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The Effectiveness of Using Smartphones as Mobile-Mini Labs in Improving Students' Beliefs in Physics

Tanti [1*)], Deliza [2], Siti Hartina [3]
UIN Sulthan Thaha Saifuddin Jambi, Indonesia[1,2], Universitas Jambi, Indonesia[3]
[*)]Corresponding E-mail: tanti@uinjambi.ac.id

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ABSTRACT
This study aims to determine the efficacy of using smartphones as portable mini-labs to improve students' beliefs about physics. This study takes a hybrid approach, using an exploratory mixed-method research design. The qualitative step entails creating teaching resources as a laboratory manual focusing on momentum and impulse. Simultaneously, the quantitative phase evaluates the usefulness of using smartphones as mobile mini laboratories to improve students' beliefs about physics and the process of learning physics using a quasi-experimental, non-equivalent control group design. According to the research findings, the laboratory manual developed during the qualitative stage has been declared valid and appropriate for learning by expert validators and teacher practitioners. Furthermore, using smartphones as portable tiny laboratories in physics teaching significantly improves students' beliefs about physics, notably the dimension of real-world connection, which has grown significantly. This research will have favourable implications for enhancing beliefs and proficiency in physics topics and cultivating students' interpersonal and communication abilities. Laboratory activities are crucial since they provide students the chance to partake in diverse genuine scientific procedures, including the design and execution of experiments, the gathering and analysis of data, and the dissemination of scientific knowledge.

INTRODUCTION

Physics, one of the older filed of science, is widely acknowledged as a crucial factor in attaining sustainable development goals [1]. The challenges faced in the 21st century, such as global climate change, high population density, the diminishing availability of water and energy, and the effective management of natural resources, necessitate international cooperation and the utilization of scientific and technological advancements. One such advancement is the development of physical science. Physics, although crucial for attaining sustainable development, is not widely favored by students. The nature of physics knowledge, mainly including abstract concepts and necessitating idealization through mathematical modelling, establishes physics as a challenging subject to learn and teach [2] [3]. In order to address challenges encountered in the field of physics education, scientists in the realm of science education employ a multiperspective framework to comprehend the impact of students' social and individual factors on the learning process. One aspect of this framework involves examining the influence of students' beliefs on their learning activities and academic performance [4] [5] [6].

Beliefs refer to the perceptions held by students on the attributes of physics knowledge and the process of acquiring physics [7]. Furthermore, Hammer & Elby [7] highlighted that students who hold the notion that the organization of physics knowledge is logical and prioritizes comprehension are more likely to exhibit a positive attitude towards physics. According to Sahin [8], students' beliefs can be established, altered, and reinforced. The findings of the study conducted by Greene et al [9] indicate that teachers have a significant impact on nurturing students' self-assurance and achievement in the field of physics. Teachers must use proper approaches, strategies, or methods for teaching the topic in order to convey the idea that physics is not merely abstract and formulaic. One such way is doing practical experiments in the laboratory, providing students with a hands-on experience. Laboratory sessions have a crucial role in the acquisition of knowledge of physics, as they enable students to comprehend concepts and establish connections between theoretical learning and practical applications in the real world [10]. Regrettably, the conduct of practical activities in laboratories is frequently hindered by limitations on the accessibility of sufficient laboratory facilities and infrastructure at educational institutions. Nevertheless, this challenge can be surmounted by employing strategies, devising plans, executing them, and assessing the effectiveness of learning using technology, sometimes referred to as technology-enhanced learning (TEL).

Smartphones have recently gained popularity as a technique of incorporating technology into teaching methods, often known as technology-enhanced learning (TEL) [11]. Furthermore, Liu et al [11] emphasize that smartphones are among the computing devices held by nearly all students and faculty. The present advancement of mobile device technology, which includes built-in electronic instruments and sensors, opens up new opportunities for conducting physics experiments. Several sensors integrated into smartphones, including accelerometers, GPS, compasses, microphones, magnetometers, and gyroscopes, allow them to be used in physics experiments. According to González et al [12], the potential for using smartphones or tablets in physics experiments considerably outstrips the reach of remote laboratories, let alone conventional laboratories. Several research has been carried out to investigate the use of smartphones as a low-cost, practical solution in physics education. Kuhn & Vogt [13] investigated the influence of smartphone-based physics experiments using acoustic instruments on students' learning motivation using a quasi-experimental research approach. Monteiro et al [14] undertook an additional study, designing a physics practicum to investigate the effects of light polarization and Malus' Law using a smartphone's light sensor. Rediansyah [15] undertook R&D research with the primary goal of producing a manual model for high school physics experiments using smartphone sensors to increase knowledge of physics ideas. Furthermore, the usefulness of using smartphone-based laboratories in physics learning was investigated, with promising results in the development of research skills among students [16]. These studies demonstrate the potential of smartphones as a tool for supporting practical activities and experimental data observation in physics learning.

Using smartphones as mobile mini-labs for studying physics is a novel and valuable educational innovation. However, the availability of engaging experiment guidebooks is also critical to maximizing the usefulness of smartphones as mobile mini-labs. This intriguing experiment guidebook will give students clear and structured instructions for experimenting with smartphones. An excellent experiment guidebook will include experiments that are relevant, exciting, and aligned with curriculum requirements, allowing students to comprehend physics concepts better. Aside from that, an intriguing experiment guidebook can provide a detailed description of the experiment's aim, implementation stages, data analysis, and necessary conclusions with a complete experiment guidebook and pictures employed in each experiment. Thus, combining smartphones as mobile mini-labs with attractive experiment guidebooks will create a more dynamic, fascinating, and compelling physics learning experience for students.

Despite the fact that smartphones offer a low-cost physics laboratory solution, their use at the high school level in Jambi Province still needs to be improved. This study will examine the effectiveness of employing smartphones as mobile mini labs in enhancing students' beliefs about physics and physics learning based on the presentation of these empirical facts. This study will have a positive impact not only on enhancing students' beliefs and knowledge of physics ideas but also on developing their soft skills. Laboratory activities are essential because they allow students to participate in authentic scientific procedures such as developing and building experiments, collecting and interpreting data, and communicating scientific knowledge.

METHOD

The primary objective of this study is to investigate the effectiveness of utilizing smartphones as portable mini laboratories to enhance students' beliefs regarding physics and the process of studying physics. In order to accomplish the research goals, the researchers employed an exploratory mixed-method research design. Creswell & Clark [17] define exploratory mixed-method study design as a two-part process comprising a qualitative step and a quantitative stage. The justification for employing this design is rooted in the necessity of creating experimental designs and developing educational resources like physics experiment guidebooks to enable using smartphones as portable mini-labs. Thus, during the preliminary phase of the study, a qualitative investigation was conducted by devising physics experiments about everyday phenomena. These experiments employed the accelerometer and microphone sensor to measure contact duration and acceleration, determine impulses, and quantify a bouncing ball’s energy loss. The subsequent phase involves investigating the efficacy of smartphone utilization through a quasi-experimental design with a non-equivalent control group.

RESULTS AND DISCUSSIONS

The objective of this study is to assess the effectiveness of utilizing smartphones as portable mini-laboratories in enhancing students' beliefs towards physics and their understanding of physics concepts. During the preliminary phase of the study, researchers created educational resources in the shape of a smartphone-based experiment manual that serves as practical guides for understanding momentum and impulse concepts. The inception of the experiment manual involved conducting observations of the learning process and interviews with the teacher and four students who possessed diverse academic backgrounds and cognitive skills. Observational empirical data indicates that students' level of active engagement in the learning process needs to be higher. The majority of pupils favour passively acquiring information through teacher explanations. In addition, the physics education in class X MIPA SMA NEGERI 14 Sarolangun primarily emphasizes the transmission of theoretical knowledge. As per the physics teacher at SMA NEGERI 14 Sarolangun, the physics practical sessions are conducted a maximum of two times per semester. The scarcity of functional equipment in the science laboratory at SMA NEGERI 14 Sarolangun is the primary factor contributing to the infrequent implementation of practical physics activities. Teachers expressed a strong interest in utilizing smartphones as an affordable and effective solution, specifically for practical physics teaching. The interviews conducted with students exposed a notable deficiency in both their interest and motivation towards the study of physics. Physics is widely regarded as a challenging discipline by students due to its complex nature and extensive reliance on mathematical concepts. Monotonous delivery of material in class is a contributing factor to the decline in student interest and motivation in studying physics.

Researchers surveyed to assess students' beliefs towards physics. The survey used the CLASS (The

Colorado Learning Attitudes about Science Survey) questionnaire. The examination of the CLASS questionnaire indicates that the dimensions of personal interest and conceptual connections have the lowest average scores. The personal interest dimension assesses students' opinions of the appeal and practicality of learning physics. In contrast, the relationship between ideas dimension evaluates students' comprehension of the logical and interconnected nature of physics knowledge. The below-average scores of students on these two criteria indicate that students' attitudes and views towards the discipline of physics as a whole still need to be higher. Students' attitudes and perceptions regarding physics play a significant role in shaping their comprehension of physics topics and their ability to solve physics issues [18]. According to Ibrahim et al [19], a contributing factor to students' negative attitudes or opinions regarding physics is the absence of a meaningful link between the content taught in physics courses and real-world applications, which renders physics abstract and inconsequential. The study conducted by Belay et al [20] asserts that teachers can foster favourable attitudes and views about physics among students by establishing a classroom environment that is enjoyable, captivating, and comprehensible. Furthermore, Carroll & Lincoln [21] asserted that doing experiments in the context of physics education fosters an interactive learning atmosphere, promotes the cultivation of students' social connections, and enhances students' aptitude for problem-solving and comprehension of physics principles.

According to a curriculum analysis, physics instruction at SMA NEGERI 14 Sarolangun is now based on the updated 2013 curriculum. The development team opted to create a smartphone-based physics experiment manual on momentum and impulse material after reviewing core competencies (KI), basic competencies (KD), indicators, and the breadth and depth of the material. Understanding momentum and impulse material is critical for students because it allows them to fully comprehend the concept of motion and the relationship between force and motion. Achievements in cognitive and psychomotor elements are included in the description of learning indicators in momentum and impulse material. The phypox application is used by researchers to obtain data from numerous sensors on smartphones. Phypox is an acronym for physical phone experiment, an Android and iPhone application developed by a RWTH Aachen University research team [22]. According to Imtinan & Kuswanto [22] Phypox allows remote access, allowing the primary device to be connected to additional smartphone devices, as well as data analysis that may be tailored to the needs of teachers and students.

The physics experiment manual on momentum and impulse offers a set of experimental procedures for studying inelastic collisions with the floor involving objects such as marbles, footballs, and basketballs. The experiment on inelastic collisions employs a microphone sensor that acts as an acoustic stopwatch to detect and record the sound produced by a bouncing ball. Bounce time is utilized to ascertain the beginning height of the ball and the height between successive bounces and quantify the energy dissipated with each bounce. Below is the outline of practical actions for doing inelastic experiments:

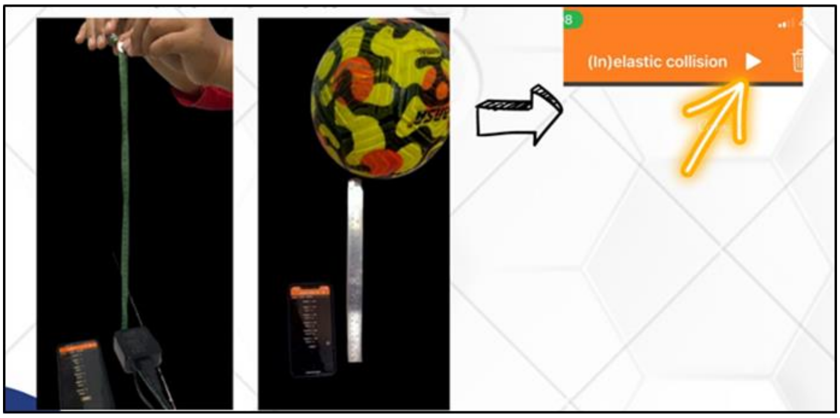

Fig 1. *Activities in The Inelastic Collision Experiment*

Figure 1 shows an inelastic collision experiment involving three distinct objects: marbles, footballs, and basketballs. The objects were dropped from heights of 50 cm, 75 cm, and 100 cm, respectively.

The subsequent phase involves the conceptual and practical validation of the physics experiment manual. Conceptual validation is conducted by validators who are experts in the subject matter and validators who specialize in media. Meanwhile, the physics teacher at SMA NEGERI 14 Sarolangun Jambi conducted procedural validation. The material validation was conducted twice to assure the precision and efficacy of the material presentation in the smartphone-based physics practical guide, utilizing the Phypox application for the topic of momentum and impulse. The validator offers recommendations to enhance the presentation of the material in order to ensure clarity, focusing on the topic of content suitability. The mean percentage score for the evaluation conducted by the validator regarding the suitability of the material's content, presentation, and context is 75%, 96%, and 89%, respectively. In general, the validation interpretation of the material is classified as satisfactory based on the criteria specified in the validation sheet.

Media validation is conducted online twice by media validators. The signs for assessing media validation include the display, navigation, and directions for use. During the initial validation phase, the media expert validator suggested enhancing the image quality in the testing procedures and refining the background selection. The media validator recommends careful attention to the material input in this physics practicum guide, along with offering a clear explanation of how to complete the experimental results table for better student comprehension. The media validation findings were scored as follows: 86% for appearance, 94% for navigation, and 100% for directions for use. The mean percentage value of media validation is 93%, indicating a high level of accuracy. The interpretation criteria fall into the "very good" category, suggesting that it is suitable for field testing without the need for any additional modifications. The last phase of the development stage for the practical guide involves doing procedural validation. The components of procedural validation assessment encompass the precision of the content, the quality of the media design, and user-friendliness. After analyzing the validation results conducted by teacher practitioners on smartphone-based practicum guides for momentum and impulse material, it was found that the average percentage score for these three aspects was 90.6%, which falls inside the outstanding category. This is a demonstration of the creation of a practical physics guide for smartphones using the Phypox program. The experiment manual focuses on the topics of momentum and impulse.

Fig 2. *Representation of experiment procedures*

The subsequent phase of the study involves the execution of a smartphone-based physics experiment manual to evaluate their effectiveness in enhancing students' beliefs towards physics, specifically in the context of impulse and momentum material. The implementation was conducted utilizing a one-group pre-test and post-test design. The researchers assessed students' beliefs by employing the CLASS questionnaire, which comprises five dimensions: real-world connection, personal interest, problem-solving, conceptual connection, and sense-making effort. Displayed below is a visual representation of the results obtained by students when completing the CLASS questionnaire:

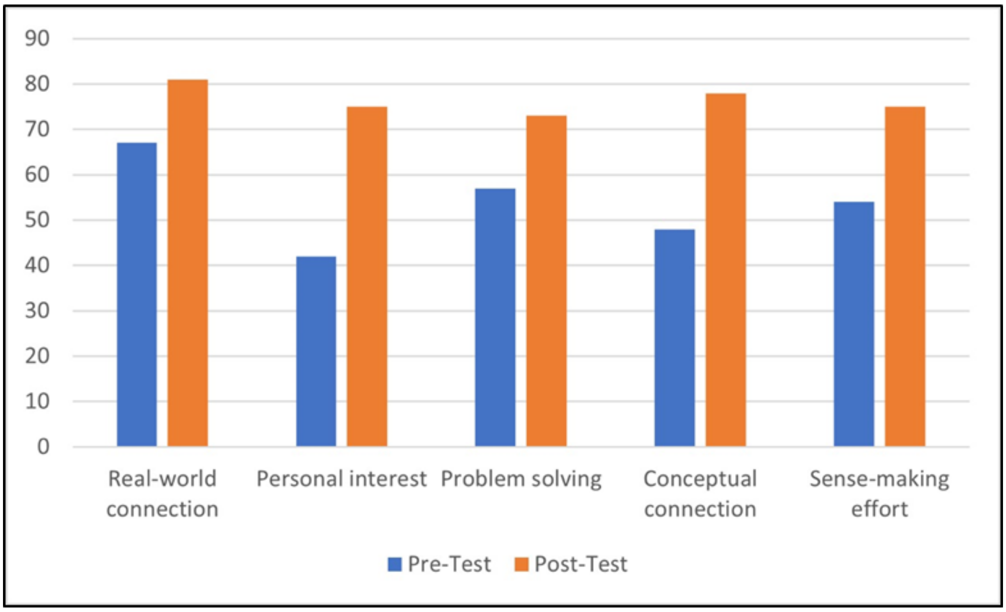

Fig 3. *The improvement of students' beliefs about physics before and after the experiment*

The percentage of students' attitude and belief scores regarding momentum and impulse material increased before and after using the smartphone-based practicum guide utilizing the Phypox application, as shown in Figure 3. The outcomes of this investigation are consistent with those of Belay et al [20] and Wilcox & Lewandowski [23]. Wilcox & Lewandowski [23] assert that students' positive attitudes and beliefs regarding physics and physics learning may be enhanced through participation in physics experiments, which afford them opportunities for active engagement and direct experience. Belay et al [20] further stated that experiments enable students to observe the results directly and observe the practical application of physics concepts; thus, they boost students' confidence and comprehension of the subject. Furthermore, physics experiments afford students the chance to investigate and discover explanations for commonplace physical phenomena, thus cultivating inquisitiveness and curiosity. Active learning has the potential to foster a more favourable perception and conviction regarding the soundness and pertinence of the field of physics. Furthermore, the implementation of laboratory-based learning activities, which grant students independence in the design and execution of experiments, can augment genuine learning encounters and shape students' epistemological stances and expectations concerning the fundamental characteristics of physics experiments [12]. Furthermore, Demkanin et al [24] said that incorporating technology into physics education improves students' learning experiences and contributes significantly to comprehension of complicated topics. Demkanin et al [24] argue that using digital technology, such as simulation software and sensors, allows students to participate in experimenting and learning actively. This practice can help students grasp physics principles in a more practical and helpful manner and improve communication and cooperation skills, which are critical components of 21st-century skills. Digital technology enables the depiction of complicated physics concepts, allowing students to learn better and absorb the information. Given technology's increasingly dominant role in modern education, there is abundant room for further research to investigate the significance of incorporating digital technology into physics learning. Research could examine how digital tools like simulations, interactive software, and online learning platforms can help students' conceptual understanding of complex physics concepts. Aside from that, it is critical to examine the impact of digital technology use on students' motivation and active participation, how students' attitudes toward physics learning when digital technology is integrated into learning, and how their beliefs of physics change as they use this digital technology.

CONCLUSION AND SUGGESTION

The effectiveness assessment demonstrates that utilizing a smartphone-based physics experiment manual for momentum and impulse topics can enhance students' favourable attitudes and convictions regarding physics and physics education. This study adds to the discussion on the utilization of smartphones in educational settings. This research aims to explore the potential of using smartphones as an affordable laboratory tool in physics education. The data collected from these smartphones can be utilized by teachers to conduct physics experiments in both classroom and non-classroom environments, hence enhancing the learning experience. The research is limited by the utilization of a one-class pre-test and post-test design, which restricts the generalizability of the acquired results on a broader scale. In addition, the duration of the intervention, including the use of smartphones in physics experiments, was limited to a period of three weeks. More time may be needed to yield substantial alterations in enhancing students' convictions regarding physics and the process of acquiring physics. To enhance future studies, it is advisable to employ a more robust randomization technique by utilizing a more intricate experimental design. Future studies should also take into account the necessity for a more extended intervention period to assess the sustained retention of students' enhanced views.

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