

Synergizing Virtual Labs and Project-Based Learning: Innovating Modern Physics Education with Interactive Modules

Sri Purwaningsih¹, Rahma Dani², Edi Yuversa²

¹ Universitas Jambi, Jambi, Indonesian; sripurwaningsih@unja.ac.id

² Universitas Jambi, Jambi, Indonesian; rahmadani@unja.ac.id

³ Universitas Jambi, Jambi, Indonesian; ediyuversa88@gmail.com

ARTICLE INFO

Keywords:

modern Physics module;
project-based learning;
virtual lab

Article history:

Received 2023-07-28

Revised 2023-10-09

Accepted 2024-03-23

ABSTRACT

Inadequate learning facilities in the Department of Physics Education contribute to the lack of student involvement during modern physics lectures. The learning approach primarily revolves around lecturers, and the effectiveness of Zoom for online learning among students is limited. Therefore, the aim of this research is to design a virtual lab-based learning module integrated with project-based learning to enhance students' conceptual understanding. This research employed a development method with the 4D model. The research subjects included two expert validators to assess the product's feasibility, five students for small-group trials, and 22 students for effectiveness trials. Validators were given questionnaires to evaluate the module's feasibility, while students were given questionnaires to gauge their responses to the module. To evaluate the efficacy of the module, students underwent pre-tests and post-tests consisting of 5 essay questions. Analysis encompassed consolidating validation outcomes and student feedback. Concurrently, test results were assessed using N-Gain tests and paired t-tests. The research outcomes indicated that the integration of virtual lab-based learning with PBL in modern physics was both feasible and effective in enhancing students' conceptual comprehension.

This is an open access article under the [CC BY-NC-SA](#) license.



Corresponding Author:

Sri Purwaningsih

Universitas Jambi, Jambi, Indonesian; sripurwaningsih@unja.ac.id

1. INTRODUCTION

In recent decades, physicists have increasingly delved into the nuances of students' grasp of physics principles (Engelhardt & Beichner, 2004; Riantoni, Yuliati, Mufti, & Nehru, 2017). The understanding of physics concepts is an understanding of the fundamental principles and laws that govern the universe and natural phenomena. Physics is a branch of natural science that focuses on understanding how the universe functions, ranging from subatomic particles to galaxies in the universe.

One of the fundamental objectives of studying physics is to elucidate natural phenomena (Tecson, Salic-Hairulla, & Soleria, 2021) and Guide students toward achieving a profound understanding of the fundamental concepts in physics (Rahmawati, Sutopo, & Zulaikah, 2017). In more detail, the objectives of learning physics are to enable students to have a strong understanding of concepts, critical thinking skills, the use of scientific methods, the development of mathematical skills, and the advancement of

scientific literacy. Additionally, physics education serves as a platform for students to explore their interests and careers, particularly enabling them to contribute to technological advancements and the understanding of the universe.

Numerous physics topics have been the subject of extensive research, with modern physics being a notable focus. Modern physics, as a branch of the discipline, places emphasis on qualitative learning approaches (Smith & van Kampen, 2011; Zacharia & de Jong, 2014). The qualitative approach is prioritized due to the significance of students' reading and analytical skills in this mode of learning (Wurdinger, Haar, Hugg, & Bezon, 2007). Moreover, modern physics presents a challenge, requiring an effective explanation of microscopic phenomena.

Key areas of research in university physics education include conceptual understanding, problem-solving strategies, curriculum development, teaching methodologies, assessment techniques, cognitive psychology applied to learning, and exploring attitudes and beliefs regarding teaching and learning (Docktor & Mestre, 2014). Each of these topics encompasses essential theoretical frameworks that necessitate ongoing study. They are aimed at devising strategies to facilitate discussions on physics more effectively. Curriculum development and teaching methodologies are particularly crucial among these highlighted areas (Leak et al., 2017). Curriculum development and teaching methodologies consistently receive emphasis in physics education due to their pivotal role in facilitating effective learning of the subject (Docktor, Strand, Mestre, & Ross, 2015; Ibrahim & Rebello, 2013). Physics educators typically prioritize the selection of learning strategies, recognizing their profound impact on student achievement and comprehension (Bilgin, 2009).

Technology integration in education, particularly during the COVID-19 pandemic, is crucial for facilitating smooth learning processes, especially with the shift toward online lectures. Given this situation, educators must create a virtual lab-based learning module that incorporates PBL. Referring to the modern physics syllabus outlined in the curriculum of the Department of Physics Education, Universitas Jambi provides a comprehensive framework for designing such a module.

Active student engagement is emphasized, encouraging participation, questioning, and critical thinking during lectures. This necessitates continuous innovation in teaching methods by lecturers. Students should be encouraged to solve problems, conduct experiments, watch instructional videos, and engage in virtual experiments related to the course material. However, a significant challenge faced by both students and lecturers is the lack of an existing product. It is the responsibility of the lecturer to develop and implement such a module to enhance the learning experience for students. The observations made during online modern physics lectures via Zoom Cloud Meeting revealed that students were primarily passive listeners, which rendered Zoom-based learning ineffective, especially for those with unstable internet connections. This limited their active participation, leading to suboptimal learning experiences. Addressing this issue is imperative, and effective solutions are required to enhance the learning process, such as increasing student engagement.

To tackle this challenge, we propose the development of interactive and innovative learning media. Specifically, we aim to design a virtual lab-based learning module integrated with project-based learning for modern physics. This approach will not only provide students with hands-on learning experiences but also encourage active participation and critical thinking. Through the integration of virtual labs and PBL into the curriculum, students can delve deeper into the material, creating a more effective and rewarding learning atmosphere, even amidst the constraints of online education.

Teaching modern physics, with its abstract and complex concepts, necessitates effective visualization methods. One approach is through the use of virtual labs, employing computerized simulations to represent intricate phenomena that may be challenging to comprehend in real-life scenarios (Corpuz & Rebello, 2011). One solution to address students' challenges in understanding abstract and complex processes is through the utilization of computerized simulations. This approach enables students to engage in virtual pre-laboratory exercises, access theoretical background information, understand practical laboratory procedures, and gain a comprehensive understanding through visualization and simulation (Jaime et al., 2016; Marcelo & Yot-Domínguez, 2019).

Employing a virtual lab based on computerized simulations offers a solution to various constraints encountered in traditional laboratory settings. Virtual labs are advantageous in terms of efficiency and safety, as they provide accessibility without the need for physical presence, addressing logistical challenges associated with traditional labs (Ceberio, Almudí, & Franco, 2016). Moreover, virtual labs can serve as substitutes for physical laboratory instruments, enabling students to collect and present data. They also offer communication and coordination tools, along with learning assistance resources to aid students in understanding various physics concepts and phenomena across different disciplines of physics (Martínez-sierra & García-gonzález, 2017).

Project-based learning (PBL) is intentionally crafted to engage students in tackling complex problems that they must understand, investigate, and solve. In PBL, students embark on an inquiry process guided by a central question, leading them to collaborate on a project that integrates various subjects from the curriculum. As students work towards answering the question, they observe key elements and principles within the discipline they are studying. PBL involves a thorough exploration of a real-life topic, requiring students' attention and effort. With each student possessing different learning styles, project-based learning provides opportunities to analyze content using methods meaningful to them and engage in collaborative experimentation.

PBL represents an innovative learning approach, emphasizing contextual learning through multifaceted activities. The core objectives of this approach are to enable students to grasp the fundamental concepts and principles of a discipline, engage them in inquiry for problem-solving and other meaningful tasks, provide opportunities for independent work to construct knowledge, and ultimately produce a tangible product as a result of their learning efforts.

Based on the described problems and the benefits of the proposed solutions, the objective of this study is to develop a virtual lab-based learning module integrated with project-based learning aimed at enhancing student engagement in learning modern physics. The research questions encompass:

- What are the results of the expert validation of the virtual lab-based and integrated project-based learning module designs that have been developed?
- How do students respond to the design of virtual lab-based modules and integrated project-based learning that has been developed?
- How is the improvement in students' conceptual understanding after being taught with a virtual lab-based learning module integrated with project-based learning?

2. METHODS

This study adopts a developmental approach utilizing the 4D model, which involves four stages of product development: defining, designing, developing, and disseminating (Dasilva, Kuswanto, Wilujeng, & Jumadi, 2019). The research design utilized in this study is illustrated in the accompanying figure 1.

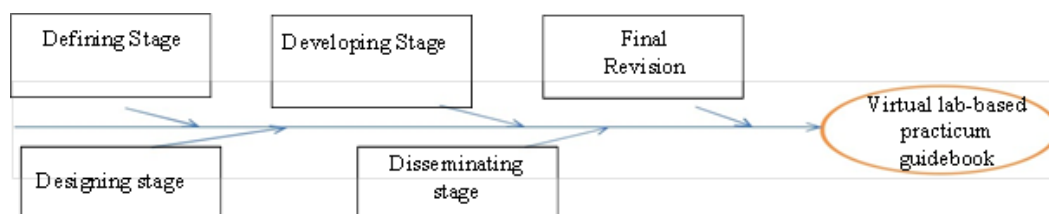


Figure 1. Illustrates the fishbone-like diagram depicting the development of virtual lab-based learning media.

The research involved two expert validators tasked with assessing the product's feasibility, along with five students participating in small group trials. Additionally, 22 students were involved in evaluating the effectiveness of the developed module. Sampling was conducted using the purposive sampling technique, and all students utilized the Virtual Lab-Based Practical Module.

Data for the study were obtained through expert validation and small-group testing. Validation encompassed 39 questions developed across four assessment aspects: Content feasibility, Presentation feasibility, Language assessment, and Approach. Small group testing involved 15 questions aimed at assessing student responses to the developed practicum guide. To assess the module's effectiveness in enhancing students' conceptual understanding, five essay questions were utilized.

The research procedure is delineated as follows: (1) Determining Stage: In this initial phase, we conduct an analysis of the curriculum, material attributes, student profiles, and virtual lab applications pertinent to modern physics. Student analysis encompasses factors such as cognitive development and their engagement with lecture topics. Material analysis involves identifying, describing, and structuring key concepts necessitating the use of videos, practicum guides, and virtual experiments. (2) Design Phase: During this stage, we formulate learning objectives based on the outcomes of the previous analyses of the curriculum, materials, and student characteristics. We determine the application media and learning strategies, and draft instruments for validating the effectiveness of the practicum and virtual experiment guides. (3) Development Phase: This phase aims to produce practical manuals and virtual experiments, followed by an expert validation process comprising content, construct, and language validation. Validation is crucial for assessing the utility of the product among students and lecturers, as well as the practicality of the developed product. Subsequently, in the effectiveness testing phase, we evaluate whether the product effectively enhances the quality of modern physics lectures.

Data collected from expert validation and student responses underwent analysis employing descriptive and statistical techniques. Quantitative data underwent processing to pinpoint any deficiencies in both material and media aspects, enabling necessary revisions to be implemented. Scores were categorized following the identification of intervals. The scale range was determined using a formula, wherein a Likert scale ranging from a minimum score of 1 to a maximum score of 4 was utilized. Moreover, to evaluate students' conceptual understanding and the efficacy of the developed module, N-gain tests and paired t-tests were employed. These tests aimed to gauge the improvement in students' conceptual understanding following the implementation of the module.

3. FINDINGS AND DISCUSSION

3.1 Expert validation results

The material expert validator assessed several feasibility aspects, encompassing presentation, content feasibility, and language, as illustrated in Figure 2. The material received a validation score of 3.9, classified as "very good" according to the Likert scale-based score classification outlined in Table 1. The feedback from the validator suggested that the module materials were generally of high quality and suitable for use. Similarly, validator 2 awarded a score of 3.6, indicating that the module was of good quality. In conclusion, based on the validation conducted by the material expert, the module was deemed feasible for development and implementation.

Following the material expert validation, the next step involved media expert validation. Validation questionnaires were distributed to media experts, with the expectation of receiving good or very good scores to further affirm the feasibility of our module.

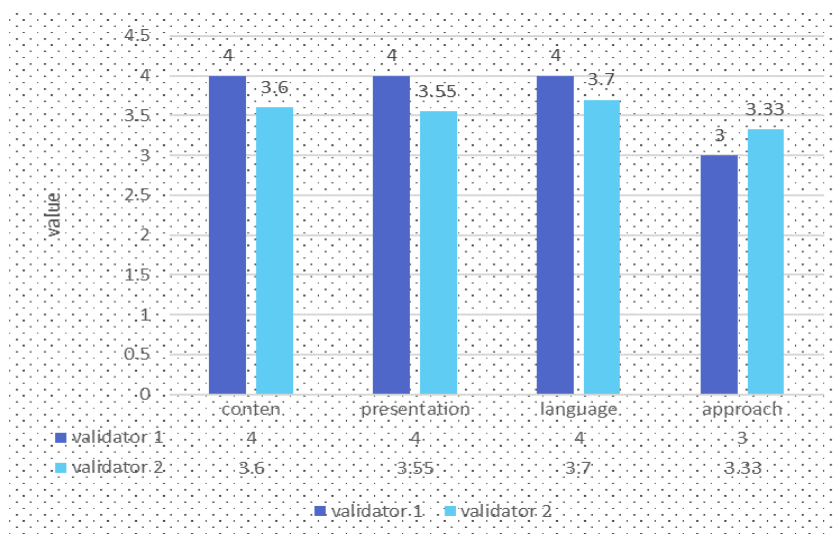


Figure 2. The validation performed by the material expert

Two validators participated in the media validation process, each assigned to evaluate the module we developed. The purpose of this validation, conducted by media experts, was to assess the overall presentation and practicality of the module. These validators examined various aspects of feasibility, such as module size, cover design, and content layout, with the aim of gauging both accuracy and usability. The results of the validation yielded valuable insights into the optimal module dimensions, attractive content presentation, and cover design, all of which received an impressive score of 4, indicating a very good rating.

Following the completion of material expert validation by validator 2, we then enlisted validator 2 to undertake both material and media validations. The subsequent validation aimed to assess the overall feasibility of the module, with the resulting score subjected to further analysis. Validator 2 assigned a score of 3.67, indicating that the module was deemed feasible.

First of all, the module includes a comprehensive understanding of modern physics concepts that are relevant to current scientific developments. Thus, students can access up-to-date material and gain a deep understanding of the topics they are studying (Gunawan, Festiyed, Yerimadesi, Ilwandri, & Gunawan, 2023). In addition, the module is also designed with students' learning needs and preferences in mind, so that it is organized in a format that is easy to understand and access, and offers a variety of additional resources that support independent learning (Siew & Ambo, 2018).

Secondly, a usable modern physics module also pays attention to integration with effective and innovative learning methods. The module integrates a problem-based project learning approach with informatics technology, such as the use of computer simulations or virtual experiments, which can increase student engagement and interest in learning (Sari, Andra, Distrik, & Aleksandervic, 2022). By combining theory with practice, the module helps students to develop critical thinking and problem-solving skills relevant to the real world (Jones & Harris, 2012). Thus, this modern physics module not only fulfills students' learning material needs, but also provides a valuable and beneficial learning experience for their academic development.

3.2 Student Responses to the Module

A pilot study was undertaken to evaluate the viability of the module among a select group of physics education students at Jambi University who were taking the modern physics course. This pilot test included assessing students' reactions through the use of questionnaire sheets. The outcomes of this assessment are outlined in Table 1.

As shown in Table 1, the average score of student responses was 3.41, which, according to the Likert scale-based classification, indicates a very good rating. This average score suggests that students

responded positively to our module, confirming its feasibility. In this research, we created a virtual lab-based learning module that integrates project-based learning for modern physics, presented in a printed format for accessibility. The module was designed with user-friendliness in mind, ensuring that students can navigate it with ease.

This module for modern physics represents an innovation in learning, particularly in light of advancements in information and communication systems. It is anticipated to enhance students' understanding of modern physics, providing them with valuable learning experiences. The module is highly recommended for students enrolled in modern physics courses. Our initial observation revealed that students encountered challenges in accessing appropriate learning materials for modern physics. Therefore, we developed this innovative module as a contribution to both modern physics lecturers and students, providing them with a valuable resource to better understand modern physics concepts. We anticipate that this module will be utilized optimally by students to enhance their comprehension of modern physics materials.

Table 1. The Module's Reception by Students

No.	Question	Mean	Category
1	Engaging in learning activities facilitated by the virtual lab-based learning module, which incorporates project-based learning and instructional videos for modern physics, aids my understanding of the presented material.	3.6	Very good
2	Utilizing the virtual lab-based learning module that integrates PBL and instructional videos for modern physics proves to be beneficial for studying the subject.	3.8	Very good
3	The issues encountered within the modern physics module are relevant to the materials covered in modern physics.	3.2	Good
4	The images or illustrations included in the module facilitate my understanding of modern physics concepts.	3.4	Very good
5	The module offers fresh insights and knowledge.	3.2	Good
6	The videos embedded within the module aid in my comprehension of the discussed materials.	3.4	Very good
7	The virtual lab utilized in the module helps me grasp the materials being discussed more effectively.	3.2	Good
8	The projects provided by the module align with the materials covered in modern physics.	3.4	Very good
9	The module facilitates my understanding of modern physics materials more readily.	3.2	Good
10	The projects presented in the module aid me in addressing problems related to modern physics materials.	3.4	Very good
11	The projects offered in the module help me articulate ideas or concepts concerning problems addressed in specific materials.	3	Good
12	The module enables me to complete the projects provided.	3.6	Very good
13	The materials within the module are easy to understand.	3.8	Very good
14	This module serves as a significant learning resource for students enrolled in the modern physics course.	3.6	Very good
Mean		3.41	Very good

This module incorporates several features, including integration with virtual labs and instructional videos, aimed at assisting students in comprehending modern physics materials. These features were implemented through iterative revisions based on feedback and suggestions from validators, as well as our own enhancements. The final product underwent refinement through pilot testing on a small group and validation by both material and media expert validators.

Validator 1 evaluated the module materials, providing a very good assessment, while validator 2's validation also yielded a very good rating, prompting the product to undergo pilot testing on a small group. Validator 1 similarly assessed the media aspect with a very good rating. Suggestions and comments from both validators were incorporated to enhance the design of the product before conducting small-group testing.

Based on previous studies, there are several reasons for students' favorable responses to a module. First of all, the quality of the learning materials presented in the module plays an important role (Widya, Maielfi, Alfiyandri, & Hamidah, 2021). Relevant, clear and interesting materials can increase students' interest in learning as well as facilitate a deep understanding of the concepts taught (Astalini, Darmaji, Kurniawan, Anwar, & Kurniawan, 2019). In addition, the structured and easy-to-understand presentation of the materials can also help students feel more confident in understanding and mastering the learning materials (Gunawan et al., 2023).

In addition, interactivity and student involvement in the learning process are also important factors in determining students' favorable responses to the module (Mustapha, Sadrina, Nashir, Azman, & Hasnan, 2020; Nikmatin Mabsutsah & Yushardi, 2022). Modules that are designed with students' needs and preferences in mind and provide opportunities to actively participate in learning activities, such as discussions, interactive exercises, or experiments, tend to receive positive responses from students. The module's ability to stimulate curiosity, arouse learning motivation, and facilitate collaboration between students can also be a determining factor in creating a favorable student response to the module (Siew & Ambo, 2018).

3.3 The Effectiveness of The Module on Improving Students' Conceptual Understanding.

Students' conceptual understanding scores were measured using a conceptual understanding test instrument. The test instrument used was created based on the concept attainment indicators according to the revised Bloom's taxonomy. This instrument consisted of 5 essay questions. The test was conducted before and after the learning process with a virtual lab-based learning module integrated with project-based learning. The description of the conceptual understanding scores can be seen in Table 2.

Table 2. The description of the conceptual understanding scores

Statistics	Score	Category
<i>t-value</i>	17,64	
Asymp. Sig. (2-tailed) (Paired Sample Test)	0,000	Significant differences, Posttest > Pretest
<i>N-Gain</i>	0,55	sedang

The data presented in Table 2 indicates a notable improvement in students' conceptual understanding following instruction with a module. The paired t-test yielded a t-value of 17.64 with a significance level of 0.000. As per Morgan et al. (2004), when the significance level is less than 0.05, it suggests a significant difference in students' conceptual understanding scores before and after instruction with a module. In this scenario, students demonstrated higher conceptual understanding after instruction with the module compared to before instruction. The operational efficacy of the module in enhancing students' conceptual understanding is classified as strong.

However, when examining the magnitude of N-Gain, the improvement in students' conceptual understanding after instruction with the module is categorized as moderate, with an N-Gain value of

0.55. There are several possible reasons why students' conceptual understanding remains in the moderate category even though they have been provided with a teaching module. Some possible reasons include the fact that modern physics material is often complex and abstract. Students may still face difficulties in comprehending some challenging concepts, even after being given a teaching module (Putra, Nur Kholifah, Subali, & Rusilowati, 2018). Although the teaching module has been implemented, the teaching methods used may not fully support better conceptual understanding (Gross, Latham, & Armstrong, 2012). Additionally, each student has a different level of understanding (Lindstrøm & Sharma, 2011). Some students may already have a better background of knowledge or skills in dealing with this material, while others may require more support (Hsu, Lai, & Hsu, 2015). Conceptual understanding often requires continuous learning. The teaching module may be the first step in this process, and students may need more practice and in-depth understanding over time.

4. CONCLUSION

Based on the results and discussion, several conclusions can be drawn. Firstly, we have successfully developed an innovative research product: a module for modern physics. The validation process and pilot testing on a small group demonstrated positive responses, indicating that the module is feasible for use. Additionally, the effectiveness test results showed an improvement in students' conceptual understanding after engaging with the module. However, it's important to acknowledge the limitations of this research, particularly in its application to a larger group. To better assess the effectiveness of the module, it is necessary to implement it with a larger and more diverse group of students with different backgrounds. This would provide a more comprehensive understanding of the module's impact on student learning outcomes.

Acknowledgments: The author expresses gratitude to the LPPM Jambi University for providing funding for this research. Additionally, thanks are extended to the Department of Physics Education for granting permission to conduct the research in the Basic Physics Lab.

REFERENCES

- Astalini, Darmaji, Kurniawan, W., Anwar, K., & Kurniawan, D. A. (2019). Effectiveness of using e-module and e-assessment. *International Journal of Interactive Mobile Technologies*, 13(9), 21–39. <https://doi.org/10.3991/ijim.v13i09.11016>
- Bilgin, I. (2009). The effects of guided inquiry instruction incorporating a cooperative learning approach on university students' achievement of acid and bases concepts and attitude toward guided inquiry instruction. *Scientific Research and Essays*, 4(10), 1038–1046.
- Ceberio, M., Almudí, J. M., & Franco, Á. (2016). Design and Application of Interactive Simulations in Problem-Solving in University-Level Physics Education. *Journal of Science Education and Technology*, 25(4), 590–609. <https://doi.org/10.1007/s10956-016-9615-7>
- Corpuz, E. D., & Rebello, N. S. (2011). Investigating students' mental models and knowledge construction of microscopic friction. II. Implications for curriculum design and development. *Physical Review Special Topics - Physics Education Research*, 7(2), 1–8. <https://doi.org/10.1103/physrevstper.7.020103>
- Dasilva, B. E., Kuswanto, H., Wilujeng, I., & Jumadi. (2019). SSP Development with a Scaffolding Approach Assisted by PhET Simulation on Light Refraction to Improve Students' Critical Thinking Skills and Achievement of Science Process Skills. *Journal of Physics: Conference Series*, 1233(1). <https://doi.org/10.1088/1742-6596/1233/1/012044>
- Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics - Physics Education Research*, 10(2), 1–58. <https://doi.org/10.1103/PhysRevSTPER.10.020119>
- Docktor, J. L., Strand, N. E., Mestre, J. P., & Ross, B. H. (2015). Conceptual problem solving in high school physics. *Physical Review Special Topics - Physics Education Research*, 11(2), 1–13.

- <https://doi.org/10.1103/PhysRevSTPER.11.020106>
- Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, 72(1), 98–115. <https://doi.org/10.1119/1.1614813>
- Gross, M., Latham, D., & Armstrong, B. (2012). Improving Below-Proficient Information Literacy Skills: Designing an Evidence-Based Educational Intervention. *College Teaching*, 60(3), 104–111. <https://doi.org/10.1080/87567555.2011.645257>
- Gunawan, R. G., Festiyed, F., Yerimadesi, Y., Ilwandri, I., & Gunawan, R. G. (2023). The Problem-Based Learning Model Integrated with The Integrated Learning Model in Science Learning: A Systematic Literature Review. *Indonesian Journal of Science and Mathematics Education*, 6(2), 227–237. <https://doi.org/10.24042/ij sme.v6i2.17576>
- Hsu, Y.-S., Lai, T.-L., & Hsu, W.-H. (2015). A Design Model of Distributed Scaffolding for Inquiry-Based Learning. *Research in Science Education*, 45(2), 241–273. <https://doi.org/10.1007/s11165-014-9421-2>
- Ibrahim, B., & Rebello, N. S. (2013). Role of mental representations in problem solving: Students' approaches to nondirected tasks. *Physical Review Special Topics - Physics Education Research*, 9(2), 1–17. <https://doi.org/10.1103/PhysRevSTPER.9.020106>
- Jaime, A., Blanco, J. M., Domínguez, C., Sánchez, A., Heras, J., & Usandizaga, I. (2016). Spiral and Project-Based Learning with Peer Assessment in a Computer Science Project Management Course. *Journal of Science Education and Technology*, 25(3), 439–449. <https://doi.org/10.1007/s10956-016-9604-x>
- Jones, F., & Harris, S. (2012). Benefits and Drawbacks of Using Multiple Instructors to Teach Single Courses. *College Teaching*, 60(January 2015), 132–139. <https://doi.org/10.1080/87567555.2012.654832>
- Leak, A. E., Rothwell, S. L., Olivera, J., Zwickl, B., Vosburg, J., & Martin, K. N. (2017). Examining problem solving in physics-intensive Ph.D. research. *Physical Review Physics Education Research*, 13(2), 1–13. <https://doi.org/10.1103/PhysRevPhysEducRes.13.020101>
- Lindstrøm, C., & Sharma, M. D. (2011). Teaching physics novices at university: A case for stronger scaffolding. *Physical Review Special Topics - Physics Education Research*, 7(1), 1–14. <https://doi.org/10.1103/PhysRevSTPER.7.010109>
- Marcelo, C., & Yot-Domínguez, C. (2019). From chalk to keyboard in higher education classrooms: changes and coherence when integrating technological knowledge into pedagogical content knowledge. *Journal of Further and Higher Education*, 43(7), 975–988. <https://doi.org/10.1080/0309877X.2018.1429584>
- Martínez-sierra, G., & García-gonzález, M. S. (2017). Students' Emotions in the High School Mathematical Class: Appraisals in Terms of a Structure of Goals. *International Journal of Science and Mathematics Education*, 349–369. <https://doi.org/10.1007/s10763-015-9698-2>
- Mustapha, R., Sadrina, Nashir, I. M., Azman, M. N. A., & Hasnan, K. A. (2020). Assessing the implementation of the project-based learning (PjBl) in the department of mechanical engineering at a Malaysian polytechnic. *Journal of Technical Education and Training*, 12(1 Special Issue), 100–118. <https://doi.org/10.30880/jtet.2020.12.01.011>
- Nikmatin Mabsutsah, & Yushardi, Y. (2022). Analisis Kebutuhan Guru terhadap E Module Berbasis STEAM dan Kurikulum Merdeka pada Materi Pemanasan Global. *Jurnal Pendidikan Mipa*, 12(2), 205–213. <https://doi.org/10.37630/jpm.v12i2.588>
- Putra, F., Nur Kholifah, I. Y., Subali, B., & Rusilowati, A. (2018). 5E-Learning Cycle Strategy: Increasing Conceptual Understanding and Learning Motivation. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 7(2), 171–181. <https://doi.org/10.24042/jipfalbiruni.v7i2.2898>
- Rahmawati, I., Sutopo, S., & Zulaikah, S. (2017). Analysis of students' difficulties about rotational dynamics based on resource theory. *Jurnal Pendidikan IPA Indonesia*, 6(1), 95–102. <https://doi.org/10.15294/jpii.v6i1.9514>
- Riantoni, C., Yuliati, L., Mufti, N., & Nehru, N. (2017). Problem solving approach in electrical energy

- and power on students as physics teacher candidates. *Jurnal Pendidikan IPA Indonesia*, 6(1), 55–62. <https://doi.org/10.15294/jpii.v6i1.8293>
- Sari, M., Andra, D., Distrik, I. W., & Aleksandervic, K. S. (2022). Problem-Based E-Module Integrated with STEM and Assisted by LMS to Foster Creative Thinking Ability. *Indonesian Journal of Science and Mathematics Education*, 5(2), 224–237. <https://doi.org/10.24042/ijsme.v5i2.13087>
- Siew, N. M., & Ambo, N. (2018). Development and evaluation of an integrated project-based and stem teaching and learning module on enhancing scientific creativity among fifth graders. *Journal of Baltic Science Education*, 17(6), 1017–1033. <https://doi.org/10.33225/jbse/18.17.1017>
- Smith, D. P., & van Kampen, P. (2011). Teaching electric circuits with multiple batteries: A qualitative approach. *Physical Review Special Topics - Physics Education Research*, 7(2), 020115. <https://doi.org/10.1103/PhysRevSTPER.7.020115>
- Tecson, C. M. B., Salic-Hairulla, M. A., & Soleria, H. J. B. (2021). Design of a 7E model inquiry-based STEM (iSTEM) lesson on digestive system for Grade 8: An open-inquiry approach. *Journal of Physics: Conference Series*, 1835(1). <https://doi.org/10.1088/1742-6596/1835/1/012034>
- Widya, W., Maielfi, D., Alfiyandri, A., & Hamidah, W. (2021). Creative Problem Solving-Based Electronic Module Integrated with 21st Century Skills. *Indonesian Journal of Science and Mathematics Education*, 4(3), 333–342. <https://doi.org/10.24042/ijsme.v4i3.7689>
- Wurdinger, S., Haar, J., Hugg, R., & Bezon, J. (2007). A qualitative study using project-based learning in a mainstream middle school. *Improving Schools*, 10(2), 150–161. <https://doi.org/10.1177/1365480207078048>
- Zacharia, Z. C., & de Jong, T. (2014). The Effects on Students' Conceptual Understanding of Electric Circuits of Introducing Virtual Manipulatives Within a Physical Manipulatives-Oriented Curriculum. *Cognition and Instruction*, 32(2), 101–158. <https://doi.org/10.1080/07370008.2014.887083>