



## Jurnal Pendidikan Fisika

<https://journal.unismuh.ac.id/index.php/jpf>

DOI: 10.26618/6z54t388



# Implementation of Student Worksheets Based on Discovery Learning Assisted by PhET Interactive Simulations to Improve Motivation and Cognitive Learning Outcomes

Siti Hajar<sup>1)\*</sup>, Adeline Silaban<sup>2)</sup>, Umi Purnama<sup>3)</sup>, Nur Ilmi Shaqinah<sup>4)</sup>,  
Mawardi Jalil Masri<sup>5)</sup>, Muhammad Akbar<sup>6)</sup>

<sup>1),2) 6)</sup> Department of Physics Education, Cenderawasih University, Jayapura, 99358, Indonesia

<sup>3)</sup> Department of Civil Engineering, Andi Djemma University, Palopo, 91911, Indonesia

<sup>4)</sup> Department of Metallurgy, Politeknik Dewantara, Palopo, 91914, Indonesia

<sup>5)</sup> Department of Physics Education, Darud Da'wah Wal Irsyad College of Education, Pinrang, 91212, Indonesia

\*Corresponding author: [sitihajar.06.1991@gmail.com](mailto:sitihajar.06.1991@gmail.com)

Received: November 20, 2025; Accepted: February 06, 2026; Published: May 04, 2026

**Abstract** - Physics learning in schools often remains dominated by conventional methods, resulting in low student motivation and suboptimal cognitive learning outcomes, particularly when abstract concepts are taught without adequate support for practicum. This condition becomes more challenging in schools with limited laboratory facilities. This study aimed to examine the implementation of discovery-learning-based student worksheets assisted by PhET Interactive Simulations and to determine their effects on students' learning motivation and cognitive learning outcomes in physics, particularly in the direct current electricity material. This study employed a quasi-experimental method with a pretest-posttest nonequivalent control group design. The research was conducted at Muhammadiyah Senior High School Jayapura and involved 41 students selected through purposive sampling. The instruments used were a learning motivation questionnaire and pretest-posttest items measuring cognitive learning outcomes. The data were analyzed using descriptive statistics, N-gain, independent-samples t-test, and MANOVA using SPSS 16.0. The results showed that students who learned with discovery-learning-based student worksheets assisted by PhET interactive simulations had higher motivation and better cognitive learning outcomes than those who learned with textbook-based worksheets. The independent-samples t-test showed a significance value of  $0.000 < 0.05$ , indicating a significant difference in learning motivation between the two groups. In addition, the MANOVA yielded a p-value of  $0.000 < 0.005$ , indicating a significant difference in both motivation and cognitive learning outcomes. The novelty of this study lies in the integrated use of discovery-learning-based student worksheets and PhET interactive simulations to simultaneously enhance student motivation and cognitive achievement in physics. In conclusion, this approach is effective in fostering active, interactive, and meaningful learning while also serving as an alternative for schools with limited laboratory resources. This study contributes to physics education by providing empirical evidence that integrating structured worksheets, discovery learning, and virtual simulations can enhance both the quality of instruction and student learning performance.

**Keywords:** cognitive outcomes; discovery learning; learning motivation; PhET simulation; student worksheets.

## I. INTRODUCTION

The development of science has accelerated technological innovation and marked substantial progress across many sectors. At present, technological advancement has entered the digital era (Lestari, 2018). In education, technology is both a product of scientific progress and a strategic resource for improving the quality of learning. Accordingly, educational practice should integrate technology to support more effective learning processes. One subject that particularly requires such support is physics, because appropriate technology integration can help motivate students to learn (Mahardika et al., 2022; Sanjaya, 2013). Based on a preliminary analysis conducted by the researchers at Muhammadiyah Senior High School in Jayapura using student questionnaires, 65.5% of students reported difficulty understanding physics lessons, 55.4% indicated that physics involves too many symbols, formulas, and terms, and 47% stated that practical activities were limited because of inadequate laboratory equipment.

Another important issue in physics instruction is the limited technological proficiency of some educators in using computers to design learning media and integrate them into classroom practice. In many cases, traditional teaching still dominates, with lessons delivered directly through teacher explanation and the use of the whiteboard. These conditions require greater attention to enable educators to implement creative, innovative, enjoyable, and engaging learning (Hidayati & Puspitarini, 2020). Therefore, information technology competence is essential for educators. Teachers are expected not only to master physics content but also to develop engaging teaching media and instructional materials. They are also expected to provide interactive, engaging, memorable, and user-friendly learning media for students (Amin et al., 2019). Several studies have developed virtual animation programs that can function as virtual laboratories to improve students' understanding of physics concepts (Purwasi & Fitriyana, 2020; Villaruel, 2025). In physics learning, students are expected not only to memorize theories and formulas but also to develop conceptual knowledge and mastery through meaningful learning experiences (Kaukaba et al., 2022). In this context, the learning process is essentially a communication process, and effective learning depends on how clearly students can convey and construct concepts. One learning tool that can support this process is the Student Worksheet, which serves as a guide for learning activities and includes tasks in the form of questions and structured activities (Nurdin & Adriantoni, 2016).

The results of a preliminary study conducted using questionnaires and pretests at Muhammadiyah Senior High School in Jayapura indicated that students' motivation and learning outcomes remained low. Interviews with physics teachers revealed that the worksheets used in learning were derived only from textbooks. Practical activities were also constrained by

incomplete laboratory equipment. In fact, learning in physics tends to be more effective when theoretical explanations are balanced with practical experience. The interviews further showed that teachers were not yet familiar with using virtual laboratory applications to address these limitations. As a result, physics learning was still dominated by lectures. Although various studies have investigated discovery learning, student worksheets, and PhET Interactive Simulations in physics learning, most have examined these components separately. Research specifically integrating discovery-learning-based Student Worksheets, assisted by PhET Interactive Simulations, to improve learning motivation and cognitive learning outcomes in high school physics, particularly in schools in Papua, remains limited. Therefore, research examining the integrated implementation of these approaches is needed to provide more contextual and comprehensive empirical evidence.

Several previous studies have investigated the use of Student Worksheets supported by PhET simulations in physics learning to improve student motivation and learning outcomes. Their findings indicate significant differences between PhET-based learning and conventional learning (Mahardika, 2022). Other studies have developed worksheets integrated with instructional models such as Problem-Based Learning (PBL) or Guided Discovery Learning. These studies show that the role of worksheets is not merely to provide exercises, but also to guide students through structured discovery processes so that they can actively construct concepts on their own (Rizki et al., 2023). In addition, some studies have focused on the quality of the worksheets themselves, showing that their contribution is reflected not only in student learning outcomes but also in their validity, feasibility, and student responses (Susilawati & Agustinasari, 2022; Kaukaba et al., 2022; Prastowo, 2014; Said et al., 2024).

Previous research has examined Student Worksheets, discovery learning, and PhET Interactive Simulations separately. However, limited research has integrated discovery-learning-based Student Worksheets with PhET Interactive Simulations and examined their effects on both learning motivation and cognitive learning outcomes. Therefore, this study was conducted to address that gap. First, discovery-learning-based Student Worksheets function as learning guides that encourage students to actively explore, observe, formulate hypotheses, and draw conclusions independently. This approach shifts students from passive recipients of information to active learners, making learning more meaningful and challenging, and thereby increasing curiosity and intrinsic motivation. Second, PhET Interactive Simulations address the limitations of real-world practicum activities and the difficulty of visualizing abstract physics concepts. Through these simulations, students can conduct interactive, safe, and flexible virtual experiments. They can directly observe physical phenomena, manipulate variables, and identify cause-and-effect relationships, thereby strengthening conceptual understanding. Third, integrating Student

Worksheets with PhET enables more structured and goal-oriented learning. The worksheets guide students' exploration within PhET so that they do not merely interact with the simulation superficially but remain focused on the intended learning objectives. This integration is expected to increase student engagement during the learning process and, ultimately, improve cognitive learning outcomes. Thus, the implementation of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations is considered a relevant and effective alternative for creating active, interactive, contextual, and student-centered physics learning.

Based on this background, the research questions are as follows: 1) How is the implementation of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations in learning? 2) Can the use of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations increase students' learning motivation? and 3) Can the use of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations improve students' cognitive learning outcomes? In line with these questions, the objectives of this study are to determine: 1) the implementation of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations in the learning process; 2) the increase in students' learning motivation after using discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations; and 3) the increase in students' cognitive learning outcomes after using discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations.

## II. METHODS

This study employed a quasi-experimental, pretest-posttest nonequivalent control group design to examine the effect of discovery-learning-based Student Worksheets integrated with PhET Interactive Simulations on students' learning motivation and cognitive learning outcomes in physics. The study was conducted at Muhammadiyah Senior High School Jayapura in October 2025. A quasi-experimental design was considered appropriate because the existing classroom structure did not allow the random assignment of participants.

The population consisted of 121 eleventh-grade students from three classes: VIII-A, VIII-B, and VIII-C. The sample comprised 41 students selected through purposive sampling based on classroom characteristics and the feasibility of implementing the treatment. The selected participants were then assigned to the experimental and control groups according to the existing class arrangement.

The research design applied in this study is presented in Table 1. As shown in the table, both groups were given a pretest and a posttest, and only the experimental group received the

intervention: discovery-learning-based Student Worksheets integrated with PhET Interactive Simulations.

**Table 1.** Nonequivalent control group design

<b>Cohort</b>	<b>Pretest</b>	<b>Intervention</b>	<b>Posttest</b>
Experiment	O <sub>1</sub>	X	O <sub>2</sub>
Control	O <sub>3</sub>	-	O <sub>4</sub>

This study involved one independent variable, namely the implementation of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations, and two dependent variables, namely students' learning motivation and students' cognitive learning outcomes. Learning motivation was measured using a questionnaire covering four indicators: desire and willingness to succeed, drive and need to learn, hopes and aspirations for the future, and appreciation of learning. Cognitive learning outcomes were measured using a pretest-posttest achievement test on direct current electricity. Supporting data were also obtained through observation and documentation.

Before the intervention, the researcher prepared the lesson plans, developed discovery-learning-based Student Worksheets integrated with PhET Interactive Simulations, and constructed the research instruments. All instructional materials and research instruments were subsequently validated by experts to ensure their relevance to the research objectives and their suitability for classroom implementation.

The research procedure consisted of four stages: preparation, implementation, data collection, and data analysis. In the preparation stage, a literature review was conducted to establish the theoretical foundation of discovery learning, Student Worksheets, interactive simulations, learning motivation, and cognitive learning outcomes. In the implementation stage, the experimental group was taught using discovery-learning-based Student Worksheets integrated with PhET Interactive Simulations, whereas the control group was taught using the worksheets commonly used in the school. During the instructional process, students in the experimental group were guided to explore concepts, identify problems, test ideas through simulations, and independently formulate conclusions. The overall sequence of the research procedure is illustrated in Figure 1.

In the data collection stage, students completed a pretest before the intervention and a posttest afterward. They also completed the learning motivation questionnaire, and observational and documentary evidence were collected to support the interpretation of the findings. The data were analyzed quantitatively using SPSS version 16.0. Descriptive statistics were used to describe students' learning motivation and cognitive learning outcomes. Improvement in cognitive

learning outcomes was determined using the normalized gain (N-gain) score, as expressed in Equation (1).

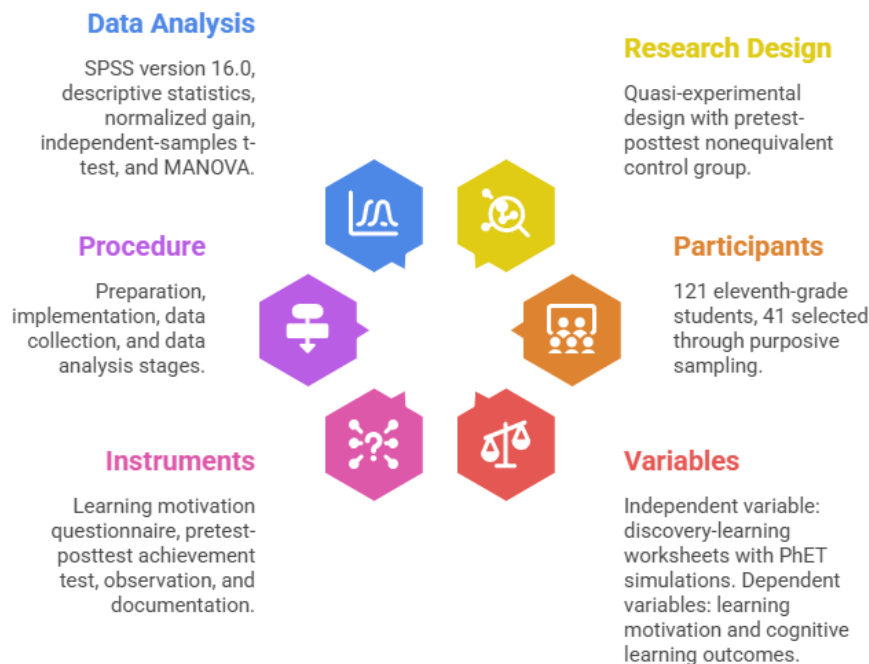
$$g = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \quad (1)$$

To facilitate the interpretation of the N-gain results, the classification criteria used in this study are presented in Table 2.

**Table 2.** N-gain criteria

N-Gain	Criteria
$g > 0.7$	High
$0.3 < g \leq 0.7$	Medium
$g \leq 0.3$	Low

In addition, an independent-samples t-test was used to identify differences between the experimental and control groups, while MANOVA was employed to examine the simultaneous effect of the intervention on both dependent variables. All statistical analyses were conducted at a significance level of 0.05. A summary of the overall methodological procedure is presented in Figure 1.



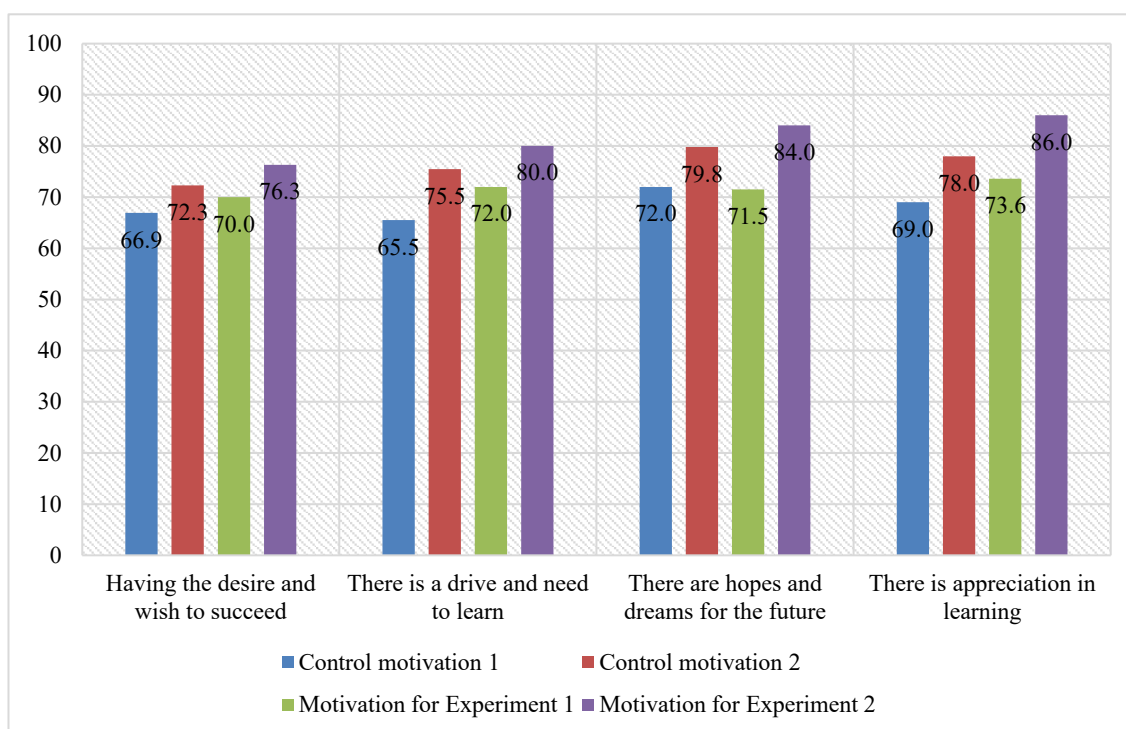
**Figure 1.** Research methodology

### III. RESULTS

The learning process took place over three meetings. The first meeting was used to administer the pretest and the first learning motivation questionnaire; the second meeting for

learning activities on direct current electricity; and the third meeting for administering the posttest and the second learning motivation questionnaire. The research data obtained are presented as follows.

The results of the independent-samples t-test, with class VIII-A as the control class and class VIII-B as the experimental class, showed a significance value of  $0.000 < 0.05$ . Therefore,  $H_0$  was rejected, and  $H_1$  was accepted. This result indicates a significant difference in learning motivation between students who learned direct current electricity using Student Worksheets assisted by PhET simulation and those who learned the same material using textbook-based worksheets. The increases in each aspect of learning motivation in the control and experimental classes are shown in Figure 1.



**Figure 1.** Percentage of learning motivation in the control and experimental classes

Figure 1 presents the results of the analysis of students' learning motivation in the control and experimental classes based on four indicators measured before and after the treatment. The treatment in the experimental class involved discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations.

For the first indicator, namely the desire and willingness to succeed, the percentage in the control class increased from 66.9 to 72.3, while in the experimental class it increased from 70.0 to 76.3. For the second indicator, namely encouragement and need in learning, the control class increased from 65.5 to 75.5, whereas the experimental class increased from 72.0 to 80.0. For the

third indicator, namely hopes and aspirations for the future, the control class increased from 72.0 to 79.8, while the experimental class increased from 71.5 to 78.0. For the fourth indicator, namely appreciation in learning, the control class increased from 69.0 to 78.0, while the experimental class increased from 73.6 to 86.0.

These results clearly show that students' motivation to learn increased after the implementation of discovery-learning-based Student Worksheets assisted by PhET Interactive Simulations. The increase was evident in both classes, but the experimental class showed higher scores after treatment. This finding indicates that the use of these worksheets supported students in experiencing a more meaningful, active, and student-centered learning process.

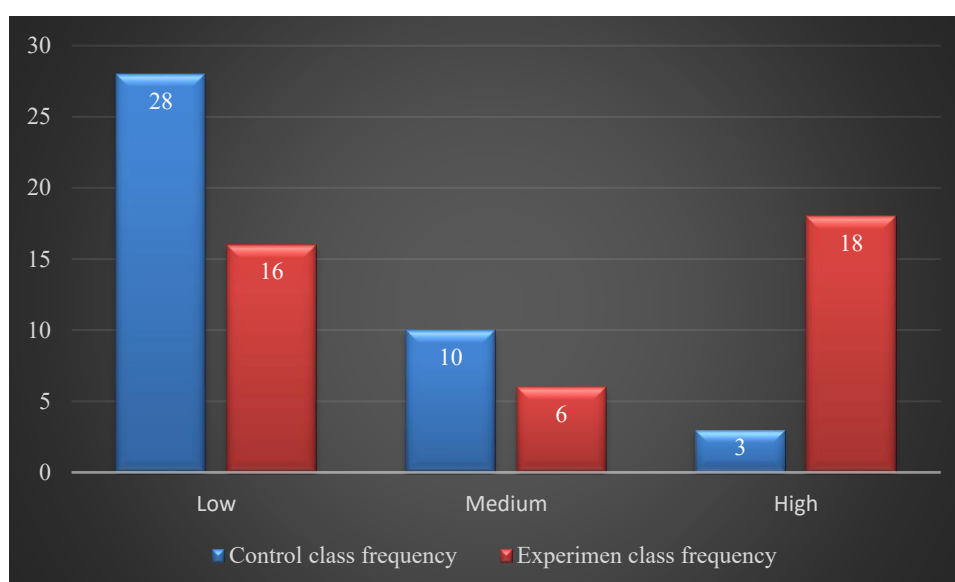
The increase in learning motivation may be attributed to the worksheets' characteristics and the use of interactive simulations. The Student Worksheets were designed not merely as sets of instructions but as guides for exploration, encouraging students to discover concepts through inquiry activities. The discovery learning model emphasizes students' active involvement in observing phenomena, identifying problems, formulating hypotheses, conducting experiments, and drawing conclusions. In this context, PhET functioned as an interactive medium that enabled students to visualize and explore physical phenomena more easily.

Through discovery-learning-based Student Worksheets, students were guided to begin learning by observing the initial phenomena presented in the PhET simulation. They were given opportunities to explore the simulation freely, which stimulated their curiosity about the observed phenomena. These observations then encouraged them to identify relevant scientific questions. The worksheets helped students record and organize these questions systematically, thereby supporting their thinking processes. Overall, the implementation of discovery-learning-based worksheets assisted by PhET Interactive Simulations had a positive effect on the quality of learning. Interactive simulations increased students' interest and motivation, while the discovery learning model promoted active engagement and higher-order thinking skills. Well-structured worksheets also helped students remain focused during exploration without reducing opportunities for independent learning. This combination made learning more effective, particularly for abstract and conceptual physics topics. This finding is in line with Khaerunnisak (2018), who stated that PhET facilitates the learning process for both teachers and students, thereby enhancing student motivation.

The results of the data analysis also indicate a difference in students' cognitive learning outcomes between learning direct current electricity using Student Worksheets assisted by PhET simulations and learning the same material using textbook-based Student Worksheets. This difference is reflected in the improvement between pretest and posttest scores. In the experimental class, the average score reached 80.35. This result is consistent with the findings of (Rusmawati,

2017), which showed that learning assisted by virtual media such as PhET can improve students' learning outcomes and conceptual understanding. Similar findings have also been reported by (Andriani et al., 2021; Inayah & Masruroh, 2021; Sudirman et al., 2021).

In this study, learning was conducted through limited face-to-face and online learning. Previous studies on the use of the discovery learning model in instruction, such as those by (Rizki et al., 2023; Nurlina, 2019), have also shown that discovery learning is appropriate for physics instruction. These findings support the view that discovery learning contributes positively to student achievement. The percentage of N-gain scores in the control and experimental classes varied across the high, medium, and low categories. The differences in these categories between the two classes are shown in Figure 2.



**Figure 2.** Comparison of cognitive learning outcomes in the experimental and control classes

The learning outcomes of the experimental class were higher than those of the control class because it used Student Worksheets integrated with PhET simulations. These worksheets included features that supported students in conducting practical activities related to direct current electricity, an abstract topic. This topic is often difficult to understand through explanation alone; therefore, PhET simulations strongly supported the learning process. The simulations enabled students to observe and manipulate key variables, such as current, resistance, and voltage, more easily.

By contrast, conventional learning using textbook-based worksheets and simple practical tools such as switches, batteries, and circuit boards could not be implemented optimally. Through PhET simulation-based worksheets, students were able to conduct experiments more independently and better understand how changes in variables affected the results (Rahayu &

Erman, 2017). Similar studies on the use of PhET simulations have also been conducted by (Yunzal & Casinillo, 2020; Khaeruddin & Bancong, 2022; Bahtiar et al., 2022; Susilawati & Agustinasari, 2022). This finding is also in line with (Hajar et al., 2025), which reported that student learning outcomes achieved through PhET simulations were better than those obtained through conventional learning methods. Furthermore, the use of PhET simulations in learning increased students' enthusiasm and interest in practical activities, which in turn contributed to better learning outcomes (Lestari, 2018).

Based on the MANOVA test, the significance value was  $0.000 < 0.005$ ; therefore,  $H_0$  was rejected, and  $H_1$  was accepted. This means that there was a significant difference between learning direct current electricity using Student Worksheets assisted by PhET simulations and learning using textbook-based worksheets in terms of both student motivation and learning outcomes at Muhammadiyah Senior High School Jayapura. Learning assisted by PhET simulations was shown to improve both students' motivation and their cognitive learning outcomes. This finding reinforces the statement of (Khaerunnisak, 2018) that the use of PhET facilitates learning for teachers and students and thereby promotes learning motivation. This result is also consistent with (Bahtiar & Azmar, 2022; Hajar et al., 2025), who stated that PhET simulations can increase students' enthusiasm and interest in practical activities, thereby improving learning outcomes.

#### IV. DISCUSSION

Further analysis showed that the experimental class achieved higher average scores in both learning motivation and cognitive learning outcomes than the control class. This finding indicates a clear difference between physics learning with Student Worksheets assisted by PhET simulations and with conventional Student Worksheets, particularly in student motivation and learning outcomes. Learning motivation and learning outcomes are closely related, as students with higher motivation tend to show better academic achievement. This finding is supported by Hajar et al. (2024), who reported that the use of PhET simulations increases students' enthusiasm and interest in practicum activities, enabling them to complete learning tasks more effectively.

The characteristics of Student Worksheets assisted by PhET simulations were shown to help students understand abstract material on direct current electricity, particularly in limited or distance-learning contexts (Nasir et al., 2021). Through these simulations, students can more easily determine current and voltage values, which are often difficult to observe through conventional practical work using batteries and simple circuit components. Thus, the use of PhET simulations enables students to conduct experiments that allow them to manipulate key variables

in direct-current materials (Rahayu & Erman, 2017). Although several obstacles were encountered during the research process, the overall implementation of learning proceeded well. The findings of this study indicate that implementing discovery-learning-based Student Worksheets, assisted by PhET Interactive Simulations, can improve students' motivation and cognitive learning outcomes in physics. This result is consistent with previous research showing that the use of PhET simulations can significantly improve students' conceptual understanding (Susilawati et al., 2022).

However, most previous studies have generally used PhET as a demonstration medium or as a direct instructional aid in teacher-centered learning, where the teacher still plays the dominant role in delivering concepts. In contrast, this study systematically integrated PhET into discovery-learning-based Student Worksheets, enabling students to actively explore, formulate hypotheses, and discover physics concepts independently through structured stages of learning. Compared with studies on discovery learning without interactive simulations, this study demonstrates additional advantages. Previous research has shown that discovery learning can improve conceptual understanding and student engagement. Nevertheless, its implementation is often constrained by limited time, laboratory facilities, and students' ability to conduct real experiments (Eveline et al., 2019). The integration of PhET in this study helps address these limitations by providing a flexible, interactive, and accessible virtual experimental environment.

Furthermore, several previous studies have focused primarily on cognitive learning outcomes, whereas the motivational aspect of learning has not been widely examined in tandem. This study complements previous findings by showing that PhET-assisted discovery learning affects not only students' conceptual understanding but also their motivation to learn, an important factor in sustaining success in physics learning (Sudirman & Qaddafi, 2023). Therefore, this study extends previous findings by confirming that the combination of Student Worksheets, discovery learning, and PhET Interactive Simulations has a more comprehensive impact on learning than either PhET or discovery learning alone, particularly in the context of physics instruction in schools with limited laboratory facilities.

## V. CONCLUSION AND SUGGESTION

The implementation of discovery-learning-based student worksheets assisted by PhET interactive simulations was effective in improving students' learning motivation and cognitive learning outcomes in physics at Muhammadiyah Senior High School Jayapura. The findings showed that students in the experimental class achieved higher motivation scores and better cognitive learning outcomes than those in the control class. These results indicate that integrating

discovery learning, structured student worksheets, and PhET interactive simulations can support a more active, meaningful, and student-centered learning process, particularly for learning direct current electricity.

This study was limited by its relatively small sample size, its implementation in only one school, and its focus on a single physics topic, which may restrict the generalizability of the findings. In addition, the study examined only learning motivation and cognitive learning outcomes, without addressing other important variables such as critical thinking, problem-solving skills, science process skills, or scientific literacy. Future research is therefore recommended to involve larger and more diverse samples, apply this approach to other physics topics, and examine a wider range of learning variables using more varied research designs. Despite these limitations, this study contributes to the field of physics education by providing empirical evidence that integrating discovery-learning-based Student Worksheets with PhET Interactive Simulations can be an effective approach to improving both motivation and cognitive achievement, especially in schools with limited laboratory facilities.

## REFERENCES

- Amin, B. D., Nurhayati, N., Azis, A., & Swandi, A. (2019). Identifikasi potensi penggunaan bahan ajar fisika berbasis simulasi komputer yang interaktif dengan model inkuiri terbimbing pada konsep abstrak: Studi literatur and survey. *Prosiding Seminar Nasional LP2M UNM*, 386-399. <https://ojs.unm.ac.id/semnaslemlit/article/view/11451>
- Andriani, A. A., Sultan, A. D., Rufaida, S., & Nurfadilah, N. (2021). Development of physics learning media based mobile learning using Adobe Flash CS6 at Muhammadiyah University of Makassar. *Jurnal Pendidikan Fisika*, 9(1), 91–97. <https://doi.org/10.26618/jpf.v9i1.4651>
- Bahtiar, B., & Azmar, A. (2022). The effect of using a virtual laboratory on students' motivation and learning outcomes in physics learning. *Jurnal Pendidikan Fisika*, 10(1), 13–21. <https://journal.unismuh.ac.id/index.php/jpf/article/view/6966>
- Bahtiar, B., Ibrahim, I., & Maimun, M. (2022). Analysis of students' scientific literacy skill in terms of gender using science teaching materials discovery model assisted by PhET simulation. *Jurnal Pendidikan IPA Indonesia*, 11(3), 371–386. <http://doi.org/10.15294/jpii.v11i3.37279>
- Eveline, E., Jumadi, J., Wilujeng, I., & Kuswanto, H. (2019). The effect of scaffolding approach assisted by PhET simulation on students' conceptual understanding and students' learning independence in physics. *Journal of Physics: Conference Series*, 1233(1), 1-11. <https://doi.org/10.1088/1742-6596/1233/1/012036>
- Hajar, S., Akbar, M., Pieter, J., Virman, V., Ayomi, A., Silaban, A., Risamassu, P. V. M., Lasmono, P. G. D., & Lumbu, A. (2024). Pemanfaatan media PhET simulation pada pembelajaran fisika di SMA Pembangunan V Yapis Kota Jayapura. *Sipakaraya*, 3(1), 21–28. <https://doi.org/10.31605/sipakaraya.v3i1.4167>

- Hajar, S., Lasmono, P. G. D., Purnama, U., Silaban, A., & Virman, V. (2025). Development of student worksheets based on discovery learning assisted by PhET interactive simulations. *Kasuari: Physics Education Journal (KPEJ)*, 8(2), 393–402. <https://journalfkipunipa.org/index.php/kpej/article/view/993>
- Hajar, S., Silaban, A., Akbar, M., & Lasmono, P. G. D. (2025). Analisis motivasi belajar mahasiswa pendidikan fisika dengan menggunakan virtual basic of application berbasis Excel. *Jurnal Pendidikan Fisika: Charm Sains*, 6(2), 155–159. <https://eurekaunima.com/index.php/jpfunima/article/view/444>
- Hidayati, A. F., & Puspitarini, I. D. (2020). Pengembangan media pembelajaran berbasis VBA (Visual Basic Application) dalam Excel pada materi hukum II Newton. *Prosiding Seminar Nasional Fisika*, 132-139. <https://proceeding.unesa.ac.id/index.php/snf/article/download/4388/956/16729>
- Inayah, N., & Masruroh, M. (2021). PhET simulation effectiveness as laboratory practices learning media to improve students' concept understanding. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, 9(2), 152–162. <https://doi.org/10.33394/j-ps.v9i2.2923>
- Kaukaba, S. Q., Nora, N., Fattikasari, D. W., Rizqiyah, D. Z., & Luthfi, A. (2022). Lembar kerja peserta didik (LKPD) berbantuan aplikasi PhET pada materi asam basa untuk meningkatkan motivasi belajar peserta didik. *UNESA Journal of Chemical Education*, 11(2), 143–157. <https://doi.org/10.26740/ujced.v11n2.p143-157>
- Khaeruddin, K., & Bancong, H. (2022). STEM education through PhET simulations: An effort to enhance students' critical thinking skills. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 11(1), 35–45. <http://doi.org/10.24042/jipfalbiruni.v11i1.10998>
- Khaerunnisak, K. (2018). Peningkatan pemahaman konsep dan motivasi belajar siswa melalui simulasi physics education technology (PhET). *Jurnal Penelitian Pendidikan IPA*, 4(2), 7-12. <https://doi.org/10.29303/jppipa.v4i2.109>
- Lestari, S. (2018). Peran teknologi dalam pendidikan di era globalisasi. *Edureligia: Jurnal Pendidikan Agama Islam*, 2(2), 94–100. <https://doi.org/10.33650/edureligia.v2i2.459>
- Mahardika, H. C., Ismawati, R., & Rahayu, R. (2022). Penerapan LKPD berbantuan simulasi PhET untuk meningkatkan motivasi dan hasil belajar kognitif IPA peserta didik SMP. *Jurnal Pendidikan Sains dan Matematika*, 10(1), 61–70. <https://doi.org/10.23971/eds.v10i1.3170>
- Nasir, N., Cari, C., Sunarno, W., & Rahmawati, F. (2021). Article diagnostic difficulties and misconceptions of light refraction: A need analysis learning abstract concepts using PhET simulation. *International Joint Conference on Science and Engineering*, 209, 317–322. <https://www.atlantis-press.com/proceedings/ijcse-21/125966549>
- Nurdin, S., & Adriantoni, A. (2016). *Kurikulum dan pembelajaran*. Rajawali Pers.
- Nurlina, N. (2019). The implementation of guided discovery learning model based on experiments toward science process skills. *Jurnal Pendidikan Fisika*, 7(2), 129–139. <https://doi.org/10.26618/jpf.v7i2.2071>
- Prastowo, A. (2014). *Panduan kreatif membuat bahan ajar inovatif*. DIVA Press.

- Purwasi, L. A., & Fitriyana, N. (2020). Pengembangan lembar kerja peserta didik (LKPD) berbasis higher order thinking skill (HOTS). *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 9(4), 894–908. <https://doi.org/10.24127/ajpm.v9i4.3172>
- Rahayu, S., & Erman, E. (2017). Penerapan pendekatan saintifik dengan media simulasi PhET pada materi gelombang untuk meningkatkan pemahaman konsep siswa SMP. *Pensa E-Jurnal: Pendidikan Sains*, 5(3), 253-256. <https://ejournal.unesa.ac.id/index.php/pensa/article/view/20170>
- Rizki, M. P., Sakdiah, H., & Ginting, F. W. (2023). Pengembangan lembar kerja peserta didik (LKPD) berbasis guided discovery learning menggunakan simulasi physics education technology (PhET) pada materi listrik dinamis kelas XII. *Jurnal Riset Inovasi Pembelajaran Fisika*, 6(1), 31–40. <https://doi.org/10.29103/relativitas.v6i1.7305>
- Rusmawati, R. (2017). Meningkatkan hasil belajar fisika peserta didik melalui strategi pembelajaran discovery terbimbing kelas X MIA2 SMA Negeri I Barru. *Jurnal Pendidikan Fisika*, 5(1), 15–24. <https://doi.org/10.26618/jpf.v5i1.337>
- Said, M. A., Ilham., Kadir, M. F. A. (2024). Fostering creativity to enhance physics achievement: An analysis of the relationship between creative thinking ability and student learning outcomes. *Unnes Science Education Journal*, 13(3), 180-188. <https://doi.org/10.15294/usej.v13i3.14516>
- Sanjaya, W. (2013). *Perencanaan dan desain sistem pembelajaran*. Kencana Prenada Group.
- Sudirman, S., & Qaddafi, M. (2023). The application of student worksheets based on PhET simulation to increase the concept understanding in Hooke's law. *Jurnal Pendidikan Fisika*, 11(1), 73–85. <https://doi.org/10.26618/jpf.v11i1.9505>
- Sudirman, S., Halima, H., & Hidayat, M. Y. (2021). Implementation of guided inquiry learning model assisted by three tier test on critical thinking. *JPF (Jurnal Pendidikan Fisika) Universitas Islam Negeri Alauddin Makassar*, 9(2), 120–129. <https://doi.org/10.24252/jpf.v9i2.23433>
- Susilawati, E., & Agustinasari, A. (2022). Validitas LKPD digital gerak harmonik sederhana berbasis PhET simulation. *Jurnal Pendidikan MIPA*, 12(1), 35–42. <https://doi.org/10.37630/jpm.v12i1.522>
- Susilawati, S., Doyan, A., Wahyudi, W., Ayub, S., & Ardhuha, J. (2022). Concept understanding of students through core physics learning tools based on guided inquiry assisted by PhET virtual media. *Journal of Physics: Conference Series*, 2165(1), 1-6. <https://doi.org/10.1088/1742-6596/2165/1/012045>
- Villaruel, S. A. L. (2025). Physics education technology (PhET) interactive simulations in learning selected topics in physics among college students. *American Journal of Education and Technology (AJET)*, 4(3), 12-21. <https://doi.org/10.54536/ajet.v4i3.4512>
- Yunzal, Jr., A. N., & Casinillo, L. F. (2020). Effect of physics education technology (PhET) simulations: Evidence from STEM students' performance. *Journal of Educational Research and Evaluation*, 4(3), 221–226. <https://doi.org/10.23887/jere.v4i3.27450>