carried out a Modern Physics practicum. Therefore, the researchers designed a physics practicum unit that was equipped with a digital practicum module. The photoelectric effect practicum device which is a research and development product will be used in the physics education laboratory of College A and one other unit will be used in College B.

In addition to designing the photoelectric effect practicum unit, the research team also designed a digital practicum module to support the use of practicum tools and practicum guides for physics education students. The learning device in the form of a digital practicum guide module presented in the form of a flipbook has several advantages such as being easily accessible to students (Nurlina et al., 2022), there is no need to print and reproduce it manually, thereby reducing student costs for duplicating practicum modules (Marisda et al., 2023). In addition, the digital practicum module is more up-to-date Marisda et al. (2022), and has adapted to the current developments in digital technology (Marisda et al., 2020).

Method

This research is development research, which refers to the 4D-Thiagarajan development model. The stages in the 4D-Thiagarajan development model are Define, Design, Develop, and Disseminate (Sugiyono, 2019). However, this article will only discuss the defined stages in a limited way which aims to find out the fundamental problems in the development of digital-based modern physics practicum devices. Define stages in developing research on digital-based Photoelectric Effect practicum devices are presented in the following figure 1.

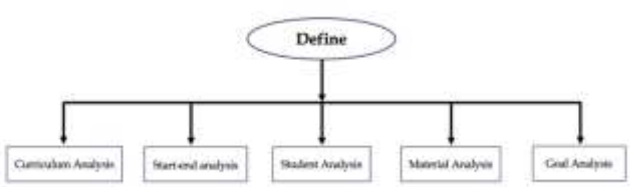

Figure 1. Define stages of the development of modern physics practicum tools

The data obtained in this research is descriptive data that analyzes the Modern Physics course curriculum, students, the selection of practicum content, and the objectives of the developed practicum. Two representatives of colleges with study programs in physics education were included in the research sample applying the incidental sampling approach. Incidental sampling is a sampling method in which the sample is found by chance with the researcher and matches the researcher's criteria (Kan & Murat, 2020). The criteria for higher education institutions used as samples in this study are private tertiary institutions, located in a city in South Sulawesi, have been established for more than five years, apply the Indonesian National Qualifications Framework curriculum, and are oriented towards an independent learning curriculum. Based on the criteria set by the researcher, the sample for this research is College A and College B.

The research instrument used was a non-test instrument in the form of observation sheets and interviews Ediyanto et al. (2022), given directly (offline) to College A and College B. At the observation stage, the researcher observed the process of Modern Physics lectures for six meetings. Criteria for researchers' observations include learning strategies or models, lecture teaching materials, learning methods (integration of lectures with practicum), Modern Physics laboratory conditions, and the number of Modern Physics practicum units. Five lecturers for the Modern Physics course, including lecturers from College A and University B, were interviewed. The lecturers teaching methods and resources over the previous three years were considered as indicators for the interview questions. The interviews conducted were unstructured interviews or open interviews (Roberts, 2020; Roulston & Choi, 2018). In addition to interviewing the subject lecturers, the researcher also randomly interviewed five students from Universities A and B to complete the acquisition of research data.

The observation sheets and draft interview questions were validated before being used. Validity analysis uses Aiken's validity. The validity of Aiken proves the validity of the contents of the instrument with the number of rating categories determined by the researcher (Aiken, 1980), reliability testing with Interclass Correlation Coefficient (ICC). The test instrument was declared valid with a V_{Aiken} coefficient of 0.75 and reliable with a coefficient of 0.8 and ICC excellent. The data obtained from observations and interviews will then be explained descriptively, by collecting the data obtained according to the indicators set by the researcher, then classifying, and analyzing the data, which culminates in making conclusions for each stage of the defined 4D-Thiagarajan stage.

Result and Discussion

The data obtained are descriptive data in the curriculum analysis, beginning-end analysis, student analysis, task analysis, material analysis, and objective analysis. The following provides an explanation for each part of the development stages at the defined stage. Curriculum analysis from the define stage considers several aspects Febrian et al. (2021), namely the analysis of government policies King et al. (2017), the demands of the Indonesian National Qualifications Framework curriculum Wahyu et al. (2020), and adjustments to the current curriculum (freedom of learning), the demands of the 21st Century on the learning outcomes of the Physics Education Study Program. Learning Outcomes Graduates of the Study Program consist of aspects of attitude, general skills, and knowledge (Sitepu & Lestari, 2018). The description of the learning outcomes of the graduates is presented as follows.

Table 1. Learning Achievements of Study Program Graduates

Domain	Learning Outcome Program
Attitude	Fear of God Almighty and able to show a religious attitude, Demonstrate a responsible attitude towards work in their field of expertise independently.
Skills	Able to demonstrate independent, quality and measurable performance, Able to make appropriate decisions in the context of solving problems in their area of expertise, based on the results of information and data analysis, Able to take responsibility for the achievement of group work results and supervise and evaluate the completion of work assigned to workers who are under their responsibility
Knowledge	Understand the theoretical concepts of classical and modern (quantum) physics in general

Initial final analysis shows that at College A, the three-credit weighted Modern Physics course is complemented by a two-credit weighted Modern Physics internship completed in same semester, i.e. in semester five. Modern Physics Practicum consists of three practicum units. While at Higher Education B, the Modern Physics course has a weight of 3 credits, is carried out in the fifth semester, and does not have a supporting practicum for the Modern Physics course, nor is it integrated into Modern Physics (theory) lectures. Student analysis describes the matrix of the relationship between the graduate profiles of physics education study programs and the learning outcomes of study program graduates. The data can be seen in Table 2.

From the learning outcomes of the courses, the lecture material is described which is arranged systematically so that learning is more directed Imanda et al. (2022), and organized (Rezeqi et al., 2020). Not all of the lecture material is listed in the lesson plan, only some of the essential material covers (Syafarina & Setiawan, 2019). The essential material has a certain classification of teaching materials that is suitable for Physics Education students. Based on these considerations, the lecturer chooses which teaching materials will be presented in the lecture planning that has been formulated previously as a frame of reference.

Table 2. Graduate Learning Achievements in Modern Physics Courses

CPMK	Course Learning Outcomes
CPMK 1	Applying the theoretical concepts of Modern Physics, the theory of relativity, and quantum theory independently and responsibly,
CPMK 2	Solving mathematical problems independently and responsibly.

Table 3. Coverage of Teaching Materials for Modern Physics Lectures

Subject	Teaching Materials
Galileo's theory of relativity	Terms of reference Newton's laws The Michelson-Morley experiment Lorentz transform Speed transformation Simultaneous State Lorentz contractions Time Dilation Doppler effect
The nature of particles and waves	Photoelectric Effect The Compton effects X-rays X-ray diffraction De Broglie waves Wave Function Particle Diffraction The principle of uncertainty
atomic models	Nuclear Atoms Electron Orbits Bohr's Atomic Theory Energy Levels and Spectra
Hydrogen atom in quantum mechanics	Bohr's Hydrogen Atomic Theory The franck-Hertz experiment
Atoms with many electrons	Electron spin Periodic table Atomic Structure Total Angular Momentum

The results of the material analysis show that the essential material in Modern Physics is what distinguishes it from classical physics, namely the dualism of wave particles. Therefore, the research team and partners chose to design a Modern Physics practicum device on the Photoelectric Effect content. The photoelectric effect is the ejection of electrons from a surface Levrini & Fantini (2013), (usually metal) when that surface is exposed to and absorbs electromagnetic radiation Michelini et al. (2014), (such as visible light and ultraviolet radiation) that is above a threshold frequency depending on the type of surface. (Maria Umma & Sucahyo, 2017; Qian, 2023). The photoelectric effect practicum device will use Arduino Uno in its assembly, while the practicum module is made in digital form using a flipbook application. Digital devices make it easier for students to access teaching materials (Berlian et al., 2023).

Conclusion

The essential material in Modern Physics is the wave-particle dualism. So that the practicum developed is a photoelectric effect practicum that uses Arduino Uno in its assembly. The photoelectric effect practicum module is made digitally with a flipbook application so it doesn't require printing costs. The next stage in this research is to design a digital-based photoelectric effect practicum device. With the development of the photoelectric effect practicum device, it is hoped that it will become the forerunner to the development of research on the development of Modern Physics practicum devices for Physics education students.

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Conflicts of Interest
The authors declare no conflict of interest.

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