

How to Cite

Pallaroso-Figueroa, N. M., & Alcívar-Castro, E. J. (2026). Impact of virtual simulators on the teaching and learning process of physics. *International Journal of Physics and Mathematics*, 9(1), 37-44.
<https://doi.org/10.21744/ijpm.v9n1.2530>

Impact of Virtual Simulators on the Teaching and Learning Process of Physics

Nohelia Melina Pallaroso-Figueroa

Universidad Laica Eloy Alfaro de Manabí, Maestría en Educación con Mención en Innovación pedagógica Chone, Manabí, Ecuador

Corresponding author email: e1317482006@live.ulead.edu.ec

Eddie José Alcívar-Castro

Universidad Laica Eloy Alfaro de Manabí, Chone, Manabí, Ecuador

Email: eddie.alcivar@uleam.edu.ec

Abstract---Virtual simulators are digital tools that recreate complex physics experiments using mathematical models and interactive graphical environments. Their impact lies in transforming abstract concepts into hands-on experiences, enhancing students' intuitive understanding and critical thinking. This democratizes access to practical learning by offering safe, repeatable laboratories free from budgetary or physical infrastructure limitations. The objective was to analyze the impact of virtual simulators on the teaching and learning process of parabolic motion in first-year high school students. The study was conducted using a mixed-methods approach and a quasi-experimental design, with a population of 120 high school students and a sample of 30 students, divided into a control group and an experimental group of 15 students each. A pre-test and a post-test were administered to collect data, aiming to identify initial knowledge and determine changes in learning after the pedagogical intervention. The pretest results showed averages of 3.20 for the control group and 3.30 for the experimental group, indicating comparable initial conditions between both groups. Subsequently, the experimental group participated in a pedagogical intervention based on the systematic use of PhET virtual simulators to represent, explore, and analyze variables related to parabolic motion. In the posttest, the control group achieved an average of 5.06, while the experimental group obtained an average of 6.01, a difference of 0.95 points in favor of the latter.

Keywords---virtual simulators, PhET, parabolic motion, teaching and learning, educational resources.

Introduction

Teaching physics at the high school level presents an educational challenge because many topics require students to relate mathematical, graphical, and conceptual representations to physical phenomena that cannot always be directly observed. This is especially relevant in the study of parabolic motion, the understanding of which involves establishing relationships between variables such as initial velocity, launch angle, flight time, maximum height, and horizontal range. In this context, the incorporation of technological resources can contribute to creating more interactive learning experiences and fostering the understanding of physical phenomena through their representation, exploration, and analysis (Zhang, 2014).

The development of digital technologies has generated new possibilities for science education, particularly through the use of virtual simulators that allow for the representation of phenomena, the modification of variables, and the observation of their effects in real time. In physics education, these tools can complement traditional strategies by providing spaces for experimentation in which students actively participate in constructing their knowledge. A review of experimental and quasi-experimental research on the use of PhET simulations concluded that there is consistent evidence of their contribution to strengthening the conceptual understanding of physics, especially when integrated into active learning environments (Membabanda et al., 2021).

In particular, PhET interactive simulations allow students to represent different physical phenomena through digital environments where they can modify initial conditions, observe changes, and establish relationships between the variables involved. In the case of parabolic motion, these simulations make it possible to explore aspects such as launch angle, initial velocity, height, range, and the effects of air resistance, facilitating the observation of relationships that can be abstract when approached solely through mathematical expressions.

The available evidence also supports the incorporation of PhET into physics teaching processes. [Najib et al. \(2022\)](#), using a quasi-experimental design with secondary school students, compared an experimental group that worked with PhET simulations and a control group that received conventional instruction, using tests before and after the intervention. The results demonstrated the usefulness of simulation-based activities in improving academic performance in physics. Similarly, research conducted with secondary school students in Malawi found favorable effects of PhET simulation-based learning on both motivation and academic performance in physics content.

In the Latin American context, the use of virtual simulators has also gained relevance as a strategy to address the difficulties associated with teaching physics concepts. In Ecuador, [Yanchapaxi-Molina & Mérida-Córdova \(2024\)](#), analyzed the use of PhET and learning analytics in physics teaching, highlighting the usefulness of these tools in facilitating the understanding of physics concepts that can be abstract for students. Similarly, research conducted in Ecuador on the use of virtual simulators for teaching the electric field employed a quantitative and quasi-experimental design, comparing a control group with an experimental group that worked with PhET.

Recent scientific evidence has continued to strengthen this perspective. [deMedeiros Jr. et al. \(2024\)](#), based on a meta-analysis of 22 studies selected from an initial set of 1589 publications, determined that interactive PhET simulations show favorable results in physics learning and can achieve superior or at least equivalent results to those obtained through conventional methods and traditional laboratories. The authors emphasize that the effectiveness of these tools depends, among other aspects, on how they are incorporated into pedagogical activities.

Additionally, [Alsalmi et al. \(2024\)](#), analyzed the effect of PhET simulations on academic performance using a quasi-experimental design with control and experimental groups. The results showed higher average performance in the group that worked with the interactive simulations compared to the group that received instruction using traditional methodologies. These results reinforce the importance of considering virtual simulators not only as technological resources, but as tools that should be intentionally integrated into learning planning and activities.

In this sense, parabolic motion is a relevant topic for the use of virtual simulators, as it allows for the modification of variables and the immediate observation of their effects on the projectile's trajectory. This possibility fosters the relationship between the mathematical and graphical representations of the phenomenon, as well as the analysis of situations that may be difficult to reproduce in a controlled manner within the classroom. Therefore, the systematic use of PhET can provide students with opportunities to formulate predictions, verify results, modify initial conditions, and analyze the behavior of the motion from an experimental perspective ([Martin et al., 2020](#)).

This problem highlights the need to analyze the impact of virtual simulators on the learning of parabolic motion in high school students. In this context, the present research aimed to determine the changes in the academic performance of first-year high school students after a pedagogical intervention based on the use of PhET virtual simulators ([Clements et al., 2015](#)).

In accordance with the above, the objective of this research was to analyze the impact of virtual simulators on the teaching and learning process of parabolic motion in first-year high school students. To this end, the following research question was posed: What is the impact of using virtual simulators on the teaching and learning process of parabolic motion in first-year high school students?

The research hypothesis was that the use of virtual simulators improves the teaching-learning process of parabolic motion in first-year high school students.

Materials and Methods

The research was conducted using a mixed-methods approach, integrating quantitative and qualitative procedures to analyze the impact of virtual simulators on learning parabolic motion. A quasi-experimental design with pre-test and post-test was employed, consisting of a control group and an experimental group. This design allows for the assessment of changes associated with an educational intervention when working with pre-existing groups ([Jelena & Jelena, 2022](#)).

The population consisted of 120 high school students, and the sample comprised 30 first-year high school students, divided into a control group (15 students) and an experimental group (15 students). A knowledge test on parabolic motion was administered as a pre-test and post-test. The instrument covered aspects related to initial velocity, launch angle, trajectory, maximum height, and horizontal range.

The procedure was developed in three stages: initial diagnosis, through the application of the pre-test; didactic intervention, in which the experimental group worked with interactive PhET simulations; and final evaluation, through the application of the post-test to both groups. The didactic intervention was carried out using interactive PhET simulations, which allowed students to modify variables such as initial velocity and launch angle, and observe their effects on the projectile's trajectory. This resource has recently been used to strengthen the conceptual understanding of parabolic motion in high school students (Suherman et al., 2025).

The use of PhET was based on previous research on teaching parabolic motion. Chinaka (2021), employed a mixed experimental design to analyze the use of PhET in this subject, while recent studies continue to report its application as a resource to enhance the conceptual understanding of physical phenomena. Descriptive statistics were used for data processing, considering the arithmetic mean, standard deviation, and standard error.

Analysis and Discussion of the Results

Virtual learning offers an alternative for incorporating technological resources that promote interaction, exploration, and active student participation. In science education, simulations allow for the representation of phenomena that may be difficult to observe directly and facilitate the modification of variables to analyze their effects (Banda & Nzabahimana, 2021). Furthermore, learning experiences through simulations can contribute to the development of conceptual understanding when integrated with guided activities and clearly defined pedagogical objectives (Ramila, 2024).

In this context, virtual simulations acquire special importance in physics education, as they allow for the complementation of theoretical explanations with dynamic representations of phenomena. Various studies have reported favorable results associated with the use of PhET in learning physical concepts, especially when students actively participate in the exploration and analysis of the simulations (Diraya et al., 2021; Sukanto, 2022; Da López et al., 2023).

Features and functionalities of PhET

PhET (Interactive) Simulations is a platform that provides interactive simulations for teaching physics and other sciences. Its resources allow users to modify variables, observe visual representations, and establish relationships between the changes made and the behavior of the phenomenon being studied. These features foster learning environments based on exploration, inquiry, and the construction of scientific explanations (Ramila, 2024).

In the case of parabolic motion, simulation allows for the modification of parameters such as initial velocity and launch angle, observation of the projectile's trajectory, and the correlation of these variables with maximum height, flight time, and horizontal range. Chinaka (2021) found that the use of PhET facilitated the understanding of the integration of horizontal and vertical motions in students studying parabolic motion.

The use of PhET also allows for the development of activities through different teaching strategies. Recent research has incorporated simulations with inquiry-based learning, worksheets, prediction-observation-explanation models, and other active approaches, demonstrating its flexibility as an educational resource (Puspaningrum & Pujianto, 2022).

Benefits of using PhET

The use of PhET can promote conceptual understanding, active participation, visualization of phenomena, and learning through virtual experimentation. Studies conducted with physics students have reported improvements in learning and concept comprehension after using interactive simulations (Najib et al., 2022; Banda & Nzabahimana, 2023; Chávez Farfán & Mestres Gómez, 2023). The study by Banda and Nzabahimana reported results related to the motivation and academic performance of secondary school physics students in Malawi.

Simulations can also be an alternative when there are limitations to conducting conventional experiments. Their use allows for repeating procedures, modifying variables, and observing phenomena again, thus facilitating exploration, comparison, and analysis (Oktamuliani et al., 2021).

The accumulated evidence also supports the use of PhET in physics teaching. A review of experimental and quasi-experimental research found favorable evidence of its contribution to conceptual understanding, while a meta-analysis of selected studies from different databases reported favorable results for PhET simulations compared to conventional methods in various physics teaching contexts (de Medeiros Jr et al., 2024).

In the Ecuadorian context, research has also been conducted that reports the incorporation of PhET as a teaching resource to improve the teaching and learning process of physics. Lino-Calle et al. (2023), analyzed its use through

learning analytics in electrostatics content and noted favorable results associated with the learning of physical concepts.

Consequently, PhET's interactive features allow for the enhancement of traditional teaching through virtual experiences in which students can explore, modify variables, observe results, and relate them to physical principles. This possibility is particularly relevant for the study of parabolic motion, where understanding requires simultaneously relating different variables and representations of motion (Lino-Calle et al., 2023).

Table 1 presents the results obtained by the students in the control and experimental groups in the pretest and posttest assessments. The data show that the control group obtained an average of 3.20 points in the pretest and 5.06 points in the posttest, while the experimental group achieved averages of 3.30 and 6.01 points, respectively.

Table 1
Results of the control and experimental group in the pretest and posttest

Exp1	2.80	4.50	2.90	5.50
Exp2	3.00	5.10	3.20	5.90
Exp3	3.20	5.40	3.40	6.20
Exp4	3.10	4.80	3.10	5.70
Exp5	3.40	5.70	3.60	6.50
Exp6	3.00	5.00	3.30	6.00
Exp7	3.50	5.30	3.50	6.30
Exp8	2.70	4.60	2.80	5.80
Exp9	4.20	5.80	4.00	6.70
Exp10	3.30	5.20	3.40	6.10
Exp11	3.10	4.90	3.10	5.60
Exp12	3.40	5.50	3.50	6.40
Exp13	3.00	5.00	3.20	6.00
Exp14	3.20	5.30	3.30	6.30
Exp15	3.10	3.80	3.20	5.15
Average	3.20	5.06	3.30	6.01

Source: Prepared by the author based on the results obtained in the research

Table 2 shows the summary of the control and experimental groups in the pretest and posttest.

Table 2
Summary of the control and experimental groups in the pretest and posttest

Cluster	Pretest	Posttest	Revenue
Control	3.20	5.06	1.86
Experimental	3.30	6.01	2.71

Source: Prepared by the author based on the results obtained in the research

The comparison of average gains shows an increase of 1.86 points in the control group and 2.71 points in the experimental group. Therefore, the difference between the two gains was 0.85 points, with a greater increase in academic performance in the group that participated in the intervention using the PhET virtual simulator.

Table 3 shows the means and standard deviations obtained in each assessment. In the control group, the standard deviation increased from 0.35 in the pretest to 0.51 in the posttest. In the experimental group, it increased from 0.29 to 0.41. These values indicate relatively low variability in the scores with respect to their respective mean.

Table 3
Mean and standard deviation of the control and experimental groups

Cluster	Assessment	Average	Standard deviation
Control group	Pre-test	3.20	0.35
Control group	Post-test	5.06	0.51
Experimental group	Pre-test	3.30	0.29
Experimental group	Post-test	6.01	0.41

Source: Own elaboration

In descriptive terms, both groups improved their performance after the teaching process. However, the increase was greater in the experimental group, which achieved an average gain of 2.71 points compared to 1.86 points for the control group.

Inferential analysis

To determine whether the differences observed between the groups were statistically significant, comparisons were made using the Student's t-test for independent samples and the non-parametric Mann-Whitney test, considering a significance level of $\alpha = 0.05$.

Initial equivalence of the groups

In the pretest, the Student's t-test for independent samples showed no statistically significant differences between the control and experimental groups ($t = -0.845$; $df = 28$; $p = 0.405$). This result was corroborated by the Mann-Whitney U test ($U = 81.5$; $p = 0.203$). Consequently, the groups had statistically comparable baseline conditions before the intervention.

Post-test results

After the educational intervention, statistically significant differences were observed between the two groups. The Student's t-test showed a t-value of -5.612 , with 28 degrees of freedom and $p < 0.001$. Additionally, the Mann-Whitney U test showed a U-value of 13.5 and $p < 0.001$, confirming the existence of significant differences between the scores obtained in the post-test. The experimental group achieved an average of 6.01 points, while the control group obtained an average of 5.06 points, with a difference of 0.95 points between the two groups.

Analysis of academic gain

To determine the magnitude of the change between the pretest and posttest, individual academic gain was calculated as the difference between the two assessments. The control group showed an average gain of 1.86 points, while the experimental group reached 2.71 points. The comparison of gains showed a statistically significant difference between the groups ($t = -7.224$; $df = 28$; $p < 0.001$). The difference between mean gains was 0.85 points, indicating a greater increase in the experimental group.

Size of effect

To estimate the magnitude of the differences found, the effect size was calculated using Cohen's d. A value of $d = 2.05$ was obtained for the comparison of post-test results, while $d = 2.64$ was obtained for the comparison of academic gains. Both values represent a very large effect size, indicating a considerable difference between the groups, particularly in the magnitude of academic gain.

Summary of inferential results

The results show that the groups did not present statistically significant differences before the intervention, while after the intervention, significant differences were identified in the post-test and in academic performance. In both cases, the results favored the experimental group, which worked using PhET virtual simulators.

With a significance level of $\alpha = 0.05$, the post-test and academic gain results ($p < 0.001$) allow us to reject the null hypothesis. Consequently, the findings provide statistical evidence compatible with the research hypothesis, as a greater increase in academic performance was observed in the students who participated in the PhET virtual simulator intervention.

Discussion

The results obtained show statistically significant differences between the groups after the educational intervention. Although both groups showed improvements between the pre-test and post-test, the experimental group achieved a mean of 6.01 points, compared to 5.06 points for the control group. This difference was accompanied by a greater academic gain in the experimental group (2.71 points) compared to the control group (1.86 points). Furthermore, inferential tests confirmed significant differences in the post-test ($t = -5.612$; $p < 0.001$) and in academic gain ($t = -7.224$; $p < 0.001$), while the pre-test did not show statistically significant differences between the groups ($p > 0.05$). Overall, these results indicate that the students who participated in the PhET simulator intervention experienced a greater increase in academic performance than that observed in the control group.

The magnitude of the differences is also reflected in the effect sizes obtained. The d -value of 2.05 for the post-test and d -value of 2.64 for academic gain correspond to very large effect sizes. These results suggest that the difference between the groups is not limited to statistical significance but is also of a relevant magnitude in terms of academic performance. However, due to the quasi-experimental nature of the research, these results should be interpreted in light of the specific context of the intervention and the characteristics of the sample studied.

The findings are consistent with previous research that has examined the use of PhET simulations in physics teaching. [Najib et al. \(2022\)](#) and [Alsalihi et al. \(2024\)](#), reported favorable results in the academic performance of students who participated in learning experiences supported by interactive simulations. This correlation suggests that the use of virtual environments can contribute to learning when simulations are incorporated as part of a pedagogical strategy and not merely as a supplementary resource.

Regarding parabolic motion, the results show a particular correspondence with those reported by [Chinaka \(2021\)](#), who studied the use of PhET to facilitate the understanding of the integration of motion along two independent axes. The ability to modify variables and simultaneously observe their effects on the trajectory allows for establishing relationships between the horizontal and vertical components of the motion, a fundamental aspect for understanding this phenomenon. Similarly, [Suherman et al. \(2025\)](#), found favorable results in the conceptual understanding of parabolic motion through a learning strategy based on PhET simulations, which is related to the improvement observed in the experimental group of the present study.

A possible explanation for these results lies in the interactive characteristics of the simulations. Students can modify initial conditions, observe their effects, and compare the results with the mathematical and conceptual explanations developed during the class. This interaction fosters the connection between different representations of the physical phenomenon and can facilitate the understanding of content that requires the simultaneous integration of variables such as initial velocity, launch angle, height, flight time, and horizontal range. In this sense, the results obtained are consistent with the evidence highlighting the importance of integrating simulations within pedagogically oriented exploration and inquiry activities.

The results also align with the evidence synthesized by [de Medeiros Jr. et al. \(2024\)](#), whose meta-analysis, based on 22 selected studies from 1,589 identified publications, found favorable results for the use of PhET in physics teaching compared to traditional methods and conventional laboratories. The authors point out that simulations can achieve superior results, or at least results equivalent to other teaching modalities. This evidence provides a broader framework for interpreting the results of the present research and allows us to situate them within a trend of studies examining the potential of interactive simulations to support physics learning.

Similarly, the results align with [Membabanda et al. \(2021\)](#), who indicated that PhET simulations can contribute to conceptual understanding when integrated into active learning environments. This consideration is relevant for interpreting the results obtained, since the intervention was not limited to exposing students to a simulation but was instead geared towards exploring variables and analyzing the behavior of parabolic motion. In this sense, the technological resource acquires didactic value when it is linked to learning objectives and activities that promote student participation.

In the Ecuadorian context, the results also align with the research of [Yanchapaxi-Molina & Mérida-Córdova \(2024\)](#) and [Lino-Calle et al. \(2023\)](#), who have analyzed the incorporation of digital resources and simulations in physics teaching. This background suggests that the use of virtual tools is a viable alternative within the Ecuadorian educational context, particularly for addressing content that requires graphical representations, experimentation, and manipulation of variables.

Taken together, the findings of this research provide evidence that a pedagogical intervention based on PhET simulators was associated with a greater increase in academic performance in learning parabolic motion compared to the group that developed the process using the conventional methodology. The absence of statistically significant differences in the pretest and the presence of significant differences in the posttest and in academic gain strengthen the interpretation of the results. However, the scope of these conclusions should be limited to the conditions, participants, and intervention considered in this study. Therefore, future research could expand the sample size, incorporate different educational institutions, and analyze the retention of the learning acquired after the intervention.

Conclusions

The results allow us to conclude that the incorporation of PhET virtual simulators was related to an improvement in the academic performance of first-year high school students in learning about parabolic motion. Although both groups improved their results, the average gain was greater in the experimental group (2.71 points) than in the control group (1.86 points).

In the pretest, no statistically significant differences were found between the groups ($p > 0.05$), indicating comparable initial conditions. After the intervention, statistically significant differences were identified in the posttest ($p < 0.001$) and in academic gain ($p < 0.001$), favoring the experimental group.

The effect sizes obtained were very large for both the post-test ($d = 2.05$) and academic gain ($d = 2.64$), demonstrating a considerable difference in magnitude between the groups. These results support the research hypothesis and suggest that PhET is a relevant teaching resource for strengthening the learning of parabolic motion.

Finally, the findings should be interpreted considering the quasi-experimental design, the sample size, and the specific context of the study. Further research with larger samples and different educational institutions is recommended to analyze the consistency of these results.

References

- Alsalthi, N. R., Abdelkader, A. F., Ismail, A. A. K. H., Alqatawneh, S., Alqawasmi, A., & Salem, O. (2024). The Effect of Using PhET Interactive Simulations on Academic Achievement of Physics Students in Higher Education Institutions. *Educational Sciences: Theory & Practice*, 24(1), 65–75.
- Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical review physics education research*, 17(2), 023108.
- Banda, H. J., & Nzabahimana, J. (2023). The impact of physics education technology (PhET) interactive simulation-based learning on motivation and academic achievement among malawian physics students. *Journal of science education and technology*, 32(1), 127-141.
- Chávez Farfán, J.G., & Mestres Gómez, U. (2023). PhET Simulators: As a didactic tool for the teaching and experimental learning of Physics. *Polo del Conocimiento*, 8 (11).
- Chinaka, T. W. (2021). The effect of PhET simulation vs. phenomenon-based experiential learning on students' integration of motion along two independent axes in projectile motion. *African Journal of Research in Mathematics, Science and Technology Education*, 25(2), 185-196.
- Clements, K., Pawlowski, J., & Manouselis, N. (2015). Open educational resources repositories literature review—Towards a comprehensive quality approaches framework. *Computers in human behavior*, 51, 1098-1106. <https://doi.org/10.1016/j.chb.2015.03.026>
- Da Lopez, M. A., Nikmatillah, Z., Cahyani, A., Gunawan, G., & Nisrina, N. (2023). The Use of Phet Simulations to Improve High School Students' Understanding of Physics Concepts: A Systematic Literature Review. *Indonesian Journal of Applied Science and Technology*, 4(2), 182-191.
- de Medeiros Jr, R. N., Naia, M. D., & Lopes, J. B. (2024). PhET interactive simulations in physics teaching practices: a meta-analysis. *Revista Brasileira de Ensino de Física*, 46, e20240186.
- Diraya, I., Budiyo, A., & Triastutik, M. (2021). Kontribusi Virtual Lab Phet Simulation untuk Membantu Praktikum Fisika Dasar. *Phenomenon: Jurnal Pendidikan MIPA*, 11(1), 45-56.
- Jelena, O. Z., & Jelena, M. (2022). Quasi-experimental research as an epistemological-methodological approach in education research. *International Journal of Cognitive Research in Science, Engineering and Education*, 10(3), 177-183.
- Lino-Calle, V. A., Barberán-Delgado, J. A., López-Fernández, R., & Gómez-Rodríguez, V. G. (2023). Learning analytics supported by PhET Simulations as a teaching tool in the subject of Physics. *MQRInvestigar*, 7(3), 2297–2322.
- Martin, F., Sun, T., & Westine, C. D. (2020). A systematic review of research on online teaching and learning from 2009 to 2018. *Computers & education*, 159, 104009. <https://doi.org/10.1016/j.compedu.2020.104009>
- Najib, M. N. M., Md-Ali, R., & Yaacob, A. (2022). Effects of PhET interactive simulation activities on secondary school students' Physics achievement. *South Asian Journal of Social Science and Humanities*, 3(2), 73-78.
- Oktamuliani, S., Centaury, B., Muhaimin, S., Afdal, A., Adrial, R., Muldarisnur, M., ... & Mahyudin, A. (2021). Simulasi PhET sebagai laboratorium virtual dalam peningkatan pemahaman konsep fisika siswa SMAN 3 Painan, Pesisir Selatan. *Warta Pengabdian Andalas*, 28(4), 509-513.
- Puspaningrum, D.A., & Pujianto. (2022). Pengembangan LKPD berbantuan PhET untuk meningkatkan keterampilan processes sains dan penguasaan konsep Fisika. *Jurnal Pendidikan Fisika*, 9(2), 66–84.
- Ramaila, S. (2024). Pedagogical affordances of physics education technology in teaching and learning: A systematic review. *International journal of technology, knowledge and society*, 20(2), 109-131.
- Suherman, W., Kariadinata, R., & Chusni, M. M. (2025). Effectiveness of PhET Interactive Simulation-Based Learning on Grade XI Students' Conceptual Understanding of Projectile Motion. *CAHAYA: Journal of Research on Science Education*, 3(2), 57-71.

- Sukanto, T. (2022). Pemanfaatan Media Phet Simulation Pada Pembelajaran Fisika Dengan Pendekatan Contextual Teaching and Learning. *Jurnal Educatio Fkip Unma*, 8(2), 649-654.
- Yanchapaxi-Molina, C. E., & Mérida-Córdova, E. J. (2024). Use of PHET Simulations and learning analytics to improve the teaching-learning process in Physics. *MQRInvestigar*, 8(4), 6913–6941.
- Zhang, M. (2014). Who are interested in online science simulations? Tracking a trend of digital divide in Internet use. *Computers & Education*, 76, 205-214. <https://doi.org/10.1016/j.compedu.2014.04.001>