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INTEGRATING PEER LEARNING AND INQUIRY CYCLE WITH PHET TO IMPROVE UNDERSTANDING OF DYNAMIC ELECTRICITY

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Abstract :
Most eighth-grade junior high school students often experience difficulties in understanding abstract and complex physics topics, such as dynamic electricity, which frequently leads to misconceptions and negatively impacts learning outcomes. To address this problem, researchers developed and tested an integrated learning strategy that combines peer teaching, the inquiry learning cycle model, and the use of PhET simulations, enabling students to conduct virtual experiments. This study used the ADDIE development model, which includes the stages of analysis, design, development, implementation, and evaluation. The research subjects consisted of 32 ninth-grade students of SMPN 1 Bayongbong, with a one-group pretest-posttest design to measure the learning impact. The validation of the learning tool was carried out by four experts, who obtained an average score of 0.89, indicating high theoretical feasibility. In terms of practicality, teachers gave an average rating of 91%, and students gave an average rating of 87%, both indicating a very good level of practicality. During four meetings, students took pretests and posttests, engaged in peer teaching activities, and learned concepts directly through PhET simulations. Concept understanding was measured through a structured test and then analyzed using the N-Gain method. In this study, the N-Gain score obtained was 0.57, indicating a moderate category. In addition to quantitative data, student observations and reflections showed positive impressions. These findings strengthen the evidence that this learning strategy can help students better understand the concept of dynamic electricity.

Keywords: Conceptual Understanding, Peer Lesson, PhET Simulation

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INTRODUCTION

The majority of eighth-grade junior high school students struggle to comprehend complex, abstract physics concepts. Dynamic electricity represents a common challenge that many students face. The abstract nature of this concept does not diminish its direct connection to everyday life, as it controls

basic functions such as lighting and the operation of electronic devices. The basic understanding of circuit current flow, together with voltage principles and resistance effects, must be achieved by students before they can grasp dynamic electricity concepts. Students who learn these basic principles tend to exhibit better classroom performance and stronger scientific thinking abilities. According to Samsudin et al. (2019), electrical fundamentals serve as essential components for physics advancement, particularly regarding current and voltage interactions. The challenge of learning fundamental concepts persists among students who think critically rather than memorize facts (Puspita Sari et al., 2021). Student performance suffers when their thinking patterns develop into misunderstandings because of this tendency.

Multiple studies demonstrate that interactive simulations enhance student understanding of abstract material challenges (Dy et al., 2024; Uwambajimana et al., 2023). Students find PhET simulations useful because they create engaging learning experiences, which help students understand fundamental physics concepts (Pranata, 2024). The tools help students stay motivated and independent while they learn at their own pace and develop better conceptual understanding (Firdaus et al., 2023).

Dynamic electricity remains a challenging topic for students to grasp, despite its great significance. The initial assessment performed at SMPN 1 Bayongbong revealed that 28% of ninth-grade students met the passing standard in tests on electrical circuits and current movement. The interviews with science teachers revealed that students frequently struggle to comprehend the relationship between voltage, current, and resistance. The research indicates that students across Indonesian classrooms memorize formulas without authentic comprehension, according to Usman et al. (2021). Students need more dynamic and visual learning strategies to understand abstract topics like electricity, according to Samsudin et al. (2019). Understanding physics serves dual purposes because it leads to academic success and develops essential thinking skills for understanding natural phenomena, according to Dantic and Fluraon (2022). Students develop incomplete knowledge, which can lead to the formation of enduring false beliefs. The current situation highlights the critical need for better instructional methods to create purposeful learning experiences (Isbah & Adi, 2024; Pranata, 2024; Sudirman & Qaddafi, 2023).

Physics education requires new educational methods to address its current challenges. Digital simulation tools, alongside peer lesson models, form an innovative educational system that promotes collaborative learning. The educational approach known as peer lesson (Nur Amini et al., 2022) allows student leaders to provide instruction to their classmates, which improves motivation and understanding. The model achieves its peak performance through PhET simulation exploration, which combines inquiry-based learning phases for concept development and experimentation (Yunzal & Casinillo, 2020). Inquiry-based educational approaches have demonstrated effectiveness in developing critical thinking skills (Sudirman & Qaddafi, 2023) and student comprehension strengthens when simulations are integrated into inquiry-based educational frameworks (Islanda & Darmawan, 2023; Pranata, 2024). The process of working with peers enables students to discover and fix their mistakes while fully engaging in their educational journey. Studies show that digital media, when integrated with peer learning, produces better information retention and a deeper understanding of complex concepts (Dy et al., 2024).

Collaborative learning strategies, such as peer lessons, serve as viable alternatives to technology-based educational methods. Students benefit from methods that enable them to discuss materials and teach their peers because this approach strengthens their academic understanding, social skills, and sense of responsibility. Research demonstrates that peer instruction leads to improved motivation together with better communication abilities, and enhanced learning outcomes (Dantic & Fluraon, 2022; Singh, 2016). According to Samsudin et al. (2019), visual learning environments that receive peer support lead to enhanced comprehension levels among individuals and groups in physics (Hidayat et al., 2019).

The study stands out because it unites peer learning with inquiry-based learning and PhET simulations through a single instructional framework that targets dynamic electricity conceptual problems for junior high students. The current research presents a unique combination of components through an interactive and structured approach, which prioritizes exploration alongside collaboration and conceptual mastery. The combination of inquiry learning and PhET simulations, along with peer-based instruction, leads to more meaningful student-centered scientific exploration (Pranata, 2024;

Sudirman & Qaddafi, 2023). Research has demonstrated that PhET simulations improve conceptual learning for STEM students, yet recent studies show collaborative learning methods improve both student responsibility and peer problem-solving abilities (Nur Amini et al., 2022). This integrated instructional model presents a new educational framework that has not been tested for junior high school science students.

The study introduces an original teaching framework that integrates peer learning elements with inquiry cycle procedures and PhET simulations to tackle student misconceptions in dynamic electricity concepts. The research distinguishes itself by integrating peer learning elements with inquiry cycle procedures and PhET simulations into a unified educational strategy that targets students in junior high classrooms. The model presents its innovative value through its development and validation process, which enhances both knowledge comprehension and student participation in abstract physics learning. PhET simulation media bring about substantial improvement in student problem-solving abilities and physics learning motivation, according to recent empirical studies (Dy et al., 2024)

The teacher acts as a facilitator, becoming essential in this educational framework. Teachers need to create learning activities that actively engage students while delivering helpful feedback, and build interactive learning spaces that adjust to students' requirements (Nur Amini et al., 2022) The learning strategies that enable students to choose their own learning paths through their abilities and preferences are gaining importance according to the current Merdeka Curriculum (Darmawan et al., 2023). Learning through ICT tools enables students to learn content while simultaneously building their digital literacy skills, according to Hartati et al. (2024). These learning methods support students in their academic, social, and emotional competencies. When properly structured, collaborative learning activities lead to enhanced development of students' critical thinking abilities and teamwork competencies (Brundage et al., 2023; Pratiwi et al., 2019). The study by Mejeh & Hagenauer (2023) shows that digital learning settings that adapt to students' needs enhance their independence while creating learning experiences that align with student-centered curriculum objectives.

The primary objective of this study is to develop a combined educational method that integrates peer learning with inquiry cycles based on PhET simulations. The educational approach under development aims to address common misconceptions about dynamic electricity while providing students with an interactive, adaptive learning platform during digital education. Research findings demonstrate that utilizing this educational approach leads to substantial improvements in students' knowledge retention, along with increased engagement and boosted learning confidence in physics (Nur Amini et al., 2022).

The practical model serves as an easy-to-follow teaching guide that helps junior high science teachers address electrical concept problems. The framework supports the implementation of the Merdeka Curriculum by advancing personalized learning, digital literacy skills, and student-centered educational methods. Schools can transform their teaching methods and develop fundamental 21st-century skills by following a systematic approach that combines peer learning with PhET-assisted inquiry. Research demonstrates that adding PhET simulations to science lessons boosts student engagement and enhances their understanding (Susilawati et al., 2022). The model demonstrates potential to enhance national science education outcomes and minimize student learning differences among different school resource levels in the future.

RESEARCH METHOD

Research Design

The research employed an R&D methodology to develop and evaluate an integrated learning approach that combines peer learning with the learning cycle model, utilizing PhET simulations to enhance students' dynamic comprehension of electricity. The combination of inquiry-based physics instruction and PhET simulations allows students to develop knowledge through organized stages of exploration, explanation, and evaluation, which proves particularly effective for studying electricity (Yuliati et al., 2018). A mixed methods approach was adopted to combine quantitative and qualitative methods to gain a full understanding of the learning strategy development and implementation, as well as its effects (Rosen & Kelly, 2023; Zhang, 2022).

The ADDIE development model served as the primary model for this project because it provides a structured method that guides stepwise design and development of educational tools (Cynthia et al., 2023). The research employed a case study method, which allowed in-depth investigation of strategy implementation within a particular classroom environment (Bouchée et al., 2024).

Research Target/Subject

The research took place at SMPN 1 Bayongbong, located in Garut, West Java, throughout the second semester of the 2024/2025 academic year. The study took place at SMPN 1 Bayongbong in Garut. A total of 32 ninth-grade students participated in the study, alongside students with varied academic performance, and the numbers of males and females were equal. The research participants were selected through purposive sampling because they aligned with the study's goals and had prior knowledge of basic electrical concepts. Three science teachers and two education experts joined the students during the validation and evaluation stages to assess content validity and determine both applicability and practicality of the developed strategy strategy

Research Procedure

This research executed the ADDIE model through stages of Analysis, Design, Development, Implementation, and Evaluation to develop and test the instructional approach used in this study.

Table 1. Implementation of each stage in the ADDIE development model

No	ADDIE Stage	Description of Implementation
1	Analysis	Students' learning requirements, together with their difficulties in grasping dynamic electricity concepts, became clear through classroom observations and interviews.
2	Design	Designed digital modules and student worksheets based on peer lesson and inquiry cycle.
3	Development	Developed and validated the tools with subject experts and instructional media specialists.
4	Implementation	Conducted peer teaching across four sessions in small groups based on the learning cycle.
5	Evaluation	Assessed effectiveness using questionnaires, interviews, and concept understanding tests.

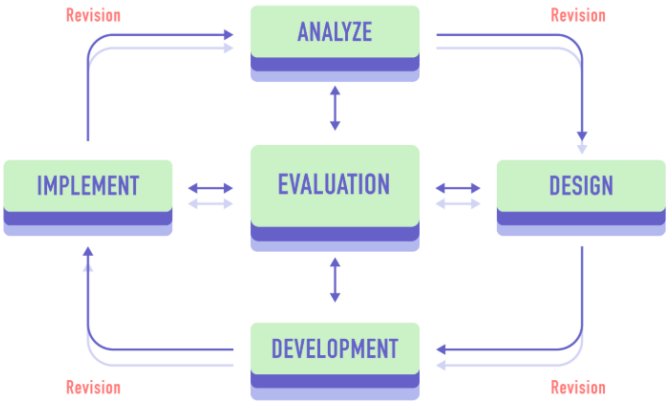

Figure 1. Flowchart of the ADDIE development model phases

During each learning session, the instruction focused on uniting the peer lesson method with the learning cycle steps, which include exploration, explanation, elaboration, evaluation, and expansion. The learning group members obtained assigned responsibilities between the tutor, recorder, and presenter roles. The interaction between students created an environment that fostered active and constructive peer learning, resulting in the maximization of learning potential (Bozzi et al., 2021). The exploration and elaboration phases included interactive PhET simulations to help students understand abstract concepts. Through simulation-based activities, students can observe concepts, formulate

hypotheses, and test their understanding by investigating electric circuit voltage, current, and resistance relationships. The method aims to minimize common misconceptions about dynamic electricity among students while simultaneously enhancing their conceptual understanding and engagement (Mahadi, 2023; Yuliati et al., 2018).

Instrumen and Data Collection Techniques

The research instruments consisted of student worksheets (LKPD) designed using the learning cycle and peer lesson model to facilitate inquiry-based teamwork, as well as product validation instruments based on the BSNP (National Education Standards Board) criteria, covering content, presentation, language, and visual design. In addition, observation sheets, practicality and effectiveness questionnaires, and interview guides were utilized to support the systematic collection of research data.

The research utilized a combined data collection methodology, which involved questionnaires, direct observations, semi-structured interviews, and document analysis. The research design enables investigators to gain comprehensive knowledge by integrating quantitative data with qualitative data. The design enables thorough investigation of quantifiable learning results and participant-experienced feedback, which creates a strong evaluation base for instructional model assessment (Mejeh et al., 2023).

The questionnaire employed a Likert scale to assess how teachers and students perceived the practicality and effectiveness of the learning method, using indicators such as instruction clarity, usability, objective relevance, participant engagement, and enhancement of conceptual understanding.: Conducted to assess student participation in group discussions, use of PhET simulations, collaboration, and the ability to ask and answer questions during activities.

The study conducted direct observations to evaluate student engagement in group discussions and their interaction with PhET simulations, as well as their teamwork abilities and their question-asking and answering capabilities during activities. The semi-structured interviews collected detailed input from teachers and students about their experience with PhET simulations and peer learning. The document analysis included a review of students' worksheets (LKPD) as well as peer lesson discussion notes and reflective journals.

Data Analysis Technique

The evaluation of content validity was performed by specialists who used a modified version of Aiken's V formula, which serves as a common method for educational instrument validation (Nurjanah & Widihastuti, 2023). The process established uniformity in expert opinions regarding the evaluation of content and construct validity. Furthermore, teacher practicality analysis was conducted using a practical assessment sheet developed by Cahaya et al. (2024) with standardized scoring methods to evaluate the practicability of teaching implementation. Student practicality analysis was then performed based on evaluation standards from contemporary educational measurement frameworks Zulkarnain et al. (2022), which emphasized how well students comprehended the material, its accessibility, and its relevance to their learning experiences. Finally, the interpretation of practicality levels referred to the classification standards proposed by Alfira et al. (2024), thereby ensuring consistency in categorizing the degree of practicality.

Table 2. Classification of practicality levels

No	Percentage (%)	Practicality Level
1	0 – 21	Not Practical
2	$21 < P \leq 41$	Less Practical
3	$41 < P \leq 61$	Moderately Practical
4	$61 < P \leq 81$	Practical
5	$81 < P \leq 100$	Highly Practical

The interactive qualitative analysis model by Mejeh et al. (2023) was applied to data from observations, interviews, and documentation. The process included data reduction, data display, and drawing conclusions or verification, enabling the systematic management of qualitative findings and their integration with quantitative results for a more comprehensive evaluation.

RESULTS AND DISCUSSION

During the development stage of the ADDIE framework, researchers implemented an extensive validation system for instructional products, which included digital modules and student worksheets (LKPD) that utilized peer lesson strategies with PhET simulations. Two educational experts, together with three experienced science teachers, performed validation using a BSNP framework-adapted instrument. The instrument evaluated four fundamental assessment areas, including content and presentation, as well as language and design. The evaluation criteria included indicators that measured user-friendliness and learning objective alignment, as well as visual presentation clarity and student involvement.

Table 3. Expert validation results

No	Aspect	Average Score	Category
1	Content	3.52	Highly Valid
2	Presentation	3.48	Highly Valid
3	Language	3.50	Highly Valid
4	Design	3.56	Highly Valid
	Average Total	3.51	Highly Valid

The evaluation process showed that each component reached the "highly valid" standard with a mean Aiken's V value of 0.89. The research findings support earlier studies that instructional materials developed using ADDIE demonstrate high levels of validity and usability (Fajarwati et al., 2023). The results confirm previous research that multimedia resources with proper integration enhance student independence while supporting conceptual learning, especially within Indonesian educational settings (Rahmasari et al., 2025). The validators suggested small changes, which led to improvements in terminology consistency, layout clarity, and language accessibility. The adjustments followed best instructional design practices through quality assurance team feedback and instructional design expert input to achieve cultural and pedagogical alignment (Al Husaeni et al., 2024).

The effectiveness of the integrated learning strategy was evaluated by conducting pre-test and post-test assessments on 32 ninth-grade students.

Table 4. Average Pretest and Posttest Results

No	Assessment Aspect	Average Score	Category
1	Pretest	56	Fair
2	Posttest	81	Good
	N-Gain	0.57	Medium

The N-Gain score of 0.57 falls into the medium category, indicating a moderate yet meaningful improvement in students' conceptual understanding of dynamic electricity. This outcome reflects the effectiveness of combining peer-assisted learning strategies with interactive digital tools. Previous Indonesian studies have emphasized that structured integration of multimedia and collaborative activities significantly enhances student engagement and comprehension in science subjects (Hindun, 2024). In contrast to other studies that reported limited effects of simulation-based learning in secondary education, this study presents more promising results, suggesting that well-designed digital media, when embedded within peer-supported instruction, can lead to higher conceptual gains. These findings align with current efforts to foster collaboration, critical reasoning, and metacognitive skills through innovative science instruction.

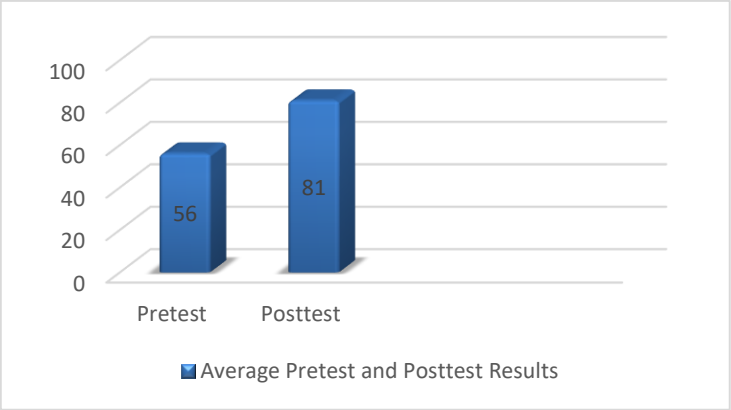

Figure 3. Average pretest and posttest scores of students on the topic of dynamic electricity

In terms of practicality, data were collected through post-implementation questionnaires completed by teachers and students.

Table 5. Practicality scores from teachers and students

Respondent	Score (%)	Category
Teachers	91%	Highly Practical
Students	87%	Highly Practical

These scores reflect the ease of implementation and perceived effectiveness. User-friendly and interactive e-modules increase motivation and engagement, a notion confirmed by both teachers and students in this study (Pratiwi et al., 2019). They described the materials as accessible, enjoyable, and well-suited to learners' needs, highlighting the practical success of the developed product.

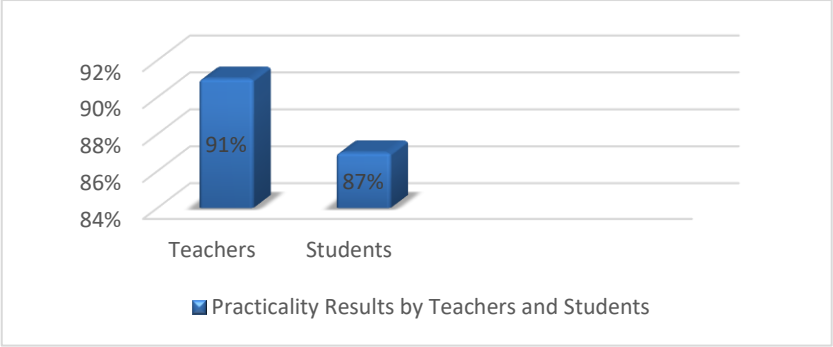

Figure 4. Practicality scores assessed by teachers and students.

Classroom observations across four learning sessions were conducted to monitor student engagement. Table 6 presents student participation across four key aspects of activity.

Table 6. Student Activity Percentage

No	Activity Aspect	Percentage (%)	Category
1	Group Discussion	89	Very Active
2	Asking and Answering Questions	85	Active
3	Independent Exploration with PhET	93	Very Active
4	Collaboration in Peer Lesson	91	Very Active

These results indicate that the integration of peer lessons and inquiry-based learning, supported by PhET, effectively fosters active participation (Dy et al., 2024; Pratiwi et al., 2019). This combination enhances not only engagement but also deepens understanding through peer interaction and self-directed learning.

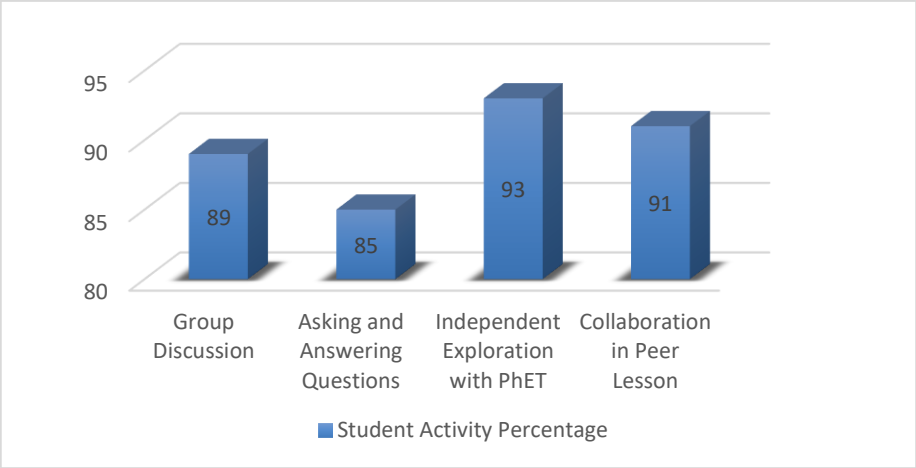

Figure 5. Percentage of student activities during the learning process

Qualitative data were obtained through in-depth interviews with teachers and students, along with document analysis (peer lesson notes and student work). The data were analyzed using a three-step model of thematic analysis—data reduction, data display, and conclusion drawing—based on recent adaptations of the Miles & Huberman framework (Basuki, 2019).

The qualitative findings indicated that students found PhET simulations particularly helpful in visualizing the relationships between current, voltage, and resistance during learning activities, allowing them to understand abstract physics concepts better (Anisa & Astriani, 2022). The application of peer teaching methods led students to develop better self-assurance when they asked questions and explained concepts to their classmates, thus creating an environment that promoted self-directed learning (Nailah Zamnah & Meta Ruswana, 2018) . Teachers observed significant student development in teamwork abilities and self-confidence during all instructional phases, but especially during discussions and peer leadership activities (Santoso et al., 2022).

The results match the study conducted by Pratiwi et al. (2019), which found that simulation-based inquiry enables students to visualize and develop metacognition when learning abstract physics concepts.

The data for this study were gathered through interviews with teachers and students and analysis of peer lesson notes and student work. The implementation of the learning strategy faced multiple obstacles. The major obstacle arose because students had limited access to ICT equipment. The school delivered extra laptops which students could borrow during class time. Students needed additional support to understand PhET simulation tools, so the learning cycle began with a tutorial session. Peer teaching sessions faced time management challenges when teachers had to manage group discussions alongside student roles. The solution involved setting defined time periods for discussion roles to circulate among group members, thus maintaining student participation in class activities.

Darmawan (2023) states that educational institutions must optimize ICT to enhance operational efficiency and student involvement. The practical problems, along with their resolutions, support the notion that improved ICT infrastructure serves as a critical factor for successful digital learning implementation.

The discoveries from this research establish important implications that apply to real-world practice and theoretical frameworks. Science teachers who teach both traditional and hybrid classes should consider implementing this learning model, which helps students understand abstract scientific concepts, such as electric current, through visualization. The research establishes proof for constructivist learning approaches by demonstrating how student interaction, combined with active exploration and self-directed learning, enhances conceptual understanding. The research establishes an original contribution by connecting peer lesson methods to digital educational materials and simulation activities through a unified learning framework, which previous investigations have not thoroughly examined. The combined approach enables students to construct knowledge more effectively, along with student-centered learning practices in middle school science classrooms. The findings of this study demonstrate improved conceptual development through peer instruction facilitated by digital simulations, which

enhance both retrieval practice and peer discussion. This finding aligns with previous research, which indicated limited improvement without digital tool support (Schell & Butler, 2018).

The research contains some constraints that need consideration. The research involved 32 students from one school during a brief intervention period. These elements restrict both the applicability of results across different populations and the sustainability of results over time. Future research should apply this model across various educational settings to assess its lasting influence on knowledge retention, as well as its impact on student motivation.

The findings suggest multiple recommendations for advancing the implementation of the instructional strategy. Teachers require appropriate training to effectively integrate interactive technologies with collaborative learning models into their classroom practices. Professional development programs enable educators to develop student-centered science instruction, which becomes more interactive. Schools need to focus on enhancing their ICT infrastructure because it will ensure equal access to digital tools, enabling simulation-based and collaborative learning. The integrated strategy requires future research for implementation across various science subjects and educational grades to determine its widespread applicability and enduring effects in different classroom environments (Nesi et al., 2022).

CONCLUSION

The research demonstrates that the combined teaching method, which incorporates peer instruction and inquiry learning with PhET simulations, achieves both feasibility and practical implementation, thereby enhancing junior high school students' understanding of dynamic electricity. The validation assessment demonstrated that the created educational materials met top-quality benchmarks. At the same time, practical evaluations showed that teachers and students found the tools to be simple to use and highly acceptable. The strategy demonstrated effectiveness through an average N-Gain value and noteworthy student participation in their collaborative and simulated learning activities.

This educational method proved successful in creating active learning environments, leading to increased engagement among students and a deeper understanding of abstract physics concepts. The combination of peer collaboration together with interactive digital media tools effectively solves typical learning challenges found in science education settings. The model exhibits robust potential for adoption across multiple educational settings, advancing student-centered learning practices through effective technology integration.

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It is hoped that the results of this study will be beneficial for students, teachers, and schools and contribute to the ongoing improvement of science education practices in Indonesian junior high schools.

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