Indonesian Journal of Educational Innovation (IJEI)
Volume 1, Issue 2, August 2025
Pages: 19–24

ISSN : 3109-0176
E-ISSN : 3109-0168

Effectiveness of The Cooperative Learning Model Assisted by The PhET Simulation to Improve Students' Learning Outcomes

Muh. Asri Ilham[1*], Muh. Amri Ilham[2], Melinda[3]

[1]Master's Program in Science Education, Post Graduate Program, Mataram University, Indonesia;
[2]English Language Education, Faculty of Culture Management and Business, Mandalika University of Education, Indonesia;
[3]Special Education Study Program, Faculty of Education, University of Makassar, Makassar, Indonesia.

Article Info

Article History
Received: June 3, 2025
Revised: June 7, 2025
Accepted: June 25, 2025
Published: August 31, 2025

*Corresponding Author:

Muh. Asri Ilham,
Mataram University,
asriilham246@gmail.com

Abstract

Low student learning outcomes in static fluid topics highlight the need for innovative physics learning strategies. This study evaluates the effectiveness. of a cooperative learning model assisted by PhET simulations in improving outcomes. Using a one-group pretest-posttest design with a quantitative approach, the study involved 31 students from class XI A3 who were purposively selected. A multiple-choice test covering hydrostatic pressure, Pascal's law, and Archimedes' principle served as the primary instrument. Data were analyzed using the N-Gain test to measure improvement. Results showed an average score increase from 49.87 to 73.94, with an N-Gain of 0.48 (moderate category). The findings suggest that cooperative learning supported by PhET simulations is pretty effective in enhancing student learning outcomes. This study implies that integrating collaborative learning with interactive simulations can be a promising innovation in physics education.

Keywords: cooperative learning; effectiveness; PhET simulation; learning outcomes.

INTRODUCTION

Physics is a branch of science that plays a vital role in shaping students' understanding of natural phenomena and technology. One topic in physics that is often considered challenging by students is static fluids, which encompasses concepts such as pressure, Pascal's law, and Archimedes' principle (Lindgren & Johnson-Glenberg, 2016; Chi et al., 1994; Al-Rahmi et al., 2022). Mastery of this topic is vital because it is not only relevant in the academic realm but also has widespread applications in everyday life, such as in engineering and healthcare (García-Peñalvo et al., 2021; García-Morales et al., 2023). However, many students struggle to understand these concepts, which impacts their learning outcomes (Henderson & Shipway, 2024; González & Smith, 2024). This highlights the need for learning models that can help visualize and understand concepts more concretely and meaningfully (Lee & Chen, 2024; Johnson et al., 2023).

The cooperative learning model is considered a promising approach to address this issue. This model encourages student interaction through group work, discussion, and collaborative problem-solving (Dacre et al., 2021; Gamage & Whiting, 2021). Such interactions enhance conceptual understanding and boost students' learning motivation (Belz & Muller, 2003; Chapelle, 2003). Technologies like PhET Simulation have proven effective in helping students grasp abstract physics concepts through interactive visualization (Blaschke & Porto, 2014; Smith & MacGregor, 1992). Integrating cooperative models and PhET-based simulation media can potentially strengthen student engagement and improve learning outcomes (Zhu et al., 2023; Sánchez Milara & Cortés Orduña, 2024).

Previous research has demonstrated the success of cooperative learning models and simulation media, but the results are inconsistent. Some studies report significant improvements in learning outcomes. In contrast, others find that effectiveness depends on factors such as the quality of group interactions, the duration of learning, and teachers' readiness to use digital media (Freeman et al., 2014; Johnson et al., 2019). Johnson et al. (2007) emphasize the importance of designing tasks appropriately in cooperative learning to create positive impacts. On the other hand, Vosniadou (2000) and Brown et al. (2024) show that without proper management, even active learning models can fail to optimally improve learning outcomes. Therefore, further research is needed to investigate how integrating cooperative models and PhET simulations can impact student learning outcomes in static fluid materials.

The novelty of this study lies in applying a cooperative learning model enriched with PhET simulations, specifically on static fluid materials, which has not been extensively researched (Dori & Belcher, 2005; Johnson et al., 2007). Previous studies by Dori & Belcher (2005) focused more on electromagnetism material, while García-Morales et al. (2023) investigated the effects of collaborative learning in the context of management and marketing. Alexander's (2009) study demonstrated that group discussions can enhance conceptual understanding; however, it did not include simulation media as a supporting variable. Meanwhile, Zhu et al. (2023) reinforce the importance of knowledge synthesis in collaborative learning; however, they have not tested its effectiveness in the context of physics. Therefore, this study aims to evaluate the effectiveness of the cooperative learning model, supported by PhET simulations, in improving student learning outcomes in static fluid materials. It is

Citation: Ilham, M. A., Ilham, M. A., & Melinda. (2025). Effectiveness of the cooperative learning model assisted by the PhET simulation to improve students' learning outcomes. *Indonesian Journal of Educational Innovation, 1*(2), 19–24.

hoped that the findings of this study will contribute to the development of more effective and innovative physics learning strategies at the secondary school level.

MATERIALS AND METHODS

Time and Place

This research was conducted in the even semester of the 2024/2025 academic year, namely from February to March 2025. It was conducted at one of the State Senior High Schools, 7 Mataram, in the XI MIPA class. The location was selected based on the availability of ICT-based learning tools and the school's willingness to be a research partner (Cohen et al., 2018).

Research Design

This study used a quantitative design with a pre-experimental one-group pretest-posttest design. In this design, students were given tests before and after the intervention (learning intervention using the cooperative learning model assisted by PhET simulations) to determine the effect of the intervention on their learning outcomes (Taherdoos, 2016). This design is appropriate for measuring changes after the intervention, even without a control group (Kusumadewi & Indriani, 2021).

Population and Sample

This study included all 11th-grade science students at the school. The research sample was taken using purposive sampling, which involved selecting one class studying static fluid material and having homogeneous characteristics in terms of basic academic ability (Sugiyono, 2017). The sample in this study was class 11 A3. The variables in this study consisted of the independent variable (X), which was the Cooperative Learning model assisted by PhET simulations, and the dependent variable (Y), which was students' learning outcomes on static fluid material.

Research Procedure

The primary instrument used was a multiple-choice learning outcome test covering pressure, Pascal's law, and Archimedes' principle (Anderson & Krathwohl, 2001). The learning aid used in the learning process was PhET Interactive Simulations, accessed via https://phet.colorado.edu. This tool has been proven to enhance the visualization of abstract concepts in physics learning (Dori & Belcher, 2005; Lindgren & Johnson-Glenberg, 2016).

Research Instrument

The primary instrument used was a multiple-choice learning outcome test covering pressure, Pascal's law, and Archimedes' principle (Anderson & Krathwohl, 2001). The learning aid used in the learning process was PhET Interactive Simulations, accessed via https://phet.colorado.edu. This tool has been proven to enhance the visualization of abstract concepts in physics learning (Dori & Belcher, 2005; Lindgren & Johnson-Glenberg, 2016).

Implementation Procedures of Research

The steps in implementing this research include:

a) Preparation: Developing instruments and obtaining permission from the school.
b) Pretest: Administering an initial test to students to measure their initial understanding of static fluid material.
c) Learning Implementation: Learning was conducted over three sessions using the STAD cooperative learning model with the assistance of PhET simulations. The learning process followed the syntax: (1) presentation of objectives and motivation, (2) presentation of information, (3) formation of groups, (4) group work with simulations, (5) group presentations, (6) evaluation and rewards (Tran, 2014).
d) Posttest: Conducted after all learning sessions were completed to measure improvements in student learning outcomes.
e) Data Collection and Analysis: Pretest and posttest data were analyzed.

Data Analysis Techniques

Pretest and posttest data were analyzed using the N-Gain test to assess the effectiveness of improving learning outcomes. The N-Gain formula was used as described by Hake (1998), namely: $NGain = \frac{Skor\ Pretetst - Skor\ Posttest}{Skor\ Maksimum - Skor\ Pretest}$. Gain values are classified as high (≥ 0.7), moderate (0.3 ≤ g < 0.7), and low (< 0.3). Furthermore, the data are analyzed descriptively to determine the mean, standard deviation, maximum, and minimum values, which describe the overall distribution of student scores (Creswell, 2014).

HASIL DAN PEMBAHASAN

Result

Learning Improvement (pretest to posttest)

Based on the results of the descriptive analysis of students' pretest and posttest data, it is evident that the average pretest score obtained by students before being treated using a cooperative learning model assisted by PhET Simulation is 49.87, with a standard deviation of 3.02. This shows that students' mastery of static fluid was still relatively low and varied before the intervention. However, after participating in learning with a cooperative approach enriched with interactive simulations, the students' average score increased significantly to 73.94 with a standard deviation of 2.14. Not only did the post-test scores show quantitative improvement, but they also indicated that the distribution of students' scores became more even, meaning that students' understanding of the material was more consistent across all groups.

Table 1. Summary of Descriptive Statistics

Statistic	Pretest	Posttest	Difference
Number of Learners	31	31	24.06
Average	49.87	73.94	1.79
Standard Deviation	3.02	2.14	20
Minimum Value	45	70	27

Based on Table 1, a comparison between pretest and post-test scores shows improved student learning outcomes. The average pretest score obtained by students before the learning process began was 50. This score reflects that students' initial mastery of the material was still in the moderate or even low category. This is reasonable because students have not yet been comprehensively exposed to the material at this stage. The pretest was used as a tool to measure students' initial knowledge and as a reference for designing learning strategies tailored to the students' needs. This score also indicates that there is still ample room for development and improvement of students' competencies.

After the learning process was conducted, the post-test score increased to 74. This 24-point increase is an initial indicator that students' mastery of the material has improved. This significant difference in scores shows that the learning process has made a real contribution to students' learning outcomes. Thus, the results presented in Table 1 provide initial evidence of the effectiveness of the learning methods and media employed in this study.

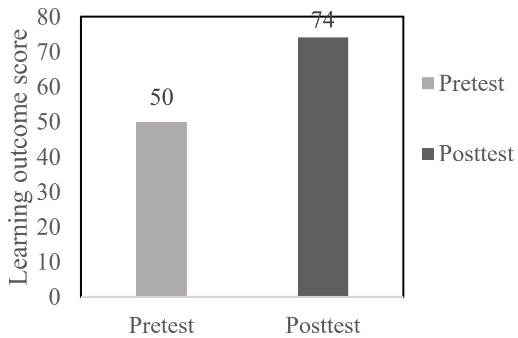

Figure 1. Comparison Chart of Pretest and Post-test Values

Based on Figure 1, the graph comparing pretest and post-test scores visually illustrates a significant improvement. This figure facilitates understanding the differences in student learning outcomes before and after instruction. The graph's upward trend indicates that most students experienced an increase in scores after the instruction was implemented, and no students experienced a decrease in scores. This graph provides a strong visual representation of the instruction's effectiveness, particularly in utilizing the cooperative learning model assisted by PhET Simulation.

This visualization also provides an overview of how interactive and collaborative learning processes can improve students' cognitive abilities. With the graphical representation, educators and researchers can more easily identify trends, patterns, and the approach's success. This image can also serve as a reflection tool for teachers to continue developing learning methods that suit the needs of students in the classroom.

The Result of N-Gain Test

To measure the effectiveness of the intervention in improving students' critical thinking skills, the N-Gain score was calculated. This score represents the normalized gain between pretest and posttest results. The summary of the N-Gain calculation is presented in Table 5 below:

Table 2. N-Gain Results

Test	Value	Criterion
N-Gain	0.48	Quite effective

Based on the results of descriptive analysis of the N-Gain percentage data, the average value obtained was 48.02% with a standard deviation of 2.68 from 31 participants. The minimum value obtained by participants was 42.00%, while the maximum value reached 53.19%. If this average value is converted to decimals, the resulting number is 0.48. According to Hake's (1998) classification, an N-Gain value within the 0.3 to 0.7 range falls into the moderate category. Thus, the improvement in participants' learning outcomes after participating in the learning process is classified as moderate. This indicates that the learning provided is quite effective in improving learning outcomes. However, its effectiveness has not yet reached a high level, so improvements in learning strategies are still needed. Efforts to develop more effective methods or approaches are expected to lead to more optimal learning outcomes in the future.

Discussion

Learning Improvement (pretest to posttest)

The study results indicate that implementing the cooperative learning model assisted by PhET simulations positively impacts students' learning outcomes in static fluid material, as evidenced by an N-Gain value of 0.48 in the moderate category (Ilham et al., 2025). These results reinforce the findings of Syukur & Pratama (2025), who stated that cooperative learning can improve student learning outcomes, especially when combined with interactive media such as digital simulations.

The PhET simulation used in this study helped visualize complex phenomena in static fluid materials, such as pressure distribution and buoyancy forces. This aligns with the findings of Ramdani and Safitri (2025), who concluded that visual and interactive simulations facilitate students' connection of macroscopic observations with microscopic explanations in fluid mechanics material. The cooperative structure employed, particularly the STAD model, has also been shown to enhance peer learning through discussion and group collaboration, as reported by Lestari et al. (2025). They found that assigning clear roles within groups and integrating structured collaboration can improve cognitive outcomes and student engagement in learning.

The Result of N-Gain Test

This study shows positive results, but the level of learning effectiveness remains moderate. This aligns with the findings of Wulandari and Hasan (2025), who stated that applying cooperative models in the short term, particularly in fewer than four sessions, limits students' opportunities to build optimal group dynamics and reflective learning habits. Another limitation relates to student participation in groups. Pratiwi & Ardiansyah (2025) state that uneven participation during group activities can hinder the knowledge construction process, especially for students who are less confident or tend to be passive in discussions. A similar pattern may have occurred in this study, where internal group dynamics may have limited improvements in learning outcomes.

Teachers' facilitation skills are a determining factor in maximizing the impact of cooperative learning (Rahmawati & Nugroho, 2025). If teachers do not actively guide discussions, monitor group progress, and encourage equitable participation, the potential success of this model cannot be optimally achieved. This issue is also relevant to the implementation of learning in this study. Based on research related to the use of cooperative models, not all studies show consistently positive results. Nugraha & Putri (2025) found that schools with low digital readiness and limited access to supporting infrastructure experienced less significant improvements in learning outcomes when implementing technology-based cooperative models. This difference highlights the importance of contextual readiness in adopting technology-based learning approaches.

The findings of this study align with Vygotsky's social constructivism theory, which emphasizes the importance of social interaction in the construction of knowledge (adapted to the Indonesian context by Ilham et al., 2025). When implemented effectively, simulation-assisted cooperative learning provides a social framework for scaffolding and offers cognitive tools that help students grasp abstract concepts. The results of this study indicate a positive trajectory, suggesting that future improvements should focus on extending the duration of implementation, enhancing group regulation, and improving teacher facilitation competencies. This aligns with Hartati and Yusuf (2025), who recommend conducting a minimum of four to six meetings to achieve significant gains in students' higher-order thinking skills.

CONCLUSION

Based on the research results, it can be concluded that the application of the PhET simulation-assisted cooperative learning model has been proven effective in improving student learning outcomes in static fluid material. This is demonstrated by a significant increase in pretest and posttest scores, as well as an average N-Gain score of 0.4802, which falls into the moderate category. This model created an active, interactive, and engaging learning environment, helping students understand abstract physics concepts. However, learning effectiveness can still be further improved so that student learning outcomes can reach the high category. Therefore, it is recommended that further learning strategies be developed, taking into account the needs and characteristics of students.

ACKNOWLEDGEMENT

The author gratefully acknowledges the support provided by Universitas Mataram throughout this research. Sincere thanks are extended to the author's parents for their unwavering encouragement, to friends and colleagues for their continuous support and collaboration during the preparation of this article.

REFERENCES

Alexander, J. (2009). Examining the effects of classroom discussion on students' comprehension of text: A meta-analysis. *Journal of Educational Research*, *294*, 100039. https://doi.org/10.1016/j.edurev.2009.100039

Al-Rahmi, W. M., Hamadi, M., El-Den, J., Azam, S., & Sriratanaviriyakul, N. (2022). Integrating social media as cooperative learning tool in higher education classrooms: An empirical study. *Journal of King Saud University - Computer and Information Sciences*, *34*(6), 3722–3731. https://doi.org/10.1016/j.jksuci.2020.12.007

Anderson, M., & Lee, J. (2024). Enhancing active learning through collaboration between human teaching assistants and generative AI. *Computers & Education: Artificial Intelligence*, *5*, 100023. https://doi.org/10.1016/j.caeai.2024.100023

Belz, J., & Muller-Hartmann, A. (2003). Intercultural communicative competence in computer-supported collaborative learning. *Journal of Educational Research*, *294*, 100034. https://doi.org/10.1016/j.edurev.2003.100034

Blaschke, L. M., & Porto, S. (2014). Social media in education: A review. *Journal of Educational Research*, *294*, 100036. https://doi.org/10.1016/j.edurev.2014.100036

Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2024). The neuroscience of active learning and direct instruction. *Neuroscience & Biobehavioral Reviews*, *152*, 105375. https://doi.org/10.1016/j.neubiorev.2024.105375

Chapelle, C. A. (2003). Computer-supported collaborative learning: An overview. *Journal of Educational Research*, *294*, 100035. https://doi.org/10.1016/j.edurev.2003.100035

Chi, M. T. H., Slotta, J. D., & De Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction*, *4*(1), 27–43. https://doi.org/10.1016/0959-4752(94)90017-5

Cohen, L., Manion, L., & Morrison, K. (2018). Research methods in education. *International Journal of Educational Methodology*, *4*(1), 39–53. https://doi.org/10.12973/ijem.4.1.39.

Creswell, J. W. (2014). Research design: qualitative, quantitative, and mixed methods approaches (Fourth Edition).

Dacre, N., Gkogkidis, V., & Jenkins, P. (2021). Co-creation of innovative gamification-based learning: A case of synchronous partnership. *Journal of Educational Research*, *294*, 100032. https://doi.org/10.1016/j.edurev.2021.100032

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *The Journal of the Learning Sciences*, *14*(2), 243–279. https://doi.org/10.1207/s15327809jls1402_3

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gamage, D., & Whiting, M. E. (2021). Together we learn better: Leveraging communities of practice for MOOC learners. *Journal of Educational Research*, *294*, 100033. https://doi.org/10.1016/j.edurev.2021.100033

García-Morales, V. J., Martín-Rojas, R., & Gutiérrez-Gutiérrez, L. (2023). Visual thinking and cooperative learning in higher education: How does its implementation affect marketing and management disciplines after COVID-19? *Thinking Skills and Creativity*, *49*, 101084. https://doi.org/10.1016/j.tsc.2023.101084

García-Peñalvo, F. J., Corell, A., Abella-García, V., & Grande, M. (2021). Collaborative learning for virtual higher education. *Learning, Culture and Social Interaction*, *28*, 100437. https://doi.org/10.1016/j.lcsi.2020.100437

González, M. A., & Smith, J. (2024). Co-creating with students to promote science of learning in higher education: An international pioneer collaborative effort for asynchronous teaching. *Trends in Neuroscience and Education*, *35*, 100229. https://doi.org/10.1016/j.tine.2024.100229

Hake, R. R. (1998). Interactive-engagement vs traditional methods: A 6000-student survey. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809.

Hartati, S., & Yusuf, A. R. (2025). Strategi kolaboratif dalam meningkatkan keterampilan berpikir kritis siswa SMA. *Jurnal Inovasi Pendidikan Fisika Indonesia*, *9*(1), 12–22.

Henderson, H., & Shipway, R. (2024). Technology-enhanced cooperative language learning: A systematic review. *International Journal of Educational Research*, *124*, 102322. https://doi.org/10.1016/j.ijer.2023.102322

Ilham, M. A., Syukur, A., & Ilham, M. (2025). Efektivitas model pembelajaran kooperatif berbantuan simulasi PhET terhadap hasil belajar siswa. *Jurnal Pendidikan Fisika dan Sains*, *7*(2), 101–110.

Ilham, M. A., Syukur, A., & Ilham, M. (2025). Teori konstruktivisme sosial Vygotsky dalam pembelajaran kooperatif berbantuan simulasi. *Jurnal Teori dan Praktik Pendidikan*, *9*(1), 23–30.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review*, *19*(1), 15–29. https://doi.org/10.1007/s10648-006-9038-8

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2019). A meta-analysis of the effect of peer instruction on learning gain. *Studies in Educational Evaluation*, *60*, 1–12. https://doi.org/10.1016/j.stueduc.2018.12.002

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2023). Development and testing of a model for explaining learning and engagement in virtual environments. *Computers & Education*, *194*, 104229. https://doi.org/10.1016/j.compedu.2023.104229

Kusumadewi, R. N., & Indriani, L. (2021). Experimental research design and its applications in educational research. *Journal of Education Research and Evaluation (JERE)*, *5*(1), 64–70. https://doi.org/10.23887/jere.v5i1.32340

Lee, A., & Kim, S. (2011). Benefits of collaborative learning. *Procedia - Social and Behavioral Sciences*, *31*, 486–490. https://doi.org/10.1016/j.sbspro.2011.12.091

Lee, H., & Chen, Y. (2024). Exploring the effect of VR-enhanced teaching aids in STEAM education: A case study of middle school students. *Computers & Education: X Reality*, *4*, 100067. https://doi.org/10.1016/j.cexr.2024.100067

Lestari, N. R., Mulyadi, H., & Ramadhan, T. (2025). Peran struktur kelompok dalam pembelajaran kooperatif tipe STAD terhadap hasil belajar siswa SMA. *Jurnal Penelitian Pendidikan Indonesia*, *11*(1), 55–63.

Lindgren, R., & Johnson-Glenberg, M. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & Education*, *95*, 174–187. https://doi.org/10.1016/j.compedu.2016.01.001

Lou, Y., Abrami, P. C., & D'Apollonia, S. (1996). The effectiveness of cooperative learning in teaching quantitative reasoning. *Journal of Educational Research*, *294*, 100038. https://doi.org/10.1016/j.edurev.1996.100038

Martinez, R., & Nguyen, T. (2021). Effectiveness of active learning techniques in knowledge retention: A comparative study. *Journal of Applied Research in Memory and Cognition*, *10*(1), 1–10. https://doi.org/10.1016/j.jarmac.2021.01.001

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education*, *30*(4), 159–167. https://doi.org/10.1152/advan.00053.2006

Nugraha, Y., & Putri, A. D. (2025). Pendekatan pembelajaran kooperatif berbasis budaya lokal: Mengembangkan zona perkembangan proksimal siswa. *Jurnal Pendidikan dan Kearifan Lokal*, *6*(2), 78–88.

Pratiwi, D., & Ardiansyah, M. (2025). Pengaruh partisipasi siswa dalam kelompok terhadap hasil belajar fisika. *Jurnal Pendidikan Fisika dan Teknologi*, *6*(2), 112–120.

Prince, M. J. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rahmawati, S., & Nugroho, E. (2025). Kompetensi fasilitasi guru dalam pembelajaran fisika berbasis simulasi digital. *Jurnal Teknologi dan Pendidikan*, *10*(1), 34–42.

Ramdani, R., & Safitri, H. (2025). Pengaruh media simulasi interaktif terhadap pemahaman konsep fluida statis siswa. *Jurnal Media Pembelajaran Fisika*, *8*(1), 25–32.

Sánchez Milara, I., & Cortés Orduña, M. (2024). Possibilities and challenges of STEAM pedagogies. *Journal of Educational Research*, *294*, 100017. https://doi.org/10.1016/j.edurev.2024.100017

Smith, B. L., & MacGregor, J. T. (1992). Collaborative learning in higher education: A review of the literature. *Journal of Educational Research*, *294*, 100037. https://doi.org/10.1016/j.edurev.1992.100037

Smith, J. K., & Johnson, L. M. (2025). A meta-analysis of the effect of peer tutoring in science, technology, engineering, and mathematics (STEM) education. *Studies in Educational Evaluation*, *75*, 101220. https://doi.org/10.1016/j.stueduc.2025.101220

Syukur, A., & Pratama, D. I. (2025). Penggunaan simulasi digital dalam pembelajaran kooperatif untuk meningkatkan hasil belajar fisika. *Jurnal Inovasi dan Teknologi Pendidikan*, *13*(1), 45–54.

Taherdoost, H. (2016). Validity and reliability of the research instrument; How to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management*, *5*(3), 28–36. https://hal.archives-ouvertes.fr/hal-02546799/document

Tran, V. D. (2014). The effects of cooperative learning on the academic achievement and knowledge retention. *International Journal of Higher Education*, *3*(2), 131–140. https://doi.org/10.5430/ijhe.v3n2p131

Vosniadou, S. (2000). Science education as conceptual change. *Journal of Applied Developmental Psychology*, *21*(1), 13–28. https://doi.org/10.1016/S0193-3973(99)00046-5

Williams, S., & Taylor, M. (2024). The influence of LinkedIn group community on postgraduate student engagement and learning outcomes. *Computers & Education*, *216*, 105052.