ISEJ Indonesian Science Education Journal

ISSN Online: 2716-3350
Vol. 5 No. 2 May 2024 Pages 56-64
https://siducat.org/index.php/isej/
Published by Yayasan Darussalam Bengkulu

Enhancing Physics Conceptual Understanding through Discussion Method and Virtual Laboratory Media: A Classroom Action Research on Light and Optical Instruments

Setiahawati[1], Diah Setiani[2], Winda Nur Khasanah[3]
Universitas Indraprasta PGRI [1,2,3]
E-mail: setiahawati2001@gmail.com

Abstract
The mastery of physics concepts among junior high school students remains a challenge, particularly in topics that involve abstract phenomena such as light and optical instruments. This study aimed to improve students' conceptual understanding and learning motivation through the integration of the discussion method and virtual laboratory media. A classroom action research (CAR) design was employed in two cycles, each consisting of planning, implementation, observation, and reflection stages, conducted with 35 eighth-grade students at SMP Al-Kindi Cipayung. Data were collected using tests, questionnaires, and observations, while results were analyzed descriptively through mean scores and mastery percentages. The findings showed a steady increase in student learning outcomes, with mastery achievement improving from 31.42% in the pre-cycle to 60% in the first cycle and 91.42% in the second cycle. Students also reported positive responses to the use of virtual laboratories, noting their role in clarifying complex concepts, enhancing interaction, and creating a more engaging learning environment. The novelty of this study lies in combining collaborative discussion with digital simulation, offering an alternative pedagogical strategy to compensate for limited physical laboratory resources. These results imply that integrating traditional discussion with virtual laboratories can serve as an effective approach to foster conceptual understanding, critical thinking, and motivation in physics learning, and that broader implementation across schools could enhance the quality of science education in resource-constrained settings.

Keywords: Conceptual Understanding; Classroom Action Research; Discussion Method; Physics Learning; Virtual Laboratory.

INTRODUCTION

Physics is one of the most fundamental branches of science, as it seeks to explain natural phenomena through concepts, laws, and theories that govern matter, energy, and their interactions. Mastery of physics requires not only mathematical competence but also the ability to understand and apply concepts in everyday contexts. Conceptual understanding is therefore considered central to meaningful physics learning, as it enables students to connect abstract theories with real-world experiences (De Haro, 2020; Luft et al., 2022; van Lunteren, 2024). However, in many school settings, physics instruction remains dominated by rote memorization and algorithmic problem-solving, which often leads to misconceptions and shallow learning outcomes (Martin-Alguacil et al., 2024; Podschuweit & Bernholt, 2018; Xie et al., 2021). Students' difficulties in linking theoretical constructs to observable phenomena hinder their engagement and reduce their ability to apply scientific knowledge in problem-solving contexts.

Recent surveys in Indonesian junior high schools reveal that a significant proportion of students continue to struggle with physics, particularly in the topics of light and optical instruments. At SMP Al-Kindi Cipayung, for example, 68% of grade VIII students reported difficulties in mastering these topics, largely because instruction was delivered in a conventional, teacher-centered manner with limited use of experiments or interactive learning media. These findings are consistent with international studies showing that physics topics involving abstract concepts such as optics, electricity, and thermodynamics are among the most challenging for students to understand without concrete learning supports (Eryılmaz Muştu & Şen, 2019; Gouvea et al., 2013; Guisasola et al., 2023). The persistence of these challenges highlights the need for innovative teaching approaches that actively involve students in the learning process, foster conceptual reconstruction, and provide opportunities for inquiry.

Teaching methods play a critical role in shaping students' understanding of scientific concepts. A well-structured instructional strategy not only facilitates knowledge acquisition but also nurtures scientific attitudes, critical thinking, and collaborative skills (Eskiyurt & Özkan, 2024; Rehman et al., 2024; Zamiri & Esmaeili, 2024). Among various strategies, discussion-based learning has been shown to be particularly effective in enhancing conceptual understanding, as it allows students to articulate ideas, negotiate meaning, and clarify misconceptions through peer and teacher interaction (Chan & Lee, 2021; Gillies, 2014; Rapanta & Felton, 2022). Studies demonstrate that students engaged in guided discussions achieve higher learning outcomes compared to those taught through traditional lectures, as active dialogue fosters deeper processing of knowledge and the development of scientific reasoning skills (Darling-Hammond et al., 2020; Kwangmuang et al., 2021; van Alten et al., 2019).

In addition to discussion, practical experimentation is a crucial element of effective science education, as it provides students with first-hand experiences that promote inquiry and reinforce conceptual understanding. However, the limited availability of laboratory facilities, inadequate equipment, and lack of trained technicians often prevent schools from conducting meaningful experiments, particularly in developing countries (Haleem et al., 2022; Mustafa et al., 2024; Nicol et al., 2022). To overcome these barriers, virtual laboratories have emerged as an innovative instructional medium, enabling students to conduct simulated experiments that visualize abstract physics concepts in dynamic and interactive ways (Abdelmoneim et al., 2022; Al-Duhani et al., 2024; El Kharki et al., 2021). Research suggests that virtual laboratories can be as effective as, or even superior to, real laboratories in certain contexts, as they reduce safety risks, allow repeated practice, and accommodate a wider range of experimental scenarios (Hu-Au & Okita, 2021; Poo et al., 2023; Sapriati et al., 2023).

Despite the growing body of evidence supporting both discussion-based learning and virtual laboratory use, few studies have examined the combined application of these strategies in physics education at the junior high school level, particularly in Indonesia. Most prior research has focused on either the effectiveness of classroom discussions or the advantages of virtual laboratories as stand-alone interventions (Abdelmoneim et al., 2022; Sapriati et al., 2023; Tokatlidis et al., 2024). There remains a lack of empirical studies that investigate how the integration of discussion methods and virtual laboratory media can synergistically enhance students' conceptual understanding, motivation, and confidence in learning physics, especially on abstract topics such as light and optical instruments.

Therefore, the present study seeks to address this gap by investigating the effectiveness of combining discussion methods with virtual laboratory media in improving the conceptual understanding of grade VIII students on the topic of light and optical instruments at SMP Al-Kindi Cipayung, Depok. Specifically, the study aims to evaluate changes in learning outcomes across multiple instructional cycles, assess students' perceptions of virtual laboratory use, and analyze how discussion-based learning contributes to students' engagement and reasoning. By integrating these approaches, the study intends to contribute both theoretically and practically to the advancement of physics education, offering insights for teachers, curriculum developers, and policymakers seeking to improve science teaching through innovative pedagogical and technological interventions.

METHODS

This study employed a Classroom Action Research (CAR) design that was conducted in two cycles, with each cycle comprising the stages of planning, implementation, observation, and reflection. The research was carried out at SMP Al-Kindi Cipayung, Depok City, during the 2020/2021 academic year with 35 students of grade VIII as the participants. The primary aim was to improve students' conceptual understanding of light and optical instruments by integrating the discussion method with the use of a virtual laboratory provided by the Ministry of Education and Culture of Indonesia. The discussion method was chosen to encourage active participation, collaborative learning, and critical thinking, while the virtual laboratory was utilized to provide an interactive and safe environment for conducting experiments that were otherwise limited due to the lack of physical laboratory facilities. Instruments used in this study included lesson plans, student worksheets, multiple-choice test items, and structured questionnaires. The test instrument consisted of 30 multiple-choice questions, each with five answer options, designed to assess students' mastery of physics concepts related to light and optics. The questionnaires were developed to capture students' perceptions of the effectiveness and usability of the virtual laboratory, with items measured using a Likert scale. Data collection was conducted through both tests and questionnaires, complemented by direct classroom observation to capture student engagement and participation during the learning process. The data were analyzed using descriptive statistics to compare student performance across the pre-cycle, cycle I, and cycle II, while the questionnaire responses were summarized into mean scores for each indicator to evaluate the practicality and effectiveness of the virtual laboratory. The study adhered to ethical principles by obtaining informed consent, ensuring voluntary participation, and maintaining confidentiality of student data. Through this methodological approach, the research aimed to systematically identify, implement, and evaluate improvements in students' learning outcomes by combining pedagogical innovation with technology-enhanced media in physics instruction.

$$KB = \frac{The\ Number\ of\ Students\ Who\ Achieved\ or\ Did\ Not\ Achieve\ Mastery}{Overall\ Number\ of\ Students}\ x\ 100\%$$

RESULTS AND DISCUSSION

Improvement of Learning Outcomes Across Cycles

Table 1. Learning Mastery in Pre-Cycle, Cycle 1, and Cycle 2

No	Mastery	Pre-Cycle		Cycle 1		Cycle 2	
		Total	Percentage	Total	Percentage	Total	Percentage
1	Completed	11	31,42%	21	60%	32	91,42%
2	Not Completed	24	68,57%	14	40%	3	8,57%
Total		35	100%	35	100%	35	100%

The results showed a progressive improvement in students' mastery of physics concepts from the pre-cycle through cycle I to cycle II. In the pre-cycle, only 11 out of 35 students (31.42%) achieved the minimum mastery criteria (KKM), while 24 students (68.57%) did not meet the standard. After the implementation of the discussion method in cycle I, the number of students achieving mastery increased to 21 (60%), with 14 students (40%) still below the threshold. By cycle II, the results demonstrated a significant improvement, with 32 students (91.42%) meeting the KKM and only 3 students (8.57%) remaining below the standard. These findings indicate that the combined use of discussion and virtual laboratory media substantially improved students' conceptual understanding of light and optical instruments.

Student Engagement and Classroom Interaction

Table 2. Result of the First Variable Statement

No	The Effectiveness of the Kemendikbud Virtual Laboratory (Vlab) in Facilitating Physics Learning	STS	TS	RG-RG	S	SS
1	Learning by using the Kemendikbud Virtual Laboratory (Vlab) makes the topic of Light and Optical Instruments easier to remember.	0 (0%)	0 (0%)	3 (8,57%)	12 (34,28%)	20 (57,14%)
2	Learning by using the Kemendikbud Virtual Laboratory (Vlab) is very useful in my physics learning process.	0 (0%)	0 (0%)	4 (11,42%)	18 (51,42%)	13 (37,14%)
3	Learning by using the Kemendikbud Virtual Laboratory (Vlab) makes me more enthusiastic and more challenged.	0 (0%)	0 (0%)	7 (20%)	16 (45,71%)	12 (34,28%)
4	Learning by using the Kemendikbud Virtual Laboratory (Vlab) can improve my ability to understand physics concepts.	0 (0%)	0 (0%)	3 (8,57%)	18 (51,42%)	14 (40%)
5	Learning by using the Kemendikbud Virtual Laboratory (Vlab) can stimulate my thinking and reasoning skills.	0 (0%)	0 (0%)	4 (11,42%)	22 (62,85%)	9 (25,71%)

Table 3. Mean Score of the First Variable Questionnaire

No	Question	Average
1	Learning by using the Kemendikbud Virtual Laboratory (Vlab) makes the topic of Light and Optical Instruments easier to remember.	4,485
2	Learning by using the Kemendikbud Virtual Laboratory (Vlab) is very useful in my physics learning process.	4,257
3	Learning by using the Kemendikbud Virtual Laboratory (Vlab) makes me more enthusiastic and more challenged.	4,142
4	Learning by using the Kemendikbud Virtual Laboratory (Vlab) can improve my ability to understand physics concepts.	4,314
5	Learning by using the Kemendikbud Virtual Laboratory (Vlab) can stimulate my thinking and reasoning skills.	4,142
Total		21,340
Average		4,268

Observations revealed notable changes in student engagement during the two cycles. In cycle I, although students showed enthusiasm toward the discussion method, many were hesitant to ask questions or express their ideas, and group discussions were not fully optimized. By cycle II, with more structured facilitation and integration of virtual laboratory simulations, students became more confident, demonstrated greater willingness to present their ideas, and actively participated in problem-solving activities. This shift in classroom interaction reflects a positive change in learning culture, where students transitioned from passive recipients to active contributors.

Effectiveness of Virtual Laboratory Media

Table 4. Results of the Second Variable Statement

No	The Effectiveness of the Kemendikbud Virtual Laboratory (Vlab) in Facilitating Physics Learning	STS	TS	RG-RG	S	SS
1	The display of the Kemendikbud Virtual Laboratory (Vlab) used for practicum activities is very clear and easy to understand.	0 (0%)	0 (0%)	2 (5,71%)	27 (77,14%)	6 (17,14%)
2	Practicum activities using the Kemendikbud Virtual Laboratory (Vlab) are more effective and more efficient.	0 (0%)	3 (8,57%)	5 (14,28%)	19 (54,28%)	8 (22,85%)
3	Practicum activities using the Kemendikbud Virtual Laboratory (Vlab) make me not easily bored.	0 (0%)	0 (0%)	4 (11,42%)	18 (51,42%)	13 (37,14%)
4	Practicum activities using the Kemendikbud Virtual Laboratory (Vlab) make me more interested and feel more enjoyable.	0 (0%)	0 (0%)	3 (8,57%)	23 (65,71%)	9 (25,71%)
5	The use of the Kemendikbud Virtual Laboratory (Vlab) as a practicum activity makes learning easier for me and easily accessible	0 (0%)	0 (0%)	2 (5,71%)	19 (54,28%)	14 (40%)

Table 5. Mean Score of the Second Variable Questionnaire

No	Question	Average
1	The interface of the Kemendikbud Virtual Laboratory (Vlab) used in practicum activities is presented clearly and is easy to comprehend.	4,114
2	Conducting practicum activities through the Kemendikbud Virtual Laboratory (Vlab) is more effective and efficient compared to conventional methods.	4,914
3	Practicum activities facilitated by the Kemendikbud Virtual Laboratory (Vlab) help maintain student engagement and reduce the likelihood of boredom.	4,257
4	The use of the Kemendikbud Virtual Laboratory (Vlab) in practicum sessions increases student interest and contributes to a more enjoyable learning experience.	4,171
5	The integration of the Kemendikbud Virtual Laboratory (Vlab) into practicum activities enhances the ease of learning and provides greater accessibility.	4,342
Total		20,798
Average		4,159

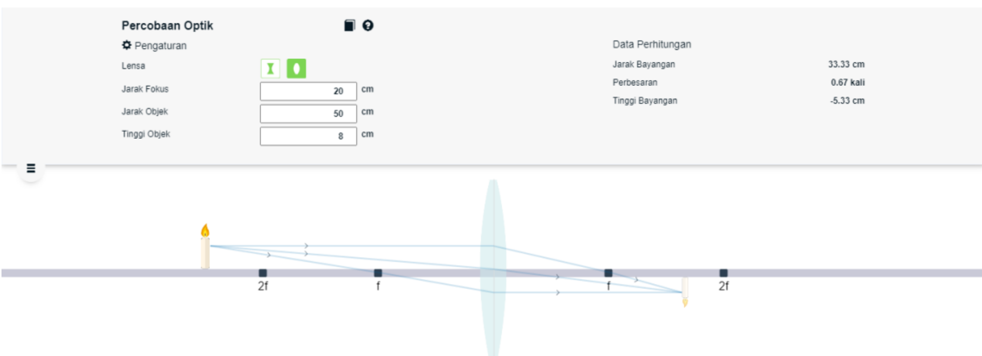

Figure 1. Virtual Simulation Interface in the Kemendikbud Vlab for Optical Experiments

Questionnaire results further supported the effectiveness of the virtual laboratory (Vlab) provided by the Indonesian Ministry of Education. For the first variable measuring students' perception of the ease of using Vlab, the mean score was 4.268 on a 5-point Likert scale, indicating strong agreement that Vlab enhanced conceptual understanding, improved memory retention, and stimulated reasoning. For the second variable regarding students' acceptance of Vlab, the mean score was 4.159, showing that students perceived Vlab as accessible, effective, and enjoyable. These findings suggest that virtual laboratory integration can address the limitations of conventional laboratory facilities and provide students with authentic scientific experiences in a safe and interactive environment.

Discussion

The results of this study confirm the effectiveness of combining discussion methods with virtual laboratory media in improving students' physics learning outcomes. Similar to the findings of Johanna (2023), group discussion strategies enhance student activeness and conceptual understanding, while Marsini and Dwikoranto (2022) demonstrated that discussion-based instruction outperformed conventional approaches in science learning. Furthermore, Almulla (2020) highlighted that discussion methods stimulate critical thinking and collaborative problem-solving, which were evident in this study as students became more confident and participative in cycle II.

The role of virtual laboratories in strengthening conceptual understanding is consistent with research by Rehman (2024), who found that interactive simulations improved students' cognitive abilities and memory retention. Rehman (2024) reported that adaptive virtual laboratory environments significantly supported science learning, particularly in abstract topics. These findings align with the present study, where the Vlab media effectively visualized abstract concepts of light and optics, making them more accessible and engaging for students.

Compared to earlier studies conducted in Indonesian contexts (Abbas Shah et al., 2024; Chang et al., 2022; Shambare & Jita, 2024), this study extends the literature by combining discussion-based learning with virtual laboratory integration in a classroom action research framework. The novelty lies in the synergistic application of both methods, which not only enhanced conceptual understanding but also increased student confidence, motivation, and engagement. This dual strategy addresses two persistent challenges in physics education: the tendency toward rote learning and the lack of laboratory infrastructure in schools.

The implications of this study are significant for educational practice. Teachers can adopt discussion methods supported by virtual laboratory media as an effective pedagogical model for teaching abstract physics concepts, thereby fostering active learning, critical thinking, and collaborative skills. Policymakers and curriculum developers should consider integrating virtual laboratories into science curricula as a cost-effective solution to overcome laboratory limitations and to promote equitable access to quality science education.

Despite its contributions, the study has limitations. The research was conducted in a single school with a relatively small sample size, limiting the generalizability of findings. The reliance on self-reported questionnaires may also introduce bias in students' responses. Furthermore, the study was limited to the topic of light and optical instruments; thus, further research is needed to explore the applicability of this approach in other physics domains and across diverse educational contexts. Future studies should employ larger samples, multi-site designs, and experimental methodologies to validate and expand upon these findings.

CONCLUSION

This study demonstrated that the integration of the discussion method and virtual laboratory media significantly improved students' conceptual understanding, motivation, and active participation in learning physics on the topic of light and optical instruments. The findings across two classroom action research cycles revealed consistent increases in mastery learning, from 31.42% in the pre-cycle to 60% in the first cycle and 91.42% in the second cycle, while the proportion of students who did not achieve mastery decreased accordingly. In addition, students expressed positive perceptions of the virtual laboratory, indicating its effectiveness in simplifying abstract concepts, enhancing engagement, and providing accessible and interactive learning experiences. The novelty of this research lies in combining collaborative discussion with technology-based experimentation, which together created a more student-centered, inquiry-oriented learning environment. These results imply that physics education, particularly in contexts with limited physical laboratory resources, can be strengthened through the adoption of blended pedagogical approaches that integrate traditional discussion and digital simulation tools. Nonetheless, the study's scope was limited to a single school, a relatively small sample size, and one subject area, suggesting that further research with larger populations, diverse contexts, and extended subject coverage is necessary to confirm the broader applicability of these findings.

REFERENCE

Abbas Shah, S. F., Mazhar, T., Shahzad, T., Khan, M. A., Ghadi, Y. Y., & Hamam, H. (2024). Integrating educational theories with virtual reality: Enhancing engineering education and VR laboratories. *Social Sciences & Humanities Open, 10*, 101207. https://doi.org/10.1016/j.ssaho.2024.101207

Abdelmoneim, R., Hassounah, E., & Radwan, E. (2022). Effectiveness of virtual laboratories on developing expert thinking and decision-making skills among female school students in Palestine. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(12), em2199. https://doi.org/10.29333/ejmste/12708

Al-Duhani, F., Mohd Saat, R., & 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. https://doi.org/10.29333/ejmste/14282

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open, 10*(3). https://doi.org/10.1177/2158244020938702

Chan, C. K. Y., & Lee, K. K. W. (2021). Reflection literacy: A multilevel perspective on the challenges of using reflections in higher education through a comprehensive literature review. *Educational Research Review, 32*, 100376. https://doi.org/10.1016/j.edurev.2020.100376

Chang, Y.-H., Yan, Y.-C., & Lu, Y.-T. (2022). Effects of combining different collaborative learning strategies with problem-based learning in a flipped classroom on program language learning. *Sustainability, 14*(9), 5282. https://doi.org/10.3390/su14095282

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

De Haro, S. (2020). Science and philosophy: A love-hate relationship. *Foundations of Science, 25*(2), 297-314. https://doi.org/10.1007/s10699-019-09619-2

El Kharki, K., Berrada, K., & Burgos, D. (2021). Design and implementation of a virtual laboratory for physics subjects in Moroccan universities. *Sustainability, 13*(7), 3711. https://doi.org/10.3390/su13073711

Eryılmaz Muştu, Ö., & Şen, A. İ. (2019). A comparison of learning high school modern physics topics based on two different curricula. *Science Education International, 30*(4), 91-297. https://doi.org/10.33828/sei.v30.i4.6

Eskiyurt, R., & Özkan, B. (2024). Exploring the impact of collaborative learning on the development of critical thinking and clinical decision-making skills in nursing students: A quantitative descriptive design. *Heliyon, 10*(17), e37198. https://doi.org/10.1016/j.heliyon.2024.e37198

Gillies, R. M. (2014). Developments in classroom-based talk. *International Journal of Educational Research, 63*, 63-68. https://doi.org/10.1016/j.ijer.2013.05.002

Gouvea, J. S., Sawtelle, V., Geller, B. D., & Turpen, C. (2013). A framework for analyzing interdisciplinary tasks: Implications for student learning and curricular design. *CBE-Life Sciences Education, 12*(2), 187-205. https://doi.org/10.1187/cbe.12-08-0135

Guisasola, J., Campos, E., Zuza, K., & Zavala, G. (2023). Phenomenographic approach to understanding students' learning in physics education. *Physical Review Physics Education Research, 19*(2), 020602. https://doi.org/10.1103/PhysRevPhysEducRes.19.020602

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers, 3*, 275-285. https://doi.org/10.1016/j.susoc.2022.05.004

Hu-Au, E., & Okita, S. (2021). Exploring differences in student learning and behavior between real-life and virtual reality chemistry laboratories. *Journal of Science Education and Technology, 30*(6), 862-876. https://doi.org/10.1007/s10956-021-09925-0

Johanna, A., Avinash, B., & Bevoor, B. (2023). Small group discussion method to increase learning activity: Its implementation in education. *International Journal of Educational Narratives, 1*(1), 18-21. https://doi.org/10.55849/ijen.v1i1.237

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon, 7*(6), e07309. https://doi.org/10.1016/j.heliyon.2021.e07309

Luft, J. A., Jeong, S., Idsardi, R., & Gardner, G. (2022). Literature reviews, theoretical frameworks, and conceptual frameworks: An introduction for new biology education researchers. *CBE-Life Sciences Education, 21*(3). https://doi.org/10.1187/cbe.21-05-0134

Marsini, M., & Dwikoranto, D. (2022). Using Google Meet in group discussions to improve learning activities and students' problem-solving ability during the COVID-19 pandemic. *IJORER: International Journal of Recent Educational Research, 3*(5), 584-597. https://doi.org/10.46245/ijorer.v3i5.249

Martin-Alguacil, N., Avedillo, L., Mota-Blanco, R., & Gallego-Agundez, M. (2024). Student-centered learning: Some issues and recommendations for its implementation in a traditional curriculum setting in health sciences. *Education Sciences, 14*(11), 1179. https://doi.org/10.3390/educsci14111179

Mustafa, F., Nguyen, H. T. M., & Gao, X. (Andy). (2024). The challenges and solutions of technology integration in rural schools: A systematic literature review. *International Journal of Educational Research, 126*, 102380. https://doi.org/10.1016/j.ijer.2024.102380

Nicol, C. B., Gakuba, E., & Habinshuti, G. (2022). Students' opinions, views, and perceptions of science laboratory learning: A systematic review of the literature. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(3), em2087. https://doi.org/10.29333/ejmste/11793

Podschuweit, S., & Bernholt, S. (2018). Composition-effects of context-based learning opportunities on students' understanding of energy. *Research in Science Education, 48*(4), 717-752. https://doi.org/10.1007/s11165-016-9585-z

Poo, M. C.-P., Lau, Y., & Chen, Q. (2023). Are virtual laboratories and remote laboratories enhancing the quality of sustainability education? *Education Sciences, 13*(11), 1110. https://doi.org/10.3390/educsci13111110

Rapanta, C., & Felton, M. K. (2022). Learning to argue through dialogue: A review of instructional approaches. *Educational Psychology Review, 34*(2), 477-509. https://doi.org/10.1007/s10648-021-09637-2

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-century skills and student engagement in the math classroom. *Heliyon, 10*(23), e39988. https://doi.org/10.1016/j.heliyon.2024.e39988

Sapriati, A., Suhandoko, A. D. J., Yundayani, A., Karim, R. A., Kusmawan, U., Mohd Adnan, A. H., & Suhandoko, A. A. (2023). The effect of virtual laboratories on improving students' SRL: An umbrella systematic review. *Education Sciences, 13*(3), 222. https://doi.org/10.3390/educsci13030222

Shambare, B., & Jita, T. (2024). TPACK: A descriptive study of science teachers' integration of the virtual laboratory in rural school teaching. *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2365110

Tokatlidis, C., Tselegkaridis, S., Rapti, S., Sapounidis, T., & Papakostas, D. (2024). Hands-on and virtual laboratories in electronic circuits learning-knowledge and skills acquisition. *Information, 15*(11), 672. https://doi.org/10.3390/info15110672

van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis. *Educational Research Review, 28*, 100281. https://doi.org/10.1016/j.edurev.2019.05.003

van Lunteren, F. H. (2024). Physics and the quest for transcendence: A Durkheimian approach. *Endeavour, 48*(1), 100913. https://doi.org/10.1016/j.endeavour.2024.100913

Xie, L., Liu, Q., Lu, H., Wang, Q., Han, J., Feng, X., & Bao, L. (2021). Student knowledge integration in learning mechanical wave propagation. *Physical Review Physics Education Research, 17*(2), 020122. https://doi.org/10.1103/PhysRevPhysEducRes.17.020122

Zamiri, M., & Esmaeili, A. (2024). Strategies, methods, and supports for developing skills within learning communities: A systematic review of the literature. *Administrative Sciences, 14*(9), 231. https://doi.org/10.3390/admsci14090231