



Enhancing Students' Conceptual Understanding and Motivation in Electricity Through Web-Based Problem-Solving with PhET Simulations

**Patricia Hotma Minar Lubis¹, Lefudin¹, Wacharaporn Khaokhajorn², Emiliannur³,
Nanang Winarno⁴, & Lukman Hakim^{1,*}**

¹Department of Physics Education, Universitas PGRI Palembang, Indonesia

²Department of Science Education, Sakon Nakhon Rajabhat University, Thailand

³Department of Physics Education, Padang State University, Indonesia

⁴Department of Physics Education, Universitas Pendidikan Indonesia, Indonesia

Abstract: This study explores the effectiveness of web-based problem-solving learning integrated with PhET simulations in enhancing students' conceptual understanding and motivation on the topic of electrical circuits. Utilizing a quasi-experimental method, the study involved 30 students from a private university in Palembang who engaged in web-based instruction supported by interactive simulations and contextual problem-solving activities. Data were collected through a learning style questionnaire, a concept understanding test, and a motivation questionnaire administered via Google Forms. The results revealed a significant increase in students' post-test scores across five indicators of conceptual understanding electric current, potential difference, resistance, Ohm's Law, and circuit configuration with N-Gain values ranging from moderate to high. Notably, students with auditory and kinesthetic learning styles showed slightly higher gains. Learning motivation also demonstrated a very high category, with 88% of students indicating strong interest and persistence in the learning process. The integration of web-based platforms and PhET simulations not only facilitated flexible and personalized learning experiences but also supported students' engagement, exploration, and self-regulation. These findings highlight the potential of technology-enhanced science instruction to bridge cognitive and affective learning domains, making it a valuable approach for future pedagogical innovations in physics education.

Keywords: web-based learning, conceptual understanding, learning motivation.

▪ INTRODUCTION

The concept of electricity, especially in topics such as current and voltage in simple circuits, is widely recognized as one of the most abstract and challenging areas in physics education. Students often face difficulties in visualizing invisible processes, interpreting circuit diagrams, and applying algebraic formulas to understand electrical behavior. These challenges frequently result in persistent misconceptions and hinder the development of robust conceptual understanding. A lack of concrete experiences and contextual learning tools contributes to these issues, making it difficult for students to construct accurate mental models. (Berenshtein, Tesler, Hochwald, & Green, 2023).

The development of science and technology has an impact on every aspect of human life, including education. Technological innovations offer opportunities to enhance learning experiences by making content more engaging and accessible. The application of technology in education is an effort to make learning more real and engaging. Therefore, teachers and prospective teachers must have the opportunity to develop their abilities in using technology in learning, as this competence is vital for facilitating meaningful instructional practices. (Kasirye & Wok, 2023; Ojelade et al., 2022).

Web-based learning is the application of technology in learning to help students achieve learning goals by presenting material according to the media used as teaching resources. Therefore, teachers' knowledge of web-based learning is the key to student success. (Amiri, Quraishi, Hakimi, & Fazil, 2024; Astalini, Darmaji, Kurniawan, Jaya, & Husna, 2022). Studies show that web-hosted platforms have become increasingly vital to fostering independent and interactive learning. Studies show that web-hosted platforms have become increasingly essential to foster independent and interactive learning. Web-based systems provide learners with the flexibility to access learning content anytime and anywhere, which encourages self-regulated study habits. In addition, the opportunity to interact with content through simulations, hyperlinks, and online discussions cultivates a sense of ownership and engagement. These features make web-based learning a powerful tool for promoting student autonomy and deeper cognitive involvement.

Web-based learning needs to be supported by interactive media so that students can ensure involvement in the learning process. Student involvement can be observed from their activity in asking and answering questions or commenting on problems. Hence, material must be presented in various formats such as graphs, tables, or images. Student engagement can be enhanced through interpreting multimodal content aligned with their characteristics. (Hakim, Lubis, & Khaokhajorn, 2022; Vieira et al., 2022). Research by Wulandari, Hakim, Sulistyowati, & Mian (2022) and Simamora, De Fretes, Purba, & Pasaribu (2020) supports the role of Google Sites-based multimedia in strengthening concept understanding and student participation. The implementation of diverse learning strategies (Chinnasami Sivaji, Murugan, & Raja, 2022; Chua, Sibbaluca, Mack, & Militante, 2020; Safar et al., 2022) further promotes active involvement.

Among the various interactive media, simulations such as PhET stand out due to their capacity to support exploratory and inquiry-based strategies like problem-solving. Learning strategies that enhance engagement include problem-solving approaches. Web-based problem-solving learning involves students in addressing real-life phenomena using virtual tools like PhET simulations. These open-access simulations help learners explore core physics topics, particularly current and potential difference in simple circuits. By integrating simulations into instructional design, students gain firsthand experience constructing circuits and analyzing results (Lane, Garousi-Nejad, Gallagher, Tarboton, & Habib, 2021; Roski, Ewerth, Hoppe, & Nehring, 2024).

However, it is crucial to recognize that the effectiveness of such simulations may vary based on student characteristics, such as prior knowledge, learning preferences, and technological fluency. Some students may benefit more from hands-on physical labs or require additional scaffolding when transitioning to abstract representations. Therefore, thoughtful instructional planning is required to align simulation tasks with students' cognitive readiness and to ensure that simulations do not become mere visual animations but function as tools for active inquiry and reflection.

Furthermore, the learning outcomes from PhET-integrated instruction may be influenced by contextual factors such as teacher facilitation, curriculum alignment, and classroom culture. Without structured guidance, students might interact with simulations superficially, limiting the development of deep conceptual understanding. Future studies should consider exploring how different instructional frameworks—such as flipped classrooms, collaborative learning, or guided discovery—interact with simulation-based problem-solving to maximize student engagement and learning outcomes.

To solve these problems, students construct circuits via PhET and measure variables such as current and voltage across resistors, using steps identical to real lab procedures. These tasks also encourage students to explain the reasoning behind their configurations, developing both analytical and verbal competencies. The capacity to reflect on problem-solving strategies fosters deeper understanding (Batsaikhan, Kurtz, & Hachinger, 2022; Zhu, 2023).

PhET simulations visualize abstract concepts through images, videos, and interactive modules. Activities such as measuring current at various resistors captivate students' attention and reduce fatigue. They offer alternatives to formulaic calculations, empowering students through autonomy and experimentation. These activities motivate learners to tackle new challenges, gradually transitioning to theoretical applications like Ohm's Law (Kalogiannakis, Papadakis, & Zourmpakis, 2021).

The integration of web-based problem-solving with PhET simulations in this study has proven effective in enhancing both students' conceptual understanding and their learning motivation. From a theoretical perspective, PhET simulations play a crucial role in helping students grasp abstract concepts by providing visual and interactive representations of otherwise invisible phenomena, such as electric current and voltage. These simulations also serve as virtual laboratories, allowing students to conduct experiments that would otherwise be difficult to perform due to limited access to physical equipment. This virtual experimentation supports students' representational competence the ability to translate between verbal, symbolic, graphical, and schematic forms of information, which is essential for mastering scientific concepts.

In parallel, the structured problem-solving approach employed in the learning sessions guided students to construct knowledge through contextual problems actively. Rather than passively receiving information, students were required to engage in inquiry, make predictions, test hypotheses via simulations, and reflect on the outcomes. This process aligns with constructivist theory, where learning occurs as students actively build and refine their mental models. By integrating these two strategies—PhET-based visualization and inquiry-oriented problem-solving—the learning environment not only bridged abstract content and real-world application but also fostered deeper cognitive engagement and intrinsic motivation. Additional research further supports this finding. Buar & Obiedo (2025) demonstrated that the integration of the 4MAT teaching model with PhET simulations enhances both conceptual understanding and learning motivation in physics education. Similarly, Furqon (2023) found that PhET-assisted instruction improves students' scientific consistency and critical thinking skills. Studies by Khaeruddin & Bancong (2022) and Bancong (2022), as well as Taibu, Mataka, & Shekoyan (2021), also reinforce the value of PhET in strengthening scientific reasoning and engagement. Furthermore, Salame & Makki (2021) emphasized that PhET supports learning style differentiation and improves students' attitudes toward science. Together, they provided a comprehensive scaffold that empowered students to explore, understand, and apply complex physics concepts independently.

This research aims to investigate how web-based problem-solving learning using PhET impacts students' conceptual understanding. The findings will contribute to ongoing discourse on educational technology integration and inform future science pedagogy practices (DeCoito & Estaiteyeh, 2022). Specifically, the study examines how the combination of simulation-based visual learning and inquiry-driven problem-solving

facilitates conceptual development in abstract physics topics. It also seeks to explore the extent to which this approach supports student motivation and engagement in a technology-rich learning environment.

▪ METHOD

Participants

The research method used in this research is a descriptive method to describe the situation that occurred as thoroughly as possible (Fraenkel & Wallen, 2009). The research was conducted at a private university in Palembang, involving 30 students as samples for the research. The sampling technique used was convenience sampling, as participants were selected based on their availability and accessibility during the study period. This method was considered appropriate due to the exploratory nature of the research and the limitations in accessing a randomized population. The sample consisted of undergraduate students in their first semester who were enrolled in the General Science Concepts course, with a gender distribution of 18 females and 12 males. Students who participated in this research learned via the web.

Research Design and Procedures

The web used in this study was developed using a freely available and accessible platform, namely Google Sites. The researchers did not build a custom website from scratch but instead utilized the features provided by Google Sites to organize instructional content, integrate learning activities, and embed interactive media. PhET simulations were directly embedded into specific sections of the Google Site, allowing students to access and manipulate simulations online without needing external downloads.

Learning worksheets (LKPD) were designed in the form of short-answer questions and distributed through Google Forms, with links placed strategically on the site to guide students through each activity. While Google Sites offers simplicity and ease of access, it also presents a key limitation: the learning activities are distributed across separate pages or tools, requiring students to navigate between different browser windows or tabs. This structure may cause discomfort or cognitive disruption for some students, especially those unfamiliar with managing multiple interfaces during a single session. Despite this, the platform was chosen due to its integration with Google's ecosystem, minimal technical barriers, and suitability for rapid deployment in an educational setting.

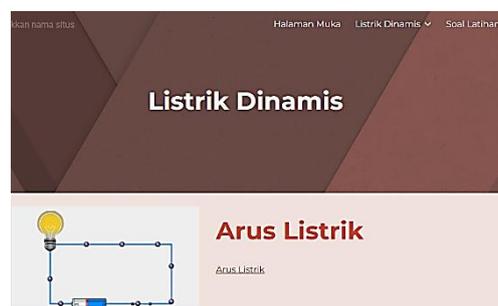


Figure 1. Web page display

Students who participated in this research learned via the web. Each session followed a consistent sequence of activities: (1) Students logged into the web platform

using a personal access code. When logging in, students are required to enter the access code provided to proceed to the learning webpage; (2) They read a contextual problem scenario related to the topic of dynamic electricity; (3) They opened the relevant PhET simulation embedded in the platform; (4) Students conducted guided virtual experiments using the simulation; (5) They completed an online worksheet designed to help them reflect on the simulation outcomes; and (6) Participated in a discussion forum to share their findings and ask questions.

An example of a contextual problem presented to students was: "A group of campers plans to use a set of flashlight bulbs and batteries to create a lighting system for their tent. How should they arrange the batteries and bulbs to make the light brighter and last longer? Use the PhET simulation to test different arrangements and explain your reasoning based on current, resistance, and voltage. The web used in this study was developed using a freely available and accessible platform, namely Google Sites. The researchers did not build a custom website from scratch but instead utilized the features provided by Google Sites to organize instructional content, integrate learning activities, and embed interactive media. PhET simulations were directly embedded into specific sections of the Google Site, allowing students to access and manipulate simulations online without needing external downloads.

Learning worksheets were designed in the form of short-answer questions and distributed through Google Forms, with links placed strategically on the site to guide students through each activity. While Google Sites offers simplicity and ease of access, it also presents a key limitation: the learning activities are distributed across separate pages or tools, requiring students to navigate between different browser windows or tabs. This structure may cause discomfort or cognitive disruption for some students, especially those unfamiliar with managing multiple interfaces during a single session. Despite this, the platform was chosen due to its integration with Google's ecosystem, minimal technical barriers, and suitability for rapid deployment in an educational setting.

Content analysis is an essential step in implementing web-based learning to develop various student skills, especially to develop students' conceptual understanding. The content used in this research is dynamic electricity following the applied curriculum. The content used in the curriculum is a means of developing various student skills (Drake & Savage, 2016) apart from cognitive and attitude. These skills include the ability to interpret graphical data, apply principles of scientific reasoning, and reflect critically on experimental outcomes. By aligning instructional content with competencies emphasized in the curriculum, web-based learning can promote both disciplinary knowledge and transferable skills essential for lifelong learning.

Instruments

The instruments used in this research consisted of a learning style questionnaire, a concept understanding test, and a motivation questionnaire for learning using the web. This instrument is given to students online via Google Forms. The learning style questionnaire consists of forty items related to student learning styles, namely visual, auditory, and kinesthetic. This questionnaire is scored and accumulated to see students' learning style tendencies. The results of the learning style test are the basis for grouping students who will receive the material provided.

The concept understanding test consists of thirty multiple choice questions on the subject of dynamic electricity consisting including current strength, potential difference,

Ohm's law, series circuits, parallel circuits, Kirrchhof's law. The indicators of concept understanding used are explaining, differentiating, interpreting, and exemplifying. The concept understanding test instrument, before use, is validated by experts.

Instrument validation includes construct validation and criterion or empirical validation. Construct validation is carried out by experts who aim to guarantee that the test instrument is valid so that it can be used to measure students' understanding of concepts. Aspects assessed at the construct validation stage include suitability between basic competencies and indicators, suitability between indicators and questions, the sentences used in the questions are understandable and unambiguous, each question has only one correct answer choice, and the questions and answers are by spelling errors and there are no errors in writing.

Instrument assessment technique by the validator by ticking yes or no in the column provided. A yes answer indicates that the question indicator matches the question, while a no answer suggests that the question indicator does not match the question given. The validator also provides comments in the column provided as input for revising questions or question indicators. The results of expert validation show that all question indicators correspond to the questions given. Likewise, other aspects are declared valid.

Criterion validity uses internal validity obtained through testing the instrument on students who have taken the subject of dynamic electricity. The question criteria are declared valid if the correlation coefficient of the score of each question item with the total score is greater than 0.3, whereas if the correlation is smaller than 0.3, the question is declared invalid. The results of instrument testing showed that all questions had a correlation coefficient of item scores with a total score greater than 0.3, so that all questions were declared valid. From the test results, the reliability of the questions was also obtained at 0.7. Thus, the instrument used is empirically valid and reliable.

The third instrument used was a student motivation questionnaire regarding learning using the web. The learning motivation indicators used in this research are 1) interested in participating in learning activities, 2) having the will to complete all the tasks given, 3) being persistent in completing the tasks given, and 4) having self-confidence in participating in learning (Sudiby et al., 2017). The questionnaire was prepared using a Likert scale consisting of four statements, namely strongly agree (SS), agree (S), disagree (TS), and strongly disagree (STS). Student responses are used as scores with the criteria SS = 4, S = 3, TS = 2, and STS = 1. Motivation to learn Physics in web learning is divided into five categories, namely very high, medium high, low, and very low. Student learning motivation is categorized into five levels based on percentage scores: very low (20–36%), low (37–52%), moderate (53–68%), high (69–84%), and very high (85–100%).

Data Analysis

Data from the concept understanding test and motivation questionnaire were analyzed quantitatively. N-Gain scores were calculated to measure improvement between pretest and post-test results for each indicator. Descriptive statistics were used to summarize motivation scores. Additionally, paired t-tests were used to analyze differences between pretest and post-test scores, provided that assumptions of normality and homogeneity were met.

▪ RESULT AND DISSCUSSION

Result

The research results show that students have different learning style types, with the indices of each learning style being visual (43%), kinesthetic (30%), and auditory (27%). According to this data, most students prefer visual learning, followed by kinesthetic and auditory preferences. These findings are consistent with previous research and align with the VARK model proposed by Lehman (2019), which categorizes learners into visual, auditory, reading/writing, and kinesthetic types. Overall, understanding the variety of learning styles among students can help educators tailor their teaching methods to better accommodate the diverse needs of their students. By incorporating visual aids, hands-on activities, and auditory cues into their lessons, teachers can create a more inclusive and effective learning environment. Additionally, awareness of individual learning preferences can empower students to advocate for their own learning needs and seek out resources that align with their preferred style. Ultimately, recognizing and accommodating different learning styles can lead to improved academic performance and a more engaging educational experience for all students.

Test Results for Students' Understanding of the Concept of Static Electricity, where the pretest score of 57 increased to 87 on the post-test with an N-Gain value of 0.7. This result shows the effectiveness of the web-based problem-solving approach in improving students' learning outcomes. Web-based learning is an educational innovation that presents material in various formats, making it appear more tangible for students. As a form of innovation, this learning method significantly contributes by providing opportunities for students to observe, demonstrate, and engage in activities that enhance their involvement in learning. (Zahara et al., 2024).

The results of the paired sample t-test showed a significant difference in students' understanding of electrical concepts before and after being involved in the Web-Based Problem Solving learning approach integrated with PhET Simulation. The standard deviation was 28.01 with a standard error of 3.61. The calculated t-value was 0.000 ($p < 0.05$), which confirmed that the increase in students' conceptual understanding was significantly different. Thus, web-based learning with PhET simulation significantly improved students' understanding of electrical concepts (Al-Duhani, Saat, & Abdullah, 2024). Therefore, tailoring instruction particularly for abstract science topics like electricity to visual learners using animated videos, digital simulations, and interactive graphics while also incorporating auditory and kinesthetic features is crucial. This approach not only aligns with the constructivist model but also promotes better learning outcomes through adaptive, student-centered instruction.

Figure 2 presents the results of the students' electrical concept understanding test, based on five indicators of concept understanding: electric current, potential difference, resistance, Ohm's Law, and electrical circuits. There was a significant increase in scores from the pretest to the post-test for all indicators. For example, on the electrical current indicator, the score increased from 55 to 93 with an N-Gain of 71. Similar improvements also occurred in other indicators, with N-Gain values ranging from 52 to 73. This improvement demonstrates that the web-based learning approach, combined with problem-solving strategies, can significantly enhance students' understanding of various aspects of dynamic electricity concepts. The effectiveness of using PHET simulations in

this context is also validated by Anisa & Astriani (2022), who demonstrated improved understanding through discovery learning.

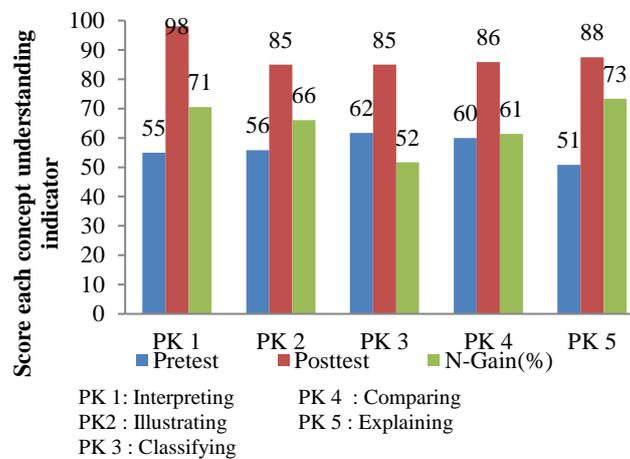


Figure 2. The results of students' conceptual understanding tests are based on indicators of understanding electrical concepts

Based on the three primary learning styles of visual, auditory, and kinesthetic, students' electrical concept comprehension scores can be seen in Figure 3. The pretest scores, which are 54 for visual, 59 for auditory, and 55 for kinesthetic, show an almost equal range. Nonetheless, the post-test showed a significant improvement, with scores of 85, 89, and 87, respectively. The auditory learning style had the highest N-Gain score (0.73), followed by the kinesthetic (0.68) and visual (0.67) learning styles. This result demonstrates that the problem-solving-based web-based learning approach benefits all learning styles and produces consistent improvement in every category. These findings align with Ramezani et al. (2022), who emphasized that problem-solving styles are positively associated with learning achievements across diverse cognitive approaches. Thus, tailoring instruction particularly for abstract science topics like electricity to visual learners using animated videos, digital simulations, and interactive graphics while also incorporating auditory and kinesthetic features is crucial. This approach not only aligns with the constructivist model but also promotes better learning outcomes through adaptive, student-centered instruction.

Based on four motivation indicators (M1, M2, M3, and M4), the average percentage of students who are motivated to learn electrical concepts through a problem-solving approach. Overall, 88% of students were found to be encouraged to learn. The M3 indicator had the highest score, at 89%, while the other indicators ranged from 87% to 88%. All aspects of student learning motivation fall into the very high category, according to the data, which suggests that the web-based learning strategy used in this study was successful in providing students with an interesting, demanding, and relevant learning environment. Similar results were highlighted in the work of Aboobaker & K.H. (2021), who emphasized the importance of intrinsic motivation and learner engagement in effective web-based environments.

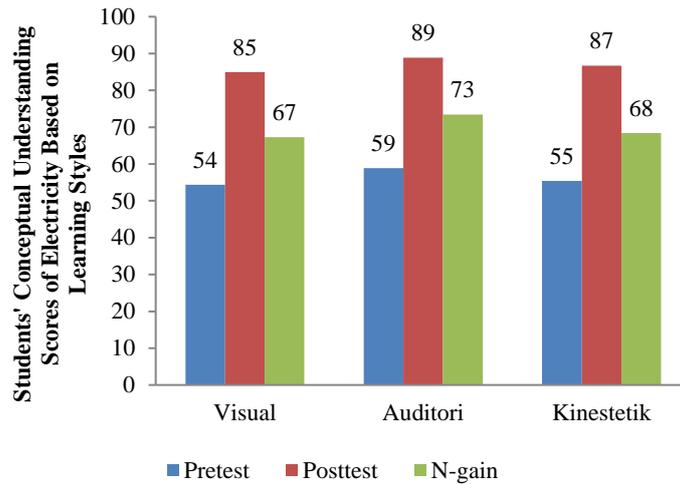


Figure 3. Results of pretest, post-test, and N-gain Concept Understanding Based on Learning Style

Discussion

The dominance of visual learning among high school students can be attributed to the highly visual nature of both traditional and digital learning environments. This finding is further corroborated by studies such as those conducted by Subagja & Rubini (2023), who analyzed student learning styles using the VARK model in science subjects, and Umbrella (2024), who profiled the learning styles of junior high school students.

The significant role of visual learning in enhancing comprehension, especially in science topics, is well-supported in the literature. (Yusnidah, Hidayat, & Maulana, 2023) Demonstrated that interactive visual media in web-based learning environments improve students' understanding of electrical materials. Likewise, Rahmawati, Hartono, & Nugroho (2024) found that visual learners benefit significantly from multimedia-based learning, particularly when studying abstract scientific topics such as dynamic and static electricity. Similar conclusions were drawn by Arni, Utami, Khoirunnisak, & Amelia (2024), who reported that different learning styles (visual, auditory, kinesthetic) significantly influence learning outcomes in science education.

Additional insights come from studies like those of Abdamia, Puteh, & Jah (2023), Alimah (2023), and Ayub, Karim, & Laraib (2023), which examined learning style distributions among various student populations and confirmed the prevalence of visual learning. Fahim et al. (2021) and Inam & Haq (2022) reinforced this through VARK-based assessments among medical and biology students. These studies highlight the importance of understanding and catering to different learning styles in educational settings. By acknowledging the prevalence of visual learning among students, educators can adapt their teaching methods to engage better and support learners. Utilizing tools and strategies that align with visual learning preferences can enhance student comprehension and retention of information.

Understanding kinesthetic learners' needs is also vital. Doyle, Chiu, Nagle, & Luczak-Roesch (2023) further analyzed how content design on digital platforms influences kinesthetic engagement in learning communities. Interestingly, auditory learners showed unexpectedly high gains in conceptual understanding—a counter-intuitive finding given the visually oriented nature of PhET simulations. One plausible

explanation is that the intervention may have unintentionally emphasized verbal-logical processing, such as structured prompts and worksheet-based reasoning, which may have favored auditory learners. Alternatively, this result might be a statistical artifact due to the limited number of participants in each learning style category. Acknowledging and discussing this complexity offers a more nuanced understanding of learning style dynamics in technology-enhanced environments. This observation still aligns with studies by Ma, Johnson, & McCrory (2023) and Siddiquei & Khalid (2021), which stress the role of multimodal online engagement and instructional adaptability.

The application of problem-solving in web-based learning provides students with the opportunity to identify the problems they face and actively engage in the problem-solving process. This process generates new knowledge, making learning more meaningful. In the problem identification stage, students are invited to understand physical phenomena to discover patterns that form the basis of new concepts. This activity fosters critical and analytical thinking skills, as supported by the findings of Pertiwi, Saputro, Yamtinah, & Kamari (2024), which indicates that problem-based approaches are highly effective in enhancing conceptual understanding of science. Choi et al. (2022) further highlight the efficacy of e-problem-based learning in improving conceptual grasp in specialized domains.

Student observations during the learning process indicate that the use of videos and dynamic simulations, such as PHET, plays a crucial role in helping students understand electrical concepts. PHET allows students to see changes in electric current and potential differences in simple circuits directly. The use of this simulation not only makes the concepts easier to understand but also provides students with opportunities to conduct virtual experiments. This aligns with the characteristics of visual and kinesthetic learning styles that are dominant in the student population and reinforces the findings (Afolabi, 2021). Studies like Kırıkkaya & Yıldırım (2021) also report improvements in student outcomes and self-directed learning through the integration of Web 2.0 tools and simulations.

Web-based learning transforms the conventional process, which is generally dominated by teacher explanations, into an active, exploration-based learning experience. Student activities become more diverse and can be tailored to each individual's learning style. This makes web-based learning more adaptive to students' learning needs compared to conventional classroom learning. Banda & Nzabanimana (2021) emphasize that this variation in activities directly impacts the improvement of learning outcomes. Providing links to materials that match students' interests increases motivation and makes learning more personal and enjoyable. According to Goodyear, Carvalho, & Yeoman (2021), activity-centered design fosters such personalization by aligning tasks with learners' cognitive and emotional engagement.

The effectiveness of this approach can be further explained by how PhET simulations facilitate conceptual development for each specific indicator. For example, the improvement in the 'circuit configuration' indicator can be attributed to the drag-and-drop feature in PhET, which allows students to kinesthetically build and manipulate circuits an experience that textbooks alone cannot provide. For the 'potential difference' indicator, real-time visualization of voltage changes across components helps clarify abstract relationships, especially for visual learners. In the case of 'Ohm's Law', students could test how varying resistance and voltage affect current flow, reinforcing the

mathematical relationships through repeated virtual trials. The resistance and electric current indicators benefited from dynamic graphs and measurement tools embedded in the simulation, enabling students to interpret data and identify patterns. Altogether, these interactive elements promote inquiry, experimentation, and personalized learning paths, all of which support deeper conceptual understanding.

In web-based learning with PhET simulations, students are given problems similar to those encountered in class. To solve the problem, students arrange the variables known from the problem and identify the variables needed to solve the problem. Students' understanding of the concept is the primary key to solving electrical problems before arranging the components to solve the problem. When solving problems involving electric current and voltage in a circuit, students must understand the concept of current and voltage dividers to determine whether a circuit is in series or parallel. Although the use of PhET is a virtual laboratory activity, students' understanding of real phenomena greatly helps them succeed in solving the problems they face. This activity can help students understand the phenomenon being faced. In solving problems, students are actively involved in taking measurements, collecting data, and explaining the results they obtain. This learning activity has an impact on students' ability to change various representations to other representations, which is an essential conceptual understanding for students. Presenting data in the form of a table of measurement results and then converting it into a graph will provide students with a learning experience that enhances their ability to interpret data. The ability to read and interpret data is a crucial skill for students in the face of global competition. Thus, web-based learning problem-solving with PhET simulations can improve students' understanding of concepts and 21st-century skills.

This improvement is closely related to the flexibility of material presentation in web-based learning. As explained by Pradana, Setyosari, & Ulfa (2023), Web-based learning enables the presentation of materials in various formats tailored to the characteristics of the students, thereby motivating them to be more actively engaged in the learning process. Visual materials, interactive animations, and virtual experiment simulations provide a more engaging and contextual learning experience. This alignment helps students form a deeper conceptual understanding because the information is presented in an easily understandable form and is relevant to their daily experiences. Önder et al. (2023) further emphasize that well-designed web-based systems can support the development of science process skills, which are foundational to understanding complex concepts.

The improvement in students' understanding of dynamic electrical concepts is generally in the moderate category, except for two indicators that fall into the high N-Gain category, namely the ability to interpret and explain. The interpretation skills developed in web-based learning include the ability to understand trends in graphs and data tables, as well as information in various formats, such as text, images, simulations, and videos. Meanwhile, the ability to explain is honed through discussion activities where students are asked to express their opinions and explain their answers. Both of these skills are essential for science learning because they help students convey and interpret concepts logically and structurally. According to Fendi, Suyatna, & Abdurrahman (2021), the integration of AR-based worksheets can also stimulate critical thinking and enhance explanatory competence.

The implications of these results for science education are vast. Web-based approaches with support for visualization and interactivity can serve as an effective learning model for science subjects. Science teachers need to utilize digital media effectively to bridge abstract concepts and accommodate diverse learning styles. The presentation of material through simulations, such as PHET, educational videos, and interactive quizzes, can enhance student engagement and create a more active and enjoyable learning environment. This approach also provides students with space to explore and validate their understanding independently. Maunula, Maunumäki, Marôco, & Harju-Luukkainen (2023) and Berenshtein et al. (2023) show that such models also positively affect student engagement and well-being, particularly in digital environments.

The consistent increase in N-Gain scores across all indicators shows that web-based learning not only enhances understanding but also strengthens students' independence and motivation to learn. They no longer rely entirely on the teacher's explanations but instead actively seek, try, and build understanding through various digital resources available to them. Web-based learning also provides a flexible learning system, allowing students to learn at their own pace and according to their own learning style, anytime and anywhere. In the context of 21st-century education, independence and digital literacy are crucial for shaping adaptive and highly competitive students.

The ability of web-based learning to present materials in various formats, including text, audio, video, and simulations, is directly tied to its success. While visual learners benefit from animations, diagrams, and visual simulations like PHET, auditory learners benefit from the use of video narration and discussion forums. Interactive elements such as virtual experiments offer kinesthetic learners an exploratory environment that mimics actual practice. El-Sabagh (2021), which emphasizes the importance of presenting content based on students' learning styles, supports these findings. Similarly, Jumadi, Perdana, Riwayani, & Rosana (2021) and Ramalingam, Yunus, & Hashim (2021) showed that online learning environments incorporating interactive labs and blended strategies enhance scientific reasoning and comprehension across varied learner profiles.

This study supports that of (Lin & Wu, 2021), who found that dynamic and interactive content in web-based science education can improve motivation and conceptual understanding. Furthermore, studies (Meng & Hong, 2024) demonstrate that digital media with an audiovisual component can significantly enhance the learning outcomes of students with diverse learning preferences. This highlights how equitable learning outcomes in diverse classrooms are facilitated by learning platforms that are sensitive to a range of learning styles. Reinforcing this, Chen (2024) underscores the importance of equity and differentiated instruction in achieving just educational outcomes. Additionally, Muhammad M Asad & Malik (2024) advocate for cybergogical approaches that blend inclusion and quality through adaptive learning in digital contexts.

Science teachers must create inclusive learning environments due to the variety of learning styles among their students. Differentiating the content is possible with web-based learning without altering the material's structure. Teachers can give students the freedom to select the learning strategies that work best for them and offer a variety of adaptable learning resources. This promotes the development of 21st-century skills, including digital proficiency, critical thinking, and self-directed learning, while also enhancing conceptual understanding. In this regard, Maya & Suseno (2022) and Ichsan, Suharyat, Santosa, & Satria (2023) all stress that integrating digital tools with 21st-

century learning outcomes significantly enhances student preparedness. Moreover, Kathayat (2024) reveals that digital differentiation supports metacognitive development, crucial for complex problem-solving.

A more individualized and flexible approach to learning is indirectly promoted by web-based learning. While visual and kinesthetic learners can select suitable animations or simulations, auditory learners can select audio-based content. This personalization accelerates the improvement of learning outcomes, enabling students to grasp complex concepts, such as electricity. This strategy aims to enhance the efficacy of science education in the digital age. As noted by Shabbir, Ayub, Khan, & Davis (2021), personalization increases both short-term and long-term motivation. Studies by Ulya, Sugiman, Rosnawati, & Retnawati (2024) further substantiate how technology-enhanced strategies empower learners through personalized inquiry and adaptive content delivery in science and math education.

These findings are consistent with research by Muhammad Mujtaba Asad, Khan, Sherwani, & Banerjee (2022), which found that using web-based learning resources can increase students' intrinsic motivation, particularly in conceptual subjects such as physics. They observed that students' motivation to learn rises dramatically when they believe they have control over the manner and speed of their education. In addition to giving students that freedom, the web-based learning approach employed in this study provides a platform for self-directed inquiry, which enhances their emotional investment in the educational process. This statement is reinforced by Özdal, Özden, Atasoy, & Güneyleli (2022), who found that self-regulated learning skills significantly influence students' attitudes toward online learning, and Doghan (2023), who linked motivation to sustainable knowledge transfer.

A strong desire to learn is a necessary condition for science education to be successful, particularly when it comes to comprehending abstract and complex ideas. More motivated students are more eager to learn more, carry out investigations, and learn more about the scientific phenomena they are studying. This method strengthens the cognitive and affective components of the learning process by providing opportunities for both independent and group learning when teaching the concept of electricity. Lajane et al. (2021) demonstrated that formative e-assessment based on the ARCS model enhances student motivation, while Oluwajana, Adeshola, & Clement (2021) showed that web-based collaboration platforms can reduce cognitive load and boost engagement in project-based learning.

Given the effectiveness of this method in boosting motivation, science instructors are encouraged to incorporate web-based learning techniques into their lessons regularly. Web-based simulations, project-based assignments, and the creation of interactive content ought to be essential components of physics and science education in general. Students are more motivated and better equipped to handle the demands of 21st-century learning thanks to this approach's emphasis on visual, interactive, and contextual components. According to Çoban & Göksu (2022), virtual reality environments can play a similar role in motivating learners, while Zourmpakis, Kalogiannakis, & Papadakis (2023) highlight the motivational impact of adaptive gamification. Moreover, Shkëmbi, Sauku, Ibrahim, & Ibrahim (2024) emphasize the broader psychological benefits of online education on student well-being and sustained motivation.

The idea that a web-based science learning design that emphasizes conceptual understanding can be used as a strategy to boost students' motivation to learn is empirically supported by this model. To design learning activities that foster deep understanding, science teachers should utilize interactive animations, virtual experiments, and simulations. Building knowledge through contextual learning experiences will increase students' motivation to learn, thereby improving the efficacy and sustainability of science education. This is echoed by Kusairi, Muhamad, Razak, & Trapsila (2022), who showed that integrating formative e-assessment in collaborative inquiry enhances conceptual comprehension.

According to this model, students should be encouraged to learn independently and with interest once they have a solid conceptual understanding. Students who have a solid conceptual understanding will be more motivated to study independently and go deeper into scientific material. Web-based learning, which provides users with access to a range of educational resources and interactive media, makes these opportunities possible. Therefore, this approach is efficacious in improving learning outcomes while also creating independent, motivated students who are well-prepared to meet the demands of education in the twenty-first century. Nonthamand & Suaklay (2021) highlight how digital literacy and self-regulated learning correlate with autonomy and improved outcomes.

Concurrently, the study's results indicate that student learning outcomes and motivation significantly improve when web-based learning, utilizing a problem-solving approach, is employed. The high post-test scores and N-Gain results demonstrate significant improvement in learning outcomes across almost all electrical concept understanding measures. Students' learning motivation also falls into the very high category, with an average percentage of 88% across the four motivation indicators. This finding implies that learning that is relevant, interactive, and tailored to the individual learning preferences of each student can simultaneously enhance affection and cognition. Phanphech et al. (2022) note that reduced anxiety in synchronous/asynchronous formats enhances engagement in physics learning.

The positive correlation between learning outcomes and motivation further supports the importance of an integrated learning approach. Web-based learning that uses simulations, visualizations, and virtual experiments not only enhances conceptual understanding but also creates a positive learning environment for students. This approach is perfect for use in the context of science education because it emphasizes observation, inquiry, and reflection three essential elements of constructivist learning. The foundation of thorough and enduring learning may be the improvement of both cognition and affect. Porras (2021) and Rao, Luo, Su, & Wang (2021) Provide further support by explaining how self-regulation minimizes academic stress and fosters deeper cognitive processing.

The results of the study show that when web-based learning is combined with a problem-solving approach, students' understanding of electrical concepts and motivation to learn are both significantly and substantially enhanced. This approach simultaneously enhances students' cognitive and affective abilities, which aligns with 21st-century learning objectives that emphasize conceptual understanding, self-directed learning, and digital literacy. Regan, Hopson, Gisondi, & Branzetti (2022) and Rusdi, Ristanto,

Prabowo, & Sarwono (2023) underscore that mastery in science involves adaptive learning behaviors and digital competencies.

Students demonstrate strong interpretative and explanatory abilities, in addition to understanding basic concepts such as current and voltage, as evidenced by the N-Gain values for all electrical concepts, which show a significant improvement in post-test scores. The N-Gain categories, which mostly fall within the medium to high level, particularly on the concept explanation indicator in Bloom's taxonomy, demonstrate how the learning process can produce a profound understanding. These conclusions are supported by data on student learning motivation, which indicates an average score of 88%, with all indicators falling into the very high category. This demonstrates that the employed learning strategy not only enhances learning outcomes but also provides students with an enjoyable, challenging, and rewarding educational experience.

One of the key factors contributing to the success of web-based learning is its capacity to accommodate different learning styles. Students with fairly evenly distributed visual, auditory, and kinesthetic learning styles all show a significant improvement in conceptual understanding after the learning process. Because the content is presented in a variety of formats, such as text, audio, animation, and interactive simulations, students are free to choose the learning strategy that best suits their preferences. The principles of Universal Design for Learning (Munfaridah, Avraamidou, & Goedhart, 2021), which emphasize the importance of presenting a range of information so that all students can access and use it, are consistent with this approach. Weruwanaruk, Kanjung, Sarakorn, & Moeikao (2023). Extend this by showing that flipped metaverse-based designs enhance conceptual understanding and engagement through learning personalization.

Furthermore, this learning model contributes to enhancing digital literacy and promoting student autonomy in their education. Students who have access to a range of online learning resources are better able to adjust to learning at their own speed, complete assignments on time, and conduct independent research. This corroborates the results of Hasas, Enayat, Hakimi, & Ahmady (2024), who discovered that digital learning fosters learning responsibility and intellectual inquiry. Instead of merely relying on the teacher's explanations, students in this environment develop into active learners who create knowledge via introspective and exploratory experiences. Utari, Hasan, Adlim, & Elisa (2023) confirm that improving self-regulation directly boosts conceptual understanding, particularly when supported by structured learning models like POGIL.

▪ CONCLUSION

This study explores the effectiveness of web-based problem-solving learning integrated with PhET simulations in enhancing students' conceptual understanding and motivation on the topic of electrical circuits. Utilizing a descriptive method, the study involved 30 students from a private university in Palembang who engaged in web-based instruction supported by interactive simulations and contextual problem-solving activities. Data were collected through a learning style questionnaire, a concept understanding test, and a motivation questionnaire administered via Google Forms. The results revealed a significant increase in students' post-test scores across five indicators of conceptual understanding electric current, potential difference, resistance, Ohm's Law, and circuit configuration with N-Gain values ranging from moderate to high. Notably, students with auditory and kinesthetic learning styles showed slightly higher gains.

Learning motivation also demonstrated a very high category, with 88% of students indicating strong interest and persistence in the learning process. The integration of web-based platforms and PhET simulations not only facilitated flexible and personalized learning experiences but also supported students' engagement, exploration, and self-regulation. These findings highlight the potential of technology-enhanced science instruction to bridge cognitive and affective learning domains, making it a valuable approach for future pedagogical innovations in physics education.

▪ REFERENCES

- Abdamia, N., Puteh, F., & Jah, N. J. A. (2023). Investigating learning modalities among diploma students. *International Journal of Academic Research in Progressive Education and Development*, 12(2). doi:10.6007/ijarped/v12-i2/16552
- Aboobaker, N., & K.H., M. (2021). Effectiveness of web-based learning environment: role of intrinsic learning motivation, computer self-efficacy, and learner engagement. *Development in Learning Organizations, an International Journal*, 36(4), 13–16. doi:10.1108/dlo-07-2021-0139
- Afolabi, F. (2021). Learning styles: Tools for understanding media selection and learners' academic achievement in physics. *Journal of Educational Sciences*, 5(4), 584–597.
- Al-Duhani, F., Saat, R. M., & Abdullah, M. N. S. (2024). Effectiveness of web-based virtual laboratory on grade eight students' self-regulated learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(3), em2410.
- Alimah, S. (2023). Profile of culinary vocational school students' learning styles as a basis for choosing science learning methods. *Journal of Mangifera Edu*, 8(1), 25–31. doi:10.31943/mangiferaedu.v8i1.174
- Amiri, F., Quraishi, T., Hakimi, M., & Fazil, A. W. (2024). Assessing the efficiency of web-hosted e-learning platforms in afghanistan academic settings. *Edutrend*, 1(1), 39–56. doi:10.59110/edutrend 309
- Anisa, V. M., & Astriani, D. (2022). Implementation of PhET simulation with discovery learning model to improve understanding of dynamic electricity concepts. *Jurnal Pijar Mipa*, 17(3), 292–301. doi:10.29303/jpm.v17i3.3438
- Arni, Y., Utami, W. W., Khoirunnisak, L., & Amelia, F. (2024). The effect of visual, auditory, kinesthetic learning styles on student learning outcomes in science subjects. *Journal of Education and Teaching Learning (Jetl)*, 6(1), 119–129. doi:10.51178/jetl.v6i1.1794
- Asad, M. M., & Malik, A. (2024). Educational quality and inclusion through collaborative hybridized cybergogy: transformative learning horizons in pakistani universities. *Interactive Technology and Smart Education*, 21(4), 672–689. doi:10.1108/itse-10-2023-0193
- Asad, M. Mujtaba, Khan, S., Sherwani, F., & Banerjee, J. S. (2022). Impact of asynchronous Web-based learning environment on students' interest and motivation in mathematics: a quantitative research study. *The International Journal of Information and Learning Technology*, 39(4), 340–359.
- Astalini, A., Darmaji, D., Kurniawan, D. A., Jaya, H., & Husna, S. M. (2022). Analysis of teacher responses to the use of web-based assessment to assess students' attitudes towards science subjects. *Integrated Science Education Journal*, 3(3), 66–71. doi:10.37251/isej.v3i3.282

- Ayub, S., Karim, A., & Laraib, A. (2023). Learning styles of medical students. *The Professional Medical Journal*, 30(09), 1214–1218. doi:10.29309/tpmj/2023.30.09.7650
- Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, 17(2), 023108.
- Batsaikhan, A., Kurtz, W., & Hachinger, S. (2022). Web technologies to support scientific research and education in citizen science a case study in germany. *Digital*, 2(1), 53–64. doi:10.3390/digital2010004
- Berenshtein, Y., Tesler, R., Hochwald, I. H., & Green, G. (2023). The perspectives of health sciences students: the new way of learning: mixed methods design. *Digital Health*, 9. doi:10.1177/20552076231216539
- Buar, C. L., & Obiedo, R. (2025). Motivating learning in physics: investigating the effects of 4 modes application technique (4MAT) teaching model integrating phet simulations on student motivation. *Physics Education*, 60(4), 045005. doi:10.1088/1361-6552/adca7d
- Chinnasami Sivaji, M. R., Murugan, A., & Raja, C. (2022). Instructional design of collaborative learning environments. *Journal on Innovations in Teaching and Learning*, 1(1), 1–8.
- Choi, Y.-R., Lee, Y., Kim, D., Park, W. H, Kwon, D. Y, & Chang, Sung O. (2022). An E-Problem-Based learning program for infection control in nursing homes: a quasi-experimental study. *International Journal of Environmental Research and Public Health*, 19(20), 13371. doi:10.3390/ijerph192013371
- Chua, E. R., Sibbaluca, B. G., Mack, M. R., & Militante, S. V. (2020). Technological strategies in teaching: Towards the design of a virtual learning environment. *International Journal of Scientific and Technology Research*.
- Çoban, M., & Göksu, İ. (2022). Using virtual reality learning environments to motivate and socialize undergraduates in distance learning. *Participatory Educational Research*, 9(2), 199–218. doi:10.17275/per.22.36.9.2
- DeCoito, I., & Estaiteyeh, M. (2022). Online teaching during the covid-19 pandemic: exploring science/stem teachers' curriculum and assessment practices in canada. *Disciplinary and Interdisciplinary Science Education Research*, 4(1). doi:10.1186/s43031-022-00048-z
- Doghan, M. A. A. (2023). Prediction of sustainable environment training towards knowledge transfer through motivation to learn. *Journal of Law and Sustainable Development*, 11(12), e2255. doi:10.55908/sdgs.v11i12.2255
- Doyle, C., Chiu, Y.-T., Nagle, T., & Luczak–Roesch, M. (2023). Unraveling the relationship between content design and kinesthetic learning on communities of practice platforms. doi:10.24251/hicss.2023.079
- Drake, S. M., & Savage, M. J. (2016). Negotiating accountability and integrated curriculum from a global perspective. *International Journal of Learning, Teaching and Educational Research*, 15(6), 127–144.
- El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on the development of students' engagement. *International Journal of Educational Technology in Higher Education*, 18(1), 53.

- Fahim, A., Rehman, S., Fayyaz, F., Javed, M., Alam, M. A., Rana, S., ... Alam, M. K. (2021). Identification of preferred learning style of medical and dental students using vark questionnaire. *Biomed Research International*, 2021(1). doi:10.1155/2021/4355158
- Fendi, R. D., Suyatna, A., & Abdurrahman, A. (2021). Augmented reality-based student worksheet to stimulate students' critical thinking skills. *Indonesian Journal of Science and Mathematics Education*, 4(2), 118–133. doi:10.24042/ij sme.v4i2.9017
- Fraenkel, J. R., & Wallen, N. E. (2009). *How to Design and Evaluate Research in Education*. McGraw-Hill Companies, Inc.
- Furqon, M. (2023). Effect of interactive conceptual instruction assisted by phet simulations on the students' scientific consistency in physics. *Jurnal Penelitian Pendidikan Ipa*, 9(10), 8040–8050. doi:10.29303/jppipa.v9i10.5193
- Goodyear, P., Carvalho, L., & Yeoman, P. (2021). Activity-Centred Analysis and Design (ACAD): Core purposes, distinctive qualities and current developments. *Educational Technology Research and Development*, 69(2), 445–464. doi:10.1007/s11423-020-09926-7
- Hakim, L., Lubis, P. H. M., & Khaokhajorn, W. (2022). Developing adaptive materials based on learning style to increase students' conceptual understanding. *Jurnal Kependidikan*, 6(1), 115–128.
- Hasas, A., Enayat, W., Hakimi, M., & Ahmady, E. (2024). A comprehensive review of ICT integration in enhancing physics education. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, 2(1), 36–44.
- Ichsan, I., Suharyat, Y., Santosa, T. A., & Satria, E. (2023). Effectiveness of STEM-Based learning in teaching 21st century skills in generation z students in science learning: a meta-analysis. *Jurnal Penelitian Pendidikan Ipa*, 9(1), 150–166. doi:10.29303/jppipa.v9i1.2517
- Inam, S., & Haq, A. (2022). Exploring the preferred learning styles among first and final year mbbs students using vark inventory at fauji foundation hospital rawalpindi. *Health Professions Educator Journal*, 5(1), 9–13. doi:10.53708/hpej.v5i1.1257
- Jumadi, J., Perdana, R., Riwayani, R., & Rosana, D. (2021). The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill. *International Journal of Evaluation and Research in Education (Ijere)*, 10(1), 16. doi:10.11591/ijere.v10i1.20593
- Kalogiannakis, M., Papadakis, S., & Zourmpakis, A.-I. (2021). Gamification in science education. a systematic review of the literature. *Education Sciences*, 11(1), 22. doi:10.3390/educsci11010022
- Kasirye, F., & Wok, S. (2023). Factors influencing the usage of web-based video conferencing platforms in knowledge acquisition among students. *International Social Science Journal*, 73(248), 261–277. doi:10.1111/issj.. 12392
- Kathayat, B. B. (2024). Metacognitive skills in mathematics learning: a systematic review of literature. *J. Musikot Campus*, 2(1), 41–57. doi:10.3126/jmc.v2i1.70785
- 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. doi:10.24042/jipfalbiruni.v11i1.10998
- Kırıkkaya, E. B., & Yıldırım, İ. (2021). Investigating the effect of the use of web 2.0 tools in 7th grade on students' academic achievements and their self-directed learning

- with technology levels. *Journal of Turkish Science Education*, 18(3), 439–460. doi:10.36681/tused.2021.83
- Kusairi, S., Muhamad, S., Razak, N. A., & Trapsila, A. P. (2022). The role of local wisdom 'ugahari' and the impact of internet and mobile technology on work-life-balance during the covid-19 outbreak: data set from malaysian workers. *Data in Brief*, 40, 1–8. doi:10.1016/j.dib.2021.107779
- Lajane, H., Arai, M., Gouifrane, R., Qaisar, R., Idrissi, W. E. machtani El, Chemsu, G., & Radid, M. (2021). A scenario of the formative e-assessment based on the arcs model: what is the impact on student motivation in educational context? *International Journal of Emerging Technologies in Learning (IJET)*, 16(24), 135–148. doi:10.3991/ijet.v16i24.24121
- Lane, B., Garousi-Nejad, I., Gallagher, M. A., Tarboton, D. G., & Habib, E. (2021). An open web-based module developed to advance data-driven hydrologic process learning: hydrological *Processes*, 35(7). doi:10.1002/hyp.14273
- Ma, J., Johnson, E. A., & McCrory, B. (2023). Understanding learning engagement with user-centered human-computer interaction in a multimodal online learning environment. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 67(1), 2018–2023. doi:10.1177/21695067231193675
- Maunula, M., Maunumäki, M., Marôco, J., & Harju-Luukkainen, H. (2023). Developing students' well-being and engagement in higher education during covid-19 a case study of web-based learning in Finland. *Sustainability*, 15(4), 3838. doi:10.3390/su15043838
- Maya, L., & Suseno, M. (2022). Investigating the incorporation of digital literacy and 21st-century skills into postgraduate students' learning activities. *Ele Reviews English Language Education Reviews*, 2(1), 13–27. doi:10.22515/elereviews.v2i1.5121
- Munfaridah, N., Avraamidou, L., & Goedhart, M. (2021). The use of multiple representations in undergraduate physics education: what do we know and where do we go from here? *Eurasia Journal of Mathematics, Science and Technology Education*, 17(1), em1934.
- Nonthamand, N., & Suaklay, N. (2021). Self-Regulation students' online learning behavior in general education courses of the University of Phayao. *International Journal of Emerging Technologies in Learning (IJET)*, 16(14), 269. doi:10.3991/ijet.v16i14.19897
- Oluwajana, D., Adeshola, I., & Clement, S. (2021). Does the use of a web-based collaborative platform reduce cognitive load and influence project-based student engagement? *Current Psychology*, 42(10), 8265–8278. doi:10.1007/s12144-021-02145-0
- Önder, E. Y., Zorluoğlu, S. L., Demirer, V., Özdemir, M., Baturay, M. H., Timur, S., & Timur, B. (2023). Needs analysis for a web-based learning system to develop students' science process skills. *Shanlax International Journal of Education*, 11(S1-July), 37–53. doi:10.34293/education.v11i1s1-july.5844
- Özdal, H., Özden, C., Atasoy, R., & Güneyli, A. (2022). Effectiveness of self-regulated learning skills on web-based instruction attitudes in online environments. *Pepegog*, 12(1). doi:10.47750/pepegog.12.01.18

- Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through stem problem-based contextual learning: an integrated e-module education website with virtual experiments. *Journal of Baltic Science Education, 23*(4), 739–766.
- Phanphech, P., Tanitteerapan, T., Mungkung, N., Arunrungrusmi, S., Chunkul, C., Songruk, A., ... Kinoshita, H. (2022). An analysis of student anxiety affecting online learning on conceptual applications in physics: synchronous vs. asynchronous learning. *Education Sciences, 12*(4), 278. doi:10.3390/educsci12040278
- Porras, J. F. C. (2021). Self-regulated learning and academic stress in university students. *Revista Gestão Inovação E Tecnologias, 11*(3), 719–726. doi:10.47059/revistageintec.v11i3.1970
- Pradana, F., Setyosari, P., & Ulfa, S. (2023). Development of gamification-based e-learning on web design topic. *International Journal of Interactive Mobile Technologies, 17*(3).
- Rahmawati, O. S., Hartono, H., & Nugroho, K. Y. (2024). EFL students' anxiety in writing scientific papers for publication: levels and types. *Journal of Advanced Multidisciplinary Research, 5*(2), 133. doi:10.30659/jamr.5.2.133-143
- Ramalingam, S., Yunus, M. M., & Hashim, H. (2021). Exploring ESL learners' blended learning experiences and their effectiveness through web-based technologies. *International Journal of Evaluation and Research in Education (Ijere), 10*(4), 1436. doi:10.11591/ijere.v10i4.21465
- Ramezani, G., Norouzi, A., Arabshahi, S. K. S., Sohrabi, Z., Zazoly, A. Z., Saravani, S., & Pourbairamian, G. (2022). Study of medical students' learning approaches and their association with academic performance and problem-solving styles. *Journal of Education and Health Promotion, 11*(1), 252. doi:10.4103/jehp.jehp_900_21
- Rao, X., Luo, L., Su, Q., & Wang, X. (2021). Online study: understanding the laws of self-regulated study. doi:10.21203/rs.3.rs-775791/v1
- Regan, L., Hopson, L. R., Gisondi, M. A., & Branzetti, J. (2022). Creating a better learning environment: a qualitative study uncovering the experiences of master adaptive learners in residency. *BMC Medical Education, 22*(1). doi:10.1186/s12909-022-03200-5
- Roski, M., Ewerth, R., Hoppe, A., & Nehring, A. (2024). Exploring data mining in chemistry education: building a web-based learning platform for learning analytics. *Journal of Chemical Education, 101*(3), 930–940. doi:10.1021/acs.jchemed.3c00794
- Rusdi, R., Ristanto, Rizhal H., Prabowo, G. O., & Sarwono, E. (2023). Self-regulated learning and digital literacy: relationship with conceptual understanding of the excretory system. *Journal of Science Learning, 6*(1), 1–10. doi:10.17509/jsl.v6i1.47269
- Safar, N. Z. M., Kamaludin, H., Ahmad, M., Jofri, M. H., Wahid, N., & Gusman, T. (2022). Intervention strategies through interactive gamification e-learning web-based application to increase computing course achievement. *JOIV: International Journal on Informatics Visualization, 6*(2), 376–381.

- Salame, I. I., & Makki, J. (2021). Examining the Use of PhET simulations on students' attitudes and learning in general chemistry II. *Interdisciplinary Journal of Environmental and Science Education*, 17(4), e2247. doi:10.21601/ijese/10966
- Sardiman, A. M. (2012). *Interaksi dan motivasi belajar mengajar*. Palembang: PT Raja Garafindo Persada.
- Shabbir, S., Ayub, M., Khan, F. A., & Davis, J. (2021). Short-term and long-term learners' motivation modeling in web-based educational systems. *Interactive Technology and Smart Education*, 18(4), 535–552. doi:10.1108/itse-09-2020-0207
- Shkëmbi, F., Sauku, V. H., Ibrahim, S., & Ibrahim, E. (2024). The psychological impact of online education on student well-being and motivation. *Issej*, 2(2), 01–08. doi:10.61424/issej.v2i2.122
- Siddiquei, N. L., & Khalid, R. (2021). Development and validation of learning style scale for e-learners. *Sage Open*, 11(2). doi:10.1177/21582440211022324
- Simamora, R. M., De Fretes, D., Purba, E. D., & Pasaribu, D. (2020). Practices, challenges, and prospects of online learning during the COVID-19 pandemic in higher education: Lecturer perspectives. *Studies in Learning and Teaching*, 1(3), 185–208.
- Subagja, S., & Rubini, B. (2023). Analysis of student learning styles using Fleming's VARK model in science subject. *Jurnal Pembelajaran Dan Biologi Nukleus*, 9(1), 31–39. doi:10.36987/jpbn.v9i1.3752
- Sudibyo, E., Jatmiko, B., & Widodo, W. (2017). *Pengembangan instrumen motivasi belajar fisika: angket*. *Jurnal Penelitian Pendidikan IPA*, 1(1), 13. doi:10.26740/jppipa.v1n1.p13-21
- Taibu, R., Mataka, L. M., & Shekoyan, V. (2021). Using PhET simulations to improve scientific skills and attitudes of community college students. *International Journal of Education in Mathematics, Science and Technology*, 9(3), 353–370. doi:10.46328/ijemst.1214
- Ulya, H., Sugiman, S., Rosnawati, R., & Retnawati, H. (2024). Technology-based learning interventions on mathematical problem-solving: a meta-analysis of research in Indonesia. *International Journal of Evaluation and Research in Education (Ijere)*, 13(1), 292. doi:10.11591/ijere.v13i1.26380
- Umbrella, G. (2024). Identify the learning styles of St. Anthony Junior High School students in the 2023/2024 academic year. *Armada*, 1(3), 151–158. doi:10.59613/armada.v1i3.2852
- Utari, A. P., Hasan, M., Adlim, M., & Elisa, E. (2023). Correlation between improving self-regulated learning and students' conceptual understanding of colloidal topics using the POGIL Approach. *Jurnal Penelitian Pendidikan Ipa*, 9(9), 7317–7325. doi:10.29303/jppipa.v9i9.4906
- Vieira, A., Vidal, M., Menassol, J.-B., Mateus, T. L., Santos, A. S., Durieux, J.-P., & Oliveira, M. D. (2022). ANIPHI: An innovative pedagogical platform based on the Delphi method to support animal welfare teaching. *Plos One*, 17(11), e0277189. doi:10.1371/journal.pone.0277189
- Weruwanaruk, P., Kanjung, I., Sarakorn, W., & Moeikao, N. (2023). The designing framework for flipped learning environment on metaverse to enhance mathematical conceptual understanding for seventh grade students. *Ijai Letters on Institutional Research*, 3, 1. doi:10.52731/lir.v003.141

- Wulandari, A., Hakim, L., Sulistyowati, R., & Mian, Y. (2022). Interactive multimedia development using Google Sites to improve student learning outcomes and energy. *EDUSAINS*, 14 (2), 188-201.
- Yusnidah, Y., Hidayat, M. I., & Maulana, D. (2023). The effectiveness of using interactive learning media based on the google sites website on dynamic electricity material. *Jurnal Sinestesia*, 13(2), 941–947.
- Zahara, S. R., Imanda, R., Alvina, S., Sirait, A. F., Irsyat, M., & Harahap, M. A. (2024). Web-Based science learning media at high school level. *Proceedings of International Conference on Social Science, Political Science and Humanities (Icospolhum)*, 4, 00033. doi:10.29103/icospolhum.v4i.410
- Zhu, L. (2023). Exploring the implementation path of teaching civics in online courses in colleges and universities under the background of big data. *Applied Mathematics and Nonlinear Sciences*, 9(1). doi:10.2478/amns.2023.2.00530
- Zourmpakis, A.-I., Kalogiannakis, M., & Papadakis, S. (2023). Adaptive gamification in science education: an analysis of the impact of implementation and adapted game elements on students' motivation. doi:10.20944/preprints202306.1513.v1