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Unlocking Scientific Potential: Using Smartphones as Mobile Mini-Labs to Improve Students' Science Process Skills

Nurlaini¹, Rayandra Asyhar², Tanti^{3*)}

Universitas Jambi, Indonesia^{1,2}, UIN Sulthan Thaha Saifuddin Jambi, Indonesia³

*)Corresponding E-mail: tanti@uinjambi.ac.id

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ABSTRACT

This study aims to analyze the effectiveness of physics-based learning based on smartphone-integrated Group Investigation (GI) as a mobile mini-labs to improve students' science process skills in learning physics. This study is a quasi-experimental research with a post-test control group design. The research sample consisted of 72 students in class XI of Science at SMAN 10 Jambi City which was divided into an experimental class (n=36) and a control class (n=36). Data were collected using science process skills observation sheets and a learning implementation checklist. The results of the analysis using the Mann-Whitney U test showed a significant difference in science process skills between the two groups ($p < 0.05$), with a high effect size value ($r = 0.86$). Experimental classes showed higher improvements in all dimensions of science process skills, especially in communication, data collection and processing, and experiment design. Observation of learning implementation showed effective implementation with an average implementation score of 3.75 out of a maximum score of 4. These findings indicate that smartphone-integrated GI-based physics learning as mobile mini-labs is effective in improving students' science process skills, and provides important implications for the development of innovative physics-based learning strategies based on technology.

INTRODUCTION

Physics is a field of science that investigates natural phenomena ranging from the atomic level to the universe using objective and quantitative scientific reasoning. It is realized by observing, measuring, designing models, and drawing conclusions. In Indonesia's education context, the learning outcomes of physics topics in high school are separated into two categories: understanding physics concepts and science process skills [1]. Understanding physics concepts refers to a person's capacity to comprehend and absorb abstract or complicated notions within a subject of study. At the same time, science process skills encompass scientific and engineering abilities such as observing, investigating, anticipating, planning and carrying out studies, processing and analyzing information data, producing, assessing,

reflecting, and conveying outcomes [2]. These two features are among the 21st-century abilities that students must acquire. However, critical components of 21st-century abilities, such as understanding concepts and science process skills, remain the primary hurdles in physics education [3].

Previous studies have reported that students' science process skills and conceptual understanding of various physics concepts were shallow [4] [5] [6]. Özgelen [5] found many misconceptions prospective physics teachers held regarding geometric optics. The findings of the study by Kiray & Simsek [6] showed that fifty percent of preservice physics teachers had scientific knowledge about density, and one-fifth of them did not have a comprehensive conceptual understanding of density. Furthermore, Kiray & Simsek [6] revealed that around a quarter of prospective student teachers have misconceptions about the concept of density, especially regarding the relationship between density and volume, density and mass, and density with the condition of objects floating or sinking when in a fluid type. This problem extends beyond conceptual understanding to practical skills. Özgelen [5] investigated students' science process skills in various types of schools (public and private) in Turkey, which were still low even though the science curriculum had emphasized the importance of science process skills. Similar results were found in the research setting in Indonesia. Research conducted by Astalini et al [7] identified the low science process skills of students in a public school in Jambi City. These low science process skills affect students' creative thinking skills. Another study conducted by Firmansyah & Suhandi [8] revealed that high school students struggle with data analysis—a cornerstone of scientific inquiry. These findings paint a concerning picture of our educational landscape, challenging educators and policymakers to rethink how we nurture the scientific minds of tomorrow. The persistent nature of these issues across different educational contexts underscores the urgent need for innovative approaches to physics education that can effectively bridge the gap between theoretical knowledge and practical scientific skills.

Students' science process skills in physics learning can be achieved by creating a learning environment that facilitates the construction of knowledge through direct experience, reflection, and discussion [9]. Tan et al [10] emphasized that conducting experiments is pivotal in physics learning, allowing students to apply theoretical concepts to real-world situations. However, the limited availability of experiment equipment in schools is often an obstacle to implementing experimental activities. An innovative solution to overcome this obstacle is to apply technology in learning or technology-enhanced learning (TEL). Liu et al [11] emphasized the popularity of smartphone use in TEL, considering that almost all students and teachers own this device. Advances in smartphone sensor technology, such as accelerometers, GPS, compasses, microphones, magnetometers, and gyroscopes, open up new opportunities for conducting more accessible physics experiments. González et al [12] argued that the potential use of smartphones in physics experiments goes beyond the reach of remote and conventional laboratories. Furthermore, González et al. [12] state that this technology integration must be accompanied by an appropriate learning model, such as group investigation, to maximize its effectiveness. This holistic approach addresses resource constraints, enriches students' learning experiences, encourages active exploration, and prepares them for future scientific challenges. Thus, the combination of TEL and an appropriate learning model can transform how students understand and apply physics concepts, paving the way for broader educational innovation.

Applying the Group Investigation (GI) learning model integrated with smartphones as mobile mini-labs offers a promising solution in this context. According to Dzemidzic Kristiansen et al [13], the group investigation method is a cooperative learning approach in which students work in groups to investigate complex topics. Dzemidzic Kristiansen et al [13] emphasized that the group investigation method begins by presenting a challenging and multifaceted problem, which directs students to ask questions to be investigated. Students work together to find information, discuss, and analyze their findings, as well as relate them to the knowledge and ideas they have. Thus, implementing practicum in the group investigation method is very important to enrich student's learning experience, develop the science process's proficiency, and deepen the concepts learned. Although smartphones offer low-cost physics laboratory solutions, their implementation at the high school level in the context of education in Jambi City still needs to be improved.

Based on the curriculum analysis, the topic of rotational motion was chosen to implement the experiment using the Phyphox application. The selection of rotational motion topic is based on a review of various research literature, which show that students still experience difficulties and challenges in understanding rotational motion concept. Research conducted by Duman et al [14] stated that students need help understanding the concept of angular momentum. According to Duman et al [14], there is a misconception about the relationship between torque and acceleration: constant torque will produce constant angular velocity. Rafika & Syuhendri [15] stated that students need help understanding rotational and rolling motion. According to Rafika & Syuhendri [15], students have a shallow understanding of the basic concepts of torque, moment of inertia, and rotational energy and need help visualizing rotational motion graphically. The use of the Phyphox application can help overcome this problem. Phyphox allows real-time visualization of various rotational motion parameters such as angular velocity, angular acceleration, and moment of inertia. This visualization will enable students to connect theoretical concepts with physical phenomena they can observe and measure directly [16]. In addition, rotational motion practicums using the Phyphox application involve various science process skills such as observation, measurement, data analysis, graph interpretation, and concluding.

Based on the challenges in physics education and the potential of technology-enhanced learning, this study aims to analyze the effectiveness of group investigation-based learning integrated with smartphones as mobile mini-labs in improving students' science process skills at SMAN 10 Kota Jambi. This study will investigate how the use of smartphones in physics learning can affect the improvement of students' science process skills, as well as analyze the implementation of the cooperative learning model stages of the group investigation type integrated with the use of smartphones. Thus, this study is expected to provide new insights into effective learning strategies in improving students' understanding of concepts and science process skills in physics subjects, as well as provide practical solutions to overcome the limitations of laboratory equipment in schools.

METHOD

This study used a quasi-experimental design to evaluate the effectiveness of the smartphone-integrated group investigation learning model in improving students' science process skills. The study sample was grade XI students of SMAN 10 Kota Jambi. Students were randomly divided into two groups: the experimental class and the control class. The experimental class received treatment by implementing the group investigation learning model integrated with smartphones, while the control class followed the direct instruction. In the experimental class, students used the Phyphox (Physical Phone Experiments) application on their smartphones as a tool to conduct physics experiments. Phyphox allows students to utilize smartphone sensors to collect and analyze experimental data in real-time, providing a more in-depth, hands-on experience in science learning.

The observation sheet is the main instrument used to measure students' science process skills. This observation sheet assesses ten aspects of science process skills, including observation skills, classification, communication, measurement, experiment design, prediction, experiment analysis, experiment implementation, data collection and processing, and data table creation. Each aspect of these skills is observed and assessed systematically during the learning process, both in the experimental and control classes. Specifically for rotational motion concept, the practicum module integrates gyroscope and accelerometer sensors through the Phyphox application. In various rotational motion experiments, students use these sensors to measure angular velocity, angular acceleration, and moment of inertia. For example, they can observe changes in angular velocity when an object rotates or analyze angular acceleration in circular motion. Phyphox, in this context, allows students to visualize abstract concepts in rotational motion, enhancing their understanding of complex physical phenomena. The normality and homogeneity test results of the science process skills data showed that the data did not meet the requirements for parametric statistical tests. Therefore, the researcher conducted a hypothesis test using the Mann-Whitney U test, a non-parametric alternative to the

independent t-test.

RESULTS AND DISCUSSIONS

Researchers developed a practical module to utilize sensors integrated with smartphones using the Phyphox application. The development of this practical module aims to facilitate the improvement of students' science process skills through more interactive and accessible experimental experiences. The Phyphox practical module development process was carried out through several stages, including conducting a needs analysis by considering the physics curriculum, the availability of sensors on smartphones, and the potential for doing experiments. The following is a picture of experiment module using Phyphox:

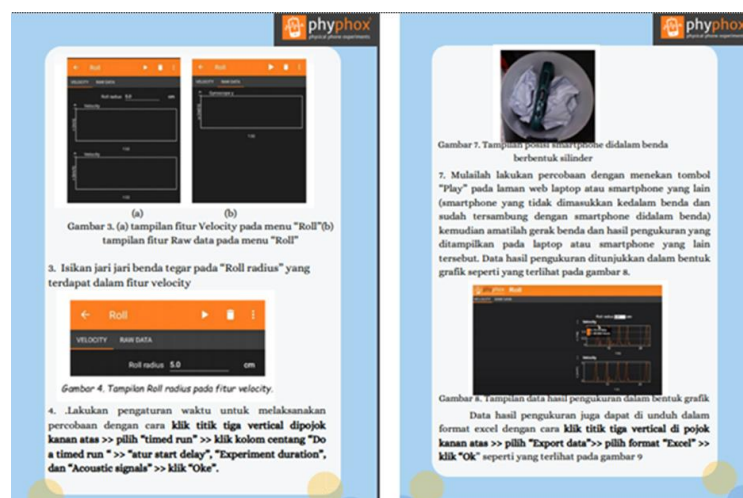


Fig 1. Picture of Experiment Module Using Phyphox

The results of descriptive statistical analysis reveal significant differences between the experimental and the control classes across various dimensions of science process skills. The experimental class, which utilized smartphone-integrated Group Investigation (GI)-based physics learning as a mobile mini-lab, consistently outperformed the control class, which employed conventional learning methods as illustrated in Figure 2.

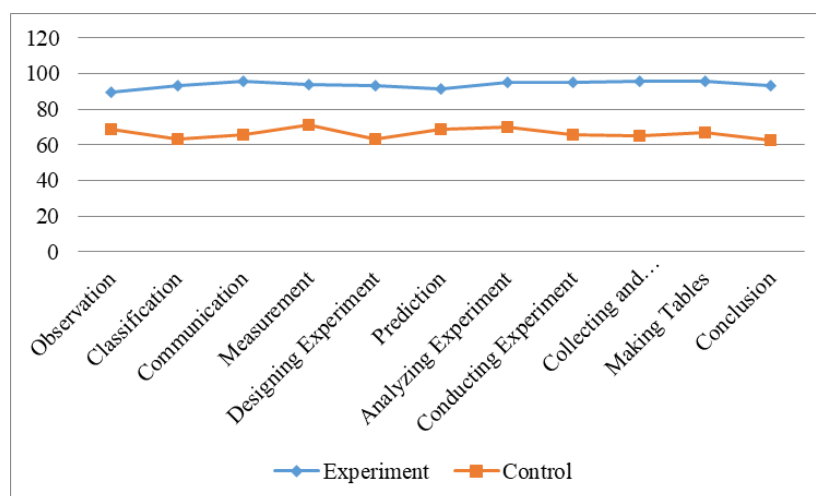


Fig 2. Percentage of Achievement of The Science Process Skills Dimension of Students in the Experimental Class and Control Class

Based on Figure 2 above, it can be seen that physics-based learning based on group investigation integrated with smartphones as mobile mini-labs has a significant positive impact on students' science process skills. The science process skills of students in the experimental class showed superior performance to the control class in all measured science process skill indicators, with percentage differences ranging from 20% to 27%. Indicators such as communication, collecting and processing data, and designing experiments showed the highest achievement in the experimental class, reaching around 95%. Meanwhile, the highest percentage control class was found in the measuring indicator, but this value was still lower than that of the experimental class. The most significant difference was in the indicators of the ability to design experiments, conduct experiments, and draw conclusions, where students in the experimental class were superior by about 27% compared to students in the control class.

Based on the homogeneity and normality tests, the data was nonhomogeneous and not distributed normally. Consequently, the researchers opted for a non-parametric statistical test to analyze the integrated GI learning model's effectiveness in improving students' science process skills using smartphones as mobile mini-labs. Researchers used the Mann-Whitney U test, which showed a significant difference in science process skills between the experimental and control classes. Furthermore, a significant effect size value ($r = 0.86$) indicates a significant impact of smartphone-integrated GI learning as a mobile mini-lab in physics learning. The results of this study are in line with the meta-analysis conducted by Lazonder & Harmsen [17] that stated that inquiry-based learning supported by technology has a positive effect on students' science learning outcomes. Furthermore, Dina et al [18] emphasized that GI-based learning encourages students to be active in the process of scientific inquiry, from planning to presentation of results. Activities in GI-based learning directly train the development of various aspects of students' science process proficiency such as observation, classification, and data analysis. The integration of smartphones as mobile mini-labs further strengthens this process by providing learners with an easily accessible and familiar measurement tool.

The Phyphox app trains students to collect data with high precision using sensors integrated inside smartphones, such as accelerometers and gyroscopes. Phyphox introduces learners to current methods of data gathering associated with technological development. This result aligns with the statement of González et al [12], in which the potential use of smartphones or tablets in physics experiments far exceeds the reach of remote laboratories, even conventional laboratories. Besides that, a practicum module prepared by the researcher plays a vital role in maximizing the effectiveness of this learning. It is designed to take the learner through smartphone sensors and phyphox applications to implement physics experiments that enable learners to apply such technologies with efficacy and meaning.

Furthermore, integrating smartphones into GI learning creates a learning environment that is more interesting and relevant to students' daily lives. Practicum activities in physics help students connect abstract physics concepts with real applications in daily life and comprehensively understand physics concepts. Assisted with smartphones, the students can perform experiments outside of formal class hours to support independence in learning. According to Kuhn & Vogt [19], using smartphones as mobile minilabs can enrich physics learning by utilizing smartphone sensors as practical and efficient experimental tools. By using familiar devices, such as smartphones, students become more motivated and involved in the learning process [19]. According to Kuhn & Vogt [19], smartphones can revolutionize the way real-time data is collected in physics experiments, allowing students to conduct more complex experiments and observe phenomena directly.

Observation of the implementation of the GI learning model syntax shows a consistent and effective implementation of the smartphone-integrated GI model with an average implementation score of 3.75. The increase in the implementation score from the first meeting to the third meeting indicates a positive learning curve for both teachers and students. This finding is in line with research conducted by Hmelo-Silver, Jordan [20], which emphasizes the importance of scaffolding and gradual adaptation in the implementation of inquiry-based learning. According to Hmelo-Silver et al [20], the success of technology integration in learning requires adequate time and support. Furthermore, the results of this

study also support the findings of the research of Liu et al [21], which highlight the crucial role of mobile technology in increasing student involvement in scientific research. This consistency and improvement in performance scores indicates that teachers have successfully overcome the initial challenges in integrating smartphones into the GI model, while learners are showing significant progress in adopting new learning approaches. This result shows the potential sustainability and scalability of the smartphone-integrated GI learning approach in the context of physics education at the high school level in Indonesia.

CONCLUSION AND SUGGESTION

The empirical findings from this study reveal the effectiveness of physics learning based on Group Investigation (GI) integrated with smartphones as mobile mini-labs in enhancing students' science process skills. Students in the experimental class showed better performance across all dimensions of science process skills compared to learners in the control class, with significant percentage differences ranging from 20% to 27%. Quantitative analysis employing the Mann-Whitney U test showed a significant difference between the two groups, yielding a large effect size ($r = 0.86$) showing a significant influence of the applied learning methods. Observation of learning implementation showed consistent and effective implementation, with an increase in scores from the first to the third meeting. This shows that there is a positive learning curve, both for teachers and students, in adopting and optimizing the use of this learning method. In particular, the use of phyphox applications for data collection and analysis showed consistent improvement, signaling a positive adaptation of learners to the integration of technology in science learning. Further research is needed to evaluate the effectiveness of this learning model in the long term and on a larger scale, including its effect on students' motivation and interest in learning physics.

REFERENCES

- [1] Kepala Badan Standar Kurikulum dan Asessmen Pendidikan. (2022). *Capaian Pembelajaran Pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah Pada Kurikulum Merdeka*. Kementerian Pendidikan, Riset, dan Teknologi, Editor. 2022, Badan Standar, Kurikulum, dan Asessmen Pendidikan: Jakarta.
- [2] Khamhaengpol, A., Nokaew, T., & Chuamchaitrakool, P. (2024). Development of STEAM activity "Eco-Friendly Straw" based science learning kit to examine students' basic science process skills. *Thinking Skills and Creativity*, 53, 101618.
- [3] Tanti, T., Deliza, D., & Hartina, S. (2024). The Effectiveness of Using Smartphones as Mobile-Mini Labs in Improving Students' Beliefs in Physics. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, 9(3), 387-394.
- [4] Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *ReseaRch in science & Technological educaTion*, 35(2), 238-260.
- [5] Özgelen, S. (2012). Students' science process skills within a cognitive domain framework. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(4), 283-292.
- [6] Kiray, S. A., & Simsek, S. (2021). Determination and evaluation of the science teacher candidates' misconceptions about density by using four-tier diagnostic test. *International Journal of Science and Mathematics Education*, 19, 935-955.
- [7] Astalini, A., Darmaji, D., Kurniawan, D. A., & Minarsih, M. (2022). Identification of HOTS creative thinking, science process skills and digital literacy in physics subject. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, 12(1), 47-61.
- [8] Firmansyah, J., & Suhandi, A. (2021, March). Critical thinking skills and science process skills in physics practicum. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012047). IOP Publishing.
- [9] Saphira, H. V., Prahani, B. K., Jatmiko, B., & Amelia, T. (2023). The emerging of digital

- revolution: A literature review study of mobile and android based e-pocket book in physics learning. *Advances in Mobile Learning Educational Research*, 3(1), 718-726.
- [10] Tan, I. G. C., Sharan, S., & Lee, C. K. E. (2007). Group investigation effects on achievement, motivation, and perceptions of students in Singapore. *The Journal of Educational Research*, 100(3), 142-154.
- [11] Liu, C. Y., Wu, C. J., Wong, W. K., Lien, Y. W., & Chao, T. K. (2017). Scientific modeling with mobile devices in high school physics labs. *Computers & Education*, 105, 44-56.
- [12] González, M. Á., Martín, M. E., Llamas, C., Martínez, Ó., Vegas, J., ... & Hernández, C. (2015). Teaching and learning physics with smartphones. *Journal of cases on Information Technology (JCIT)*, 17(1), 31-50.
- [13] Dzemiđić Kristiansen, S., Burner, T., & Johnsen, B. H. (2019). Face-to-face promotive interaction leading to successful cooperative learning: A review study. *Cogent Education*, 6(1), 1674067.
- [14] Duman, I., Demirci, N., & Şekercioğlu, A. P. D. A. (2015). University students' difficulties and misconceptions on rolling, rotational motion and torque concepts. *International Journal on New Trends in Education and Their Implications*, 6(1), 46-54.
- [15] Rafika, R., & Syuhendri, S. (2021, February). Students' misconceptions on rotational and rolling motions. In *Journal of Physics: Conference Series* (Vol. 1816, No. 1, p. 012016). IOP Publishing.
- [16] Kaps, A., Splith, T., & Stallmach, F. (2021). Implementation of smartphone-based experimental exercises for physics courses at universities. *Physics education*, 56(3), 035004.
- [17] Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of educational research*, 86(3), 681-718.
- [18] Dina, R. N., Zainuddin, Z., & Pada, A. U. T. (2022). Implementation of argument-driven inquiry learning model to enhance student's science process skills and self-efficacy. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, 7(1), 9-17.
- [19] Kuhn, J., & Vogt, P. (2022). Smartphones as mobile minilabs in physics. *Smartphones as Mobile Minilabs in Physics*.
- [20] Hmelo-Silver, C. E., Jordan, R., Eberbach, C., & Sinha, S. (2017). Systems learning with a conceptual representation: A quasi-experimental study. *Instructional Science*, 45, 53-72.
- [21] Liu, C., Zowghi, D., Kearney, M., & Bano, M. (2021). Inquiry-based mobile learning in secondary school science education: A systematic review. *Journal of Computer Assisted Learning*, 37(1), 1-23.