



AMERICAN JOURNAL OF EDUCATION AND TECHNOLOGY (AJET)

ISSN: 2832-9481 (ONLINE)

VOLUME 2 ISSUE 3 (2023)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

PHET Interactive Simulations in Learning Optics towards Pre-Service Science Teachers: A Phenomenological Study

Herman M. Lagon^{1*}

Article Information

Received: June 18, 2023

Accepted: July 20, 2023

Published: August 14, 2023

Keywords

PHET Interactive Simulations, Learning Optics, Pre-Service Science Teachers, Interactive Learning, Phenomenological Study

ABSTRACT

This phenomenological study explored the experiences of pre-service science teachers in using PHET interactive simulations to learn optics. It used a qualitative research approach and involved six participants enrolled in a science education program. Data were collected through observations and semi-structured interviews, and thematic analysis was used to analyze the data. The findings revealed that the participants had an enhanced understanding of optics concepts through PHET simulations and experienced high levels of engagement and interactivity. However, technical difficulties, challenges to internet connectivity, and gadget accessibility were identified. The study concluded that PHET simulations are beneficial in learning optics but need improvements in technical aspects. This implies key contributions to the existing literature on interactive simulations in science education, alignment with constructivist learning theory, and insights into cognitive load effects. In practice, the study suggests practical benefits for pre-service teachers and educators, such as fostering critical thinking skills and motivation in students. It recommends integrating PHET simulations in teaching, providing instructional support, addressing technical challenges, incorporating teacher training programs, and conducting further research to explore the effectiveness of the simulations in enhancing learning outcomes. The study cracks the PHET code in optics by highlighting its benefits and challenges and providing valuable insights for science education practice and research.

INTRODUCTION

Education has witnessed a significant shift toward the incorporation of technology to enhance student learning and engagement. One such educational technology that has gained prominence is the PHET interactive simulations, particularly within the realm of science education. These simulations provide a virtual, hands-on experience, enabling students to explore and manipulate scientific phenomena to enrich their understanding (Wieman *et al.*, 2008). Optics, being an integral part of science, serves as an excellent subject for these simulations, offering students a unique opportunity to interact with light and assimilate fundamental concepts (Tao *et al.*, 2017).

The purpose of this research is to delve into the lived experiences of pre-service science teachers as they interact with PHET simulations in learning optics. The study underscores the importance of understanding how these teachers perceive and navigate the virtual environment, engage with the simulation, and incorporate their experiences into their understanding of optics. Furthermore, the research intends to explore various factors that could influence these experiences, such as their prior knowledge, teaching efficacy, personal disposition, and technical skills.

Despite the increasing body of research on the use of interactive simulations in science education, there is a noticeable gap in understanding the subjective experiences of pre-service teachers in the context of PHET simulations and optics (Bautista & Lucas, 2019).

Therefore, this study is crucial in filling this knowledge gap by exploring the experiences of local pre-service science teachers in the Philippines and understanding how these simulations can be utilized to improve their pedagogical content knowledge and teaching efficacy.

The primary objective of this research is to probe into the experiences of pre-service science teachers as they use PHET interactive simulations in learning optics, examining the impact on their understanding of key optical concepts, and identifying the challenges and opportunities that present themselves in a local Philippine context. However, the research scope is restricted to pre-service science teachers enrolled in the College of Education program at the Iloilo State University of Fisheries Science and Technology-Tiwi Campus and is focused on PHET simulations and optics. Consequently, the results may have limited generalizability due to the small sample size and geographic specificity.

This research holds immense significance for pre-service science teachers, science education researchers, and science educators. It presents an opportunity for pre-service teachers to reflect on their learning experiences and its effectiveness, informing their future teaching practices. For science education researchers, this study adds to the growing literature on interactive simulations in science education. For science educators, it offers a resource for developing instructional strategies that incorporate interactive simulations to enhance science teaching and learning.

¹ Iloilo State University of Fisheries Science and Technology (ISUFST), Philippines

* Corresponding author's e-mail: hermanlagon1@gmail.com

LITERATURE REVIEW

This literature review provides a critical overview of research related to the use of PHET interactive simulations in learning optics among pre-service science teachers. The review is organized into six subsections: constructivist learning theory, cognitive load theory, the role of simulations in science education, the effectiveness of PHET interactive simulations, the use of PHET interactive simulations in optics education, and the use of simulations among pre-service science teachers.

The constructivist learning theory highlights the importance of active involvement and social interaction in the construction of knowledge. Studies, such as Yang and Tsai (2008), support the application of constructivist theory in science education, demonstrating how constructivist teaching methods improve students' conceptual understanding. The study aims to examine how the use of PHET interactive simulations affects pre-service science teachers' understanding of optics, aligning with the constructivist learning theory.

Cognitive load theory (CLT), on the other hand, is explored as a framework for designing effective instructional materials. CLT emphasizes reducing extraneous load and increasing germane load to improve learning outcomes. Studies, such as that of López-Vargas *et al.* (2019), highlight the relevance of CLT in technology-enhanced learning environments, including simulations. The study investigates the effectiveness of PHET simulations in reducing cognitive load and enhancing pre-service science teachers' learning outcomes.

Meanwhile, the role of simulations in science education is valuable in terms of teaching abstract and complex concepts (Hsu *et al.*, 2016). Studies, both in the Philippines and abroad, demonstrate the effectiveness of simulations in improving students' achievement and understanding in biology, chemistry, and physics. However, limitations and potential drawbacks, such as simplified representations and varying effectiveness for different students, are also acknowledged.

On the other hand, the effectiveness of PHET interactive simulations is examined through various studies. Positive effects, such as improved exam performance, conceptual understanding, motivation, problem-solving skills, and spatial ability, are reported (Lozada, 2019). However, studies have also identified limitations and challenges, including the need for customization and technical support, as well as the necessity of integrating simulations with other teaching methods.

Studies reveal that the use of PHET interactive simulations in optics education has positive effects of PHET simulations in improving students' conceptual understanding of optics (Yunzal & Casinillo, 2020). However, some studies report mixed results, highlighting the need to consider factors such as students' prior knowledge, technical difficulties, and curriculum integration (Liu *et al.*, 2016).

Conversely, literature on the use of simulations among pre-service science teachers shows positive outcomes,

including enhanced understanding, improved practical skills, and knowledge development, are reported (Mrani *et al.*, 2020). However, some studies highlight the need for additional instructional methods to effectively enhance pre-service teachers' understanding of complex concepts. In conclusion, the review emphasizes the benefits of using PHET simulations in teaching optics, including enhanced understanding, improved problem-solving skills, and increased engagement. However, challenges associated with implementation, such as limited access to technology and cultural barriers, need to be addressed. Further research is recommended to explore the potential of simulations as an effective tool for enhancing pre-service science teacher education.

MATERIALS AND METHOD

The chapter illustrates the utilization of a phenomenological research methodology, inspired by Creswell (2017), to delve into the lived experiences of six pre-service science teachers at ISUFST Tiwi Campus while learning optics via PHET Interactive Simulations. The qualitative study comprised a series of observations and semi-structured interviews during the first semester of the school year, from August 15, 2022, to January 6, 2023. Participants were chosen via purposive sampling with a specific focus on those with PHET simulations experience in optics education.

Data collection was multifaceted, involving classroom observations of the participants using the simulations and tracking their independent use outside of this setting through students' journals. Additionally, individual and group interviews offered further insight into participants' experiences. Both the observations and interviews underwent pilot testing to ascertain their clarity and relevance to the research objective.

In terms of ethical considerations, measures were in place to ensure that participants were well-informed about the study's procedures and objectives, reassured about their anonymity, and that their participation was entirely voluntary. Data safety was prioritized by storing the data in a secure location, accessible only by the researcher.

The data was analyzed using a phenomenological approach, consistent with the Phases of Thematic Analysis of Braun & Clarke (2006) as seen in Figure 1, to explore the essence of the collected data. The initial themes were identified through extensive examination of the transcribed data. Both NVivo and ChatGPT, an AI chatbot developed by OpenAI, were instrumental in assisting with the organization and interpretation of unstructured data and in generating relevant responses.

The study's validity was secured by pilot testing the interview questions, employing multiple data sources, and conducting member checking. In contrast, reliability was achieved by implementing a straightforward research design, maintaining a detailed record of the research process, and the researcher keeping a reflexive journal to document potential biases or assumptions.



Figure 1: Phases of Thematic Analysis of Braun & Clarke (2006)

RESULTS AND DISCUSSIONS

The six participants, herewith named using their aliases to protect their identity, share similarities in their demographic characteristics and challenges in accessing digital resources for education.

They have different motivations for choosing BSED Science as their major and varied level of first-time experiences with PHET simulations. Understanding their demographics and experiences provides insights into their unique perspectives and the impact of these factors on their learning journey.

Through the thematic analysis of the interview data, several themes emerged that captured the participants' five-month experiences with PHET simulations in learning optics, namely (1) Enhanced understanding of optics concepts, (2) Engagement and interactivity, (3) Complementing traditional instruction, and (4) Practical and personal realities.

Theme 1: Enhanced Understanding of Optics Concepts

The participants eagerly shared their experiences and perspectives on utilizing PHET simulations to enhance their understanding of optics concepts through observations, individual interviews, focus group discussions, and personal journals. Overall, they found the PHET simulations helpful in visualizing and manipulating variables to comprehend the behavior of light in different scenarios.

For Heidi, "PHET is useful in terms of visualization sg

mga (of the) concepts sa (in) optics. At first, kabudlay sya intindihon kung paano gamiton (it is difficult to understand how to manipulate it); however, as I continued to explore the geometric optics simulation, I was able to create my understanding of the concepts of reflection and refraction of light." She further added, "Mas makita ko na subong kung paano maghulag ang light sa porma sg wave kag particle sa lain-lain nga sitwasyon, nga daw budlay gid intindihon ini sa usual nga tradisyunal nga sitwasyon sa klasehan (I could now see how light in the form of wave or particle behaves in different situations, which was difficult to visualize in a traditional classroom setting."

According to the participants, it is evident that PHET interactive simulations are highly useful and relevant in enhancing the understanding of optics concepts. They consistently expressed positive views regarding the simulations' ability to create visual representations of complex concepts, thus facilitating easier comprehension. Caren emphasized, "The simulations helped me grasp the concept of refraction by visually showing how light bends when passing through different media."

The participants also appreciated the interactive nature of the simulations, as it allowed them to manipulate variables and explore different scenarios. Ryan mentioned, "I could adjust the angle of incidence in the simulation and see how it affected the angle of reflection. It made it much easier to understand the relationship between the two."

While most participants expressed positive views, it is essential to note a legitimate concern from Aeza, who found the simulations somewhat overwhelming. She

remarked, “Although I somehow learn from it also, like the rest of my classmates, I struggled more to keep up with the pace of the simulations, and at times, it felt like there were too many variables to consider. These concerns made it harder for me to grasp the core concepts.” This offset perspective highlights the need for appropriate scaffolding and instructional support to ensure optimal use of the simulations. Aside from technical challenges, Aileen also struggled in all her subjects, especially those that required mathematical calculations and covered abstract concepts.

The consolidated findings indicate that PHET interactive simulations greatly enhance the understanding of optics concepts. The simulations’ ability to provide visual representations, allow for the manipulation of variables, and engage students in active learning contributes to a deeper comprehension of the subject matter. These findings align with previous research that has demonstrated the effectiveness of interactive simulations in improving students’ understanding of complex science concepts (Smetana *et al.*, 2017).

Nonetheless, PHET interactive simulations are highly useful and relevant in enhancing the understanding of optics concepts. The participants expressed positive views regarding the simulations’ ability to create visual representations of complex concepts, allowing for easier comprehension of optics concepts.

Theme 2: Engagement and Interactivity

The findings also highlight the level of engagement and interactivity of PHET interactive simulations in learning optics concepts. They enjoyed manipulating the simulation variables and seeing the outcomes in real time. Ryan stated, “It was like a game. I was really engaged in getting the right calibrations to produce the correct outcome.”

They all expressed that PHET simulations effectively create visual representations of complex concepts, allowing for a better understanding and engagement with the subject matter. Aileen noted, “The PHET simulations provided a visual representation that made complex concepts easier to understand. I love the Color Vision simulations that helped me determine the color I see for combining red, green, and blue light. It is also able to lead me to describe the color of light that is able to pass through different filters.” This sentiment was echoed by Rose, who stated, “The virtual manipulation of colors, photons, and interfering waves helped me visualize abstract ideas and grasp them more easily. I can only imagine the RGB bulbs and the light spectrum diagram that the teacher must prepare in the actual laboratory for this to happen. We do not even have a dark room to do these in case.” These findings align with previous research on the effectiveness of interactive simulations in enhancing learning (Siti & Ismail, 2018).

The engagement with PHET simulations varied among the respondents. Some preferred to use them independently, while others engaged in collaborative learning with peers and instructors. Heidi shared, “I enjoyed exploring the

simulations on my own, which allowed me to study at my own pace and delve deeper into specific concepts.” On the other hand, Ryan mentioned, “Collaborating with classmates and discussing the simulations helped me gain new insights and broaden my understanding.” These findings align with research highlighting the benefits of independent and collaborative learning with interactive simulations and game-based activities (Lou & Yuan, 2019; Cristobal, *et al.*, 2022).

As pre-service teachers, the respondents acknowledged the value of PHET interactive simulations as a teaching strategy or tool for learning. They recognized that PHET simulations could facilitate independent and collaborative learning among students, allowing them to develop critical thinking skills and generate their ideas. Heidi stated, “Using PHET simulations in teaching can empower students to think critically and actively construct their understanding of optics concepts.” Aileen also noted, “PHET simulations can be a valuable resource for teachers, saving time and effort in lesson preparation.” These findings align with the potential of interactive simulations to enhance teaching and learning experiences in science and mathematics classes in a more practical way (Henderson & Dancy, 2007).

The consolidated findings reveal that PHET interactive simulations provide a visually engaging and interactive learning experience, promoting independent exploration, critical thinking, and collaboration. They offer a distinct advantage over traditional learning materials, leading to a deeper understanding and increased motivation among learners. As a teaching strategy or tool, PHET simulations are valuable in facilitating effective learning in science and mathematics classes for pre-service teachers and high school students.

Theme 3: Complementing Traditional Instruction

The participants reported that PHET simulations complemented traditional instruction in optics. They found it helpful to use the simulations to reinforce the concepts they learned in class. Heidi stated, “The simulations helped me to visualize what we were learning in class. It was like a hands-on experience that complemented the lectures.”

This study’s findings revealed that using PHET interactive simulations significantly enhanced student engagement and promoted active learning. Ryan expressed, “ginabuhing mga simulations ang optics kag ginahimo nga mas naka-enganyo kag interactive ang experience sa proseso ng pagtuon (simulations brought optics to life and made the learning experience more engaging and interactive).” By actively manipulating virtual optical elements and observing the immediate outcomes, he said that, “my classmates and I were motivated nga mag-manipule kag mag-experiment (to manipulate and experiment), resulting in a deeper understanding of complex optical concepts such as the nature and characteristics of light.” Participants also unanimously agreed that PHET simulations played a crucial role in improving students’

conceptual understanding of optics. According to Nelly, “The simulations allowed us to visualize abstract optical phenomena and observe their behavior in real time.” By manipulating different parameters and observing the cause-and-effect relationships, students better grasped theoretical concepts and their practical applications.

PHET simulations were also found to connect theoretical knowledge and practical application in optics effectively. Rose highlighted, “Through the simulations, we could connect the abstract theories to real-world scenarios, making the subject more relevant and tangible.” The ability to manipulate virtual optical systems and observe their outcomes provided students with a hands-on experience facilitating a deeper comprehension of the subject matter. This is true also in the study of Magayanes, *et al.* (2023) where it affirms the importance of utilization of non-traditional laboratory activities such as individual simulations and student-created videos to enhance the quality of the learning process in physics, especially optics.

While the positive aspects of PHET simulations were evident, a few potential drawbacks were also identified. Some participants expressed concerns about the need for adequate training and support for educators to incorporate simulations into their instruction effectively. Aileen shared, “the teacher may still need further strategies to ensure he makes the most of these simulations and integrate them seamlessly into the lessons.” Additionally, there was a cautious acknowledgment of the potential risk of over-reliance on virtual experiences, which could limit students’ opportunities for real-world experimentation and hands-on learning. This is consistent with Cortez’s (2018) and Tan’s (2020) findings.

Some concepts need to be fully understood using PHET. Heidi explained, “May mga few topics na duda ako kung sakto or sala ang kagpaintedi ko. That’s the time nga mavisit ako sa YouTube or other learning materials to confirm kung ang pagintindi ko saktao man bala or indi, kag para mas makaintindi pa gid ako sg concepts sa optics (There were few topics that I am not sure if I am correct or not in understanding them. That’s the time that I visit YouTube or other learning materials to confirm if my understanding is correct or otherwise, and so that I can further understand the concepts in optics).”

The findings explicitly highlight the positive impact of integrating PHET interactive simulations as a complement to traditional instruction in optics education. The simulations enhance engagement, improve conceptual understanding, bridge theory and application, provide flexibility and accessibility, and foster collaborative learning. However, it is crucial to address the potential drawbacks, such as adequate training and the risk of over-reliance on virtual experiences.

Theme 4: Practical and Personal Realities

The participants also eagerly shared their experiences regarding practical and personal realities and areas to celebrate and learn from while using the PHET interactive

simulations in optics. One of the major issues highlighted by participants was the reliance on internet connectivity and the slow loading times of the simulations. Caren expressed her frustration, stating, “The simulations were great, but the slow loading times really tested my patience. I often found myself waiting for the simulation to load instead of focusing on the concept at hand.” This issue significantly hindered the accessibility of the simulations, particularly for those using mobile devices with weak internet connections.

To address this limitation, the participants proposed several suggestions. One recommendation Aileen put forward was the school’s provision for offline access or the ability to download the simulations in cheaper analog devices like what she has. She suggested that allowing the simulations to download even on low-tech devices would eliminate concerns about internet connectivity, making it more convenient for students, especially those using mobile devices.

Aileen explained, “If we could download the simulations in our analog devices, we wouldn’t have to worry about internet connectivity issues. It would be much more convenient, especially for students using mobile devices.” The technical difficulties and frustrations faced by the participants in using PHET simulations highlighted the need for improvements in terms of accessibility and compatibility. These challenges primarily revolved around internet connectivity issues, the lack of reliable gadgets, and concerns about internet fees. Aileen shared their concern, stating, “Sometimes, I couldn’t access the simulations because my internet connection was unstable. It was frustrating because I wanted to explore the concepts using the simulations.” Nelly echoed this sentiment, saying, “Na experience ko gid ang kabudlayan nga mag-gamit sg simulations sa akon nga daan nga device.

Makadilismaya gid nga makita ang simulations nga galag kag indi mag-work sa gusto ko matabu (I firsthand faced difficulties using the simulations on my outdated device. It was frustrating to see the simulations lag and not respond as expected.”

The participants experienced technical difficulties and frustrations while using PHET simulations for learning optics concepts. Issues related to internet connectivity, device compatibility, and accessibility hindered their ability to engage with the simulations fully. Their suggestions, including offline access, compatibility with cheaper Android phones, and access to reliable devices, hoped to solve the challenges and improve the overall user experience. By considering these and working towards enhancing the technical aspects of PHET simulations, educators can maximize their potential as effective educational tools in science and mathematics classes.

Despite such, it is worth noting that participants also highlighted several positive economic implications of using PHET interactive simulations. Heidi expressed, “PHET simulations offer a cost-effective alternative to traditional laboratory setups. They eliminate the need for expensive equipment and consumables, allowing

educational institutions to allocate resources to other areas.” This sentiment was echoed by others, emphasizing the potential cost savings and increased accessibility offered by these simulations. Additionally, participants emphasized the longevity of the simulations, noting that they can be utilized across multiple semesters, reducing the need for frequent equipment upgrades and replacements. In terms of psycho-emotional concerns, participants shared positive experiences related to the use of PHET interactive simulations. Ryan remarked, “The interactive nature of the simulations made learning optics more enjoyable and engaging. It felt like I was actively participating in the experiments, which boosted my motivation to learn.” The simulations provided a sense of immersion and interactivity, fostering a positive and dynamic learning environment. Participants also noted that the simulations reduced anxiety related to laboratory experiments, as mistakes or accidents would not result in costly damages or delays.

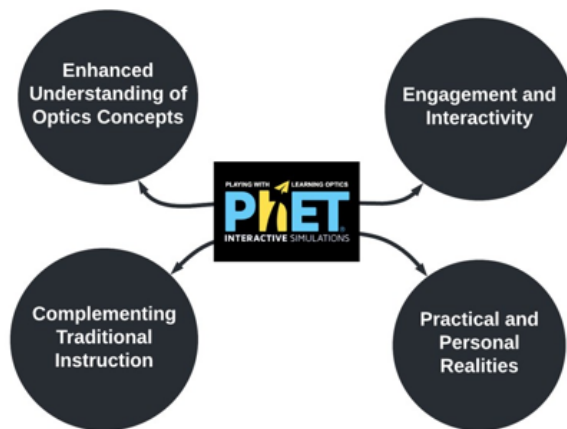


Figure 2: Cracking the PHET Code in Optics

While the economic benefits were evident, a few negative implications were also identified. Participants raised concerns about the initial cost of implementing PHET interactive simulations in the classroom. Rose mentioned, “Although the simulations themselves are freely available online, integrating them into the curriculum may require additional resources, such as laptops or tablets which we all do not have easy access to. This could challenge educational institutions and classes with limited budgets or inadequate technological infrastructure.” Institutionally, these concerns highlight the need for proper planning and investment to successfully integrate simulations into the educational setting (Larinova, 2018). Additionally, some participants mentioned that extended screen time during simulation-based activities could contribute to eye strain and fatigue, potentially impacting students’ overall well-being, which is in the same findings as that of Khan (2019). Heidi emphasized, “While simulations offer convenience and accessibility, they should be complemented with real-world laboratory experiences to provide a comprehensive learning environment.”

CONCLUSION

This chapter provides a summary of the findings and conclusions drawn from the study on using PHET simulations in learning optics. The participants reported enhanced understanding of optics concepts through the visual representations and manipulations offered by the simulations. They found the simulations more engaging and effective than traditional learning materials, fostering motivation and deepening their comprehension. However, technical challenges, such as slow loading times and limited internet connectivity, posed obstacles to the optimal use of the simulations. Despite these limitations, PHET simulations were seen as valuable teaching tools that complemented traditional instruction.

The study recommends addressing technical difficulties by providing support and resources, improving internet connectivity, and expanding compatibility with various devices. Incorporating PHET simulations into science and mathematics classes is encouraged to empower students in critical thinking and active concept construction. Teachers can benefit from the practical advantages of PHET simulations, especially in resource-constrained environments. The positive impact of PHET simulations on understanding, engagement, and motivation in learning optics highlights their potential as effective teaching tools. The findings contribute to the existing literature on the effectiveness of interactive simulations in science education, aligning with constructivist learning theory and cognitive load theory. Practical implications include integrating PHET simulations into instruction, providing instructional support, and improving technical aspects for optimal usage. Further research is recommended to explore the long-term impact of using PHET simulations and to compare their effectiveness with other instructional approaches.

By considering the findings, implications, and recommendations, educators can harness the benefits of PHET simulations to enhance science and mathematics education. The use of these simulations can foster a deeper understanding of concepts, promote engagement and active learning, and prepare students for real-world 21st century applications in optics and beyond.

REFERENCES

- Bautista, G., & Lucas, R. (2019). Enhancing students’ understanding in optics and waves through interactive simulations. *Asia-Pacific Forum on Science Learning and Teaching*, 20(2), Article 3. Retrieved from <https://www.eduhk.hk/apfslt/>
- Braun, V., Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101
- Cortez, J. M. (2018). Effects of interactive simulations on students’ conceptual understanding of optics. *International Journal of Science Education*, 40(2), 189-206.
- Creswell, John W., and Vicki L. Plano Clark (2017). *Designing and Conducting Mixed Methods Research*. (3rd ed.) Thousand Oaks, CA: SAGE Publications.

- Cristobal, J.- ar, Hermano, C., Ibane, J. B., James, M. G., Ligot, M. L., & Lampitoc, D. (2022). Improving the Grade 9 Students' Engagement in Online Synchronous Classes in English Through Interactive Games. *American Journal of Education and Technology*, 1(1), 18–25. <https://doi.org/10.54536/ajet.v1i1.326>
- Henderson, C., & Dancy, M. (2007). Barriers to the use of interactive simulations. *American Journal of Physics*, 75(5), 464-472. <https://doi.org/10.1119/1.2718647>
- Hsu, Y. S., Wang, T. I., & Lin, T. C. (2016). The effects of simulation learning on nursing students' self-efficacy and knowledge. *Journal of Educational Technology & Society*, 19(3), 291-302.
- Khan, S. (2019). Impact of Interactive Simulations in Science Education: A Systematic Review and Meta-Analysis. *Educational Technology & Society*, 22(2), 260-273.
- Larionova, V. I., & Sulimov, N. V. (2018). Virtual Laboratories: History, Classification, Types. *European Journal of Contemporary Education*, 7(3), 658-668.
- Liu, X., Guo, Z., & Wang, X. (2016). Effect of computer simulations on students' conceptual understanding of properties of light. *Physics Education*, 51(2), 1-8. <https://doi.org/10.1088/>
- López-Vargas, O., Ibáñez-Ibáñez, J., & Racines-Prada, O. (2017). Students' metacognition and cognitive style and their effect on cognitive load and learning achievement. *Educational Technology & Society*, 20(3), 145-157. Retrieved from <https://www.jstor.org/stable/26196126>
- Lou, Y., & Yuan, J. (2019). A study on the effectiveness of interactive simulations in improving students' understanding of science concepts. *EURASIA Journal of Mathematics, Science and Technology Education*, 15(12), em1794. doi: 10.29333/ejmste/109133
- Lozada, S. F. (2019). Performance of Senior High School Students using PhET Simulation in Teaching Physics. *Ascendens Asia Journal of Multidisciplinary Research Abstracts*, 3(2N).
- Magayanes, R. L. S., Sarmiento, B. G., Miguel, J. R. P., Diaz, J. J. G., Argañosa, J. B., Brillantes, L. C., Luyahan, J. T., Barachina, J. M. D., & Oca, M. D. D. (2023). Utilization of Student-Created Videos for Laboratory Activities in Physics. *American Journal of Education and Technology*, 2(2), 116–123. <https://doi.org/10.54536/ajet.v2i2.1561>
- Mrani, C.A., Hajjami, A. E., & Khattabi, E.K. (2020). Effects of the Integration of PhET Simulations in the Teaching and Learning of the Physical Sciences of Common Core (Morocco).
- Rashkovits, R., & Lavy, I. (2020). Novice Programmers' Coping with Multi-Threaded Software Design. *Journal of Information Technology Education. Innovations in Practice*, 19, 75. <https://doi.org/10.28945/4609>
- Siti, N. I. A. M., & Ismail, Z. (2018). The effectiveness of interactive simulation in enhancing students' understanding in optics. *International Journal of Emerging Technologies in Learning*, 13(5), 164-175. <https://doi.org/10.3991/ijet.v13i>
- Smetana, L. K., Bell, R. L., & Jansen, J. (2017). Learning about energy using computer-based models: A comparison of individual versus social forms of scaffolding. *Journal of Science Education and Technology*, 26(1), 31-45.
- Tan, R. (2020). The impact of integrating PHET interactive simulations in optics instruction. *Journal of Physics Education*, 35(3), 267-281.
- Tao, P.-K., Liang, J.-C., Tsai, C.-C., & Chen, Y.-H. (2017). A review of research on the use of PhET interactive simulations in teaching and learning optics. *Journal of Science Education and Technology*, 26(3), 249-265. <https://doi.org/10.1007/s10956-016-9656-5>.
- Yang, S. J. H., & Tsai, C. C. (2008). Exploring the effects of a constructivist mobile learning environment supported by a wireless handheld network. *British Journal of Educational Technology*, 39(1), 53-63. <https://doi.org/10.1111/j.1467-8535.2007.00711.x>
- Yunzal, Y. J., & Casinillo, L. M. (2020). Effect of Physics Education Technology (PHET) Simulations: Evidence from STEM Students. *European Journal of Science and Mathematics Education*, 8(1),