Mitra Mahajana: Jurnal Pengabdian Masyarakat 2(1), 2021, 286-293
ISSN 2747-1861 (print), ISSN 2747-187X (online)
https://doi.org/10.37478/mahajana.v7i2.8040 **mahajana@uniflor.ac.id**
Available online at: https://e-journal.uniflor.ac.id/index.php/mahajana/8040

COMMUNITY SERVICE ACTIVITIES USING EXPERIMENTAL SIMULATIONS AND PHYSICS LEARNING MEDIA

Angelina Rahma*, Maria Lidya Tanggo, Dominika Owa, Yasinta Embu Ika, Aloisius Harso, Melkyanus Bili Umbu Kaleka
Flores University, Ende, Flores, East Nusa Tenggara, Indonesia
*Corresponding Author, email: angelyrahma890@gmail.com

Received: 21/05/2026 *Revised: 19/06/2026* *Accepted: 20/06/2026*

Abstract*. Physics learning at SMA Negeri 1 Riung Barat faces real obstacles in the form of limited laboratory facilities and a lack of practical tools, so the learning process tends to be theoretical and makes it difficult for students to understand abstract concepts. This community service activity aims to improve the quality of physics learning using experimental simulations and innovative teaching aids, improving conceptual understanding, experimental skills, and fostering student learning motivation. The activity was carried out on May 23, 2026, targeting students in grades X, XI, and XII, and physics teachers. The implementation method included a preparation stage (survey and coordination), followed by socialization and interactive demonstrations of various alternative media such as static electricity teaching aids, hydraulic pumps, and rigid body equilibrium. After the demonstration, students carried out direct practice in small groups with the guidance of the community service team and teachers. Evaluation was carried out through observation of involvement and distribution of participant response questionnaires. The results of the activity showed an increase in students' conceptual understanding and experimental skills. The performance evaluation recorded an increase in the ability to use teaching aids from the "Low" to "Good" category, and observation and measurement skills increased from the "Fair" to "Good" category. In addition, the level of student activity jumped from the "Medium" to the "High" category. Ninety-two per cent of participants expressed great satisfaction with the program. As a form of sustainability, the program produced outputs in the form of simple experiment modules, video documentation for dissemination, and a guide to using teaching aids to support teachers in independently implementing lab-based learning.*

Keywords: *experiment simulation, physics learning, science skills, teaching aids*

Abstrak. Pembelajaran fisika di SMA Negeri 1 Riung Barat menghadapi kendala nyata berupa keterbatasan fasilitas laboratorium dan minimnya alat praktikum, sehingga proses pembelajaran cenderung teoretis dan membuat siswa kesulitan memahami konsep abstrak. Kegiatan pengabdian kepada masyarakat ini bertujuan untuk meningkatkan kualitas pembelajaran fisika melalui pemanfaatan simulasi eksperimen dan alat peraga inovatif, meningkatkan pemahaman konsep, keterampilan eksperimen, serta menumbuhkan motivasi belajar siswa. Kegiatan dilaksanakan pada 23 Mei 2026 dengan sasaran siswa kelas X, XI, XII, dan guru fisika. Metode pelaksanaan meliputi tahap persiapan (survei dan koordinasi), dilanjutkan dengan sosialisasi serta demonstrasi interaktif berbagai media alternatif seperti alat peraga listrik statis, pompa hidrolik, hingga kesetimbangan benda tegar. Setelah demonstrasi, siswa melakukan praktik langsung dalam kelompok kecil dengan pendampingan tim pengabdian dan guru. Evaluasi dilakukan melalui observasi keterlibatan serta penyebaran angket respons peserta. Hasil kegiatan menunjukkan adanya peningkatan pemahaman konsep dan keterampilan eksperimen siswa. Evaluasi performa mencatat kemampuan menggunakan alat peraga meningkat dari kategori "Rendah" menjadi "Baik", serta keterampilan pengamatan dan pengukuran naik dari kategori "Cukup" menjadi "Baik". Selain itu, tingkat keaktifan siswa melonjak dari kategori "Sedang" menjadi "Tinggi". Sebanyak 92% peserta menyatakan sangat puas terhadap program ini. Sebagai wujud keberlanjutan, kegiatan ini menghasilkan luaran berupa modul eksperimen sederhana, video dokumentasi diseminasi, dan panduan penggunaan alat peraga untuk mendukung guru dalam mengimplementasikan pembelajaran berbasis praktikum secara mandiri.

Kata Kunci: alat peraga, keterampilan sains, pembelajaran fisika, simulasi eksperimen

How to Cite: Rahma, A., Tanggo, M. L., Owa, D., Ika, Y. E., Harso, A., & Kaleka, M. B. U. (2026). COMMUNITY SERVICE ACTIVITIES USING EXPERIMENTAL SIMULATIONS AND PHYSICS LEARNING MEDIA. *Mitra Mahajana: Jurnal Pengabdian Masyarakat, 7*(2) 286-293. doi: https://doi.org/10.37478/mahajana.v7i2.8040

INTRODUCTION

Physics education fundamentally requires students to engage in laboratory activities, as physics concepts can be understood more effectively through direct observation and experimental investigation (Mirna & Annisa, 2025; Silitonga et al., 2025). Experimental activities are essential in enabling students to relate theoretical knowledge to real-world

Copyright (c) 2026 Angelina Rahma, Maria Lidya Tanggo, Dominika Owa, Yasinta Embu Ika, Aloisius Harso, Melkyanus Bili Umbu Kaleka. This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

phenomena, foster scientific process skills, and improve their critical thinking and problem-solving capabilities (Maulana & Mutmainah, 2025). However, physics learning at SMA Negeri 1 Riung Barat still faces several challenges, particularly the limited laboratory facilities and the insufficient availability of practical equipment. As a result, laboratory activities cannot be optimally implemented across all learning topics. Consequently, the learning process remains largely focused on theoretical instruction, which may lead students to experience difficulties in understanding abstract physics concepts (Bouchée et al., 2022). To address this issue, the use of experimental simulations and simple physics teaching aids offers a promising alternative, as they can help visualize physical phenomena, enhance student engagement in the learning process, and provide more meaningful learning experiences despite the limited resources available at the school.

The primary challenge faced by SMA Negeri 1 Riung Barat in physics education is the limited availability of laboratory facilities and practical equipment to support experimental activities. This condition results in a low frequency of laboratory practice, providing students with limited opportunities to directly observe and verify physics concepts through experimentation. Consequently, many students experience difficulties in understanding abstract physics concepts, such as force, motion, energy, waves, and electricity, because instruction is predominantly delivered through theoretical explanations rather than hands-on experiences. In addition, the utilization of alternative learning media to support experimental activities has not been fully optimized due to the limited skills and experience of teachers in using experimental simulations and simple teaching aids as instructional tools. This situation affects the effectiveness of physics learning and highlights the need for assistance programs aimed at promoting more interactive, contextual, and experiential learning environments.

As an effort to address the various challenges faced by the partner school, this community service program offers a solution through the implementation of physics experiment simulations that enable students to observe and understand various physical phenomena interactively, despite the limitations of laboratory facilities. The program is also complemented by demonstrations of physics teaching aids to help visualize abstract concepts, making them easier for students to comprehend. Furthermore, students will receive guidance in conducting simple experiments using readily available materials and equipment, allowing them to develop scientific process skills through direct learning experiences. To ensure the sustainability of the program, teachers will also be provided with training on the use of experimental simulations and physics teaching aids as experiment-based instructional media. This training is expected to enable teachers to independently implement these learning approaches in physics classes and continuously improve the quality of physics education at the school.

Physics learning involves the development of conceptual understanding through systematic observation, experimental activities, and scientific validation of physical phenomena (Widiarini et al., 2024). According to constructivist theory, learning becomes more meaningful when students actively build their own understanding through direct and authentic experiences (Azzahra et al., 2025; Syuaib et al., 2026). Within the context of physics learning, practical and experimental activities play a crucial role in linking theoretical concepts to observable phenomena, thereby helping students develop a more concrete understanding of abstract physics concepts (Firdausiah et al., 2025). However, limited laboratory facilities often become a major obstacle to the implementation of experiment-based learning (Mardiana & Usman, 2025). Therefore, experimental simulations and physics teaching aids can be utilized as effective alternative learning media to visualize physics concepts, enhance students' scientific process skills, and foster their motivation and active participation in learning (Hadi Imam Sutaji et al., 2025). Furthermore, the use of such media enables students to gain interactive and contextual learning experiences despite the limitations of available resources and facilities (Kalalo & Raprap, 2026).

Various previous studies and community service activities have shown that the use of experimental simulations and physics teaching aids can improve the quality of science learning (Susilo, 2020; Daruwati et al., 2024). The findings indicate that experiment-based learning can enhance conceptual understanding, scientific process skills, critical thinking abilities, and

students' learning motivation compared to instruction that is solely focused on theoretical explanation (Barokah et al., 2022). In addition, the use of simple teaching aids and interactive simulations has been proven effective in helping students understand abstract physics concepts, particularly in schools with limited laboratory facilities (Ahmad et al., 2024). These findings are in line with the results of community service activities at SMA Negeri 1 Riung Barat, which showed improvements in students' ability to use teaching aids, observational and measurement skills, learning activeness, as well as a high level of participant satisfaction with experiment-based learning (Mitrakas et al., 2024). Thus, experimental simulations and physics teaching aids can serve as an innovative and sustainable solution to support more effective and meaningful physics learning.

This community service program aims to improve the quality of physics learning at SMA Negeri 1 Riung Barat using experimental simulations and physics teaching aids as innovative learning media. Specifically, this program is designed to enhance students' understanding of physics concepts by providing more concrete and contextual learning experiences, as well as to improve students' experimental skills through direct involvement in observation, measurement, and analysis of physical phenomena. In addition, this program aims to introduce the use of physics teaching aids as an effective alternative learning medium for explaining abstract concepts in the context of limited laboratory facilities. Through various interactive and practice-based activities, the program is also expected to foster students' interest, motivation, and enthusiasm for physics learning, thereby encouraging them to become more active and confident in studying science.

METHOD

This community service activity was conducted at SMA Negeri 1 Riung Barat on May 23, 2026, with the main targets being students of grades X, XI, and XII, as well as physics teachers. The method used in this program was a participatory training method based on demonstration and experimental practice (Sumiati Side). This method was implemented through four main stages: (1) preparation, which included a needs assessment survey, coordination, and the development of learning media; (2) socialization and demonstration, involving the delivery of materials as well as demonstrations of experimental simulations and physics teaching aids; (3) practice and mentoring, in which participants conducted hands-on experiments in groups under the guidance of the community service team; and (4) evaluation, through observation of participant engagement and the distribution of response questionnaires to assess the effectiveness of the activity. The program was designed to provide a more interactive learning experience using experimental simulations and physics teaching aids. Before implementation, the community service team carried out a preparation phase, which included a school needs survey to identify the conditions of physics learning and the availability of supporting facilities, coordination with the school regarding the implementation of the program, and the development of instructional materials, experimental simulations, and teaching aids to be used during the activity. This preparation phase aimed to ensure that the implemented activities were aligned with the needs and conditions of the partner school.

At the implementation stage, the activity began with a socialization session on the importance of experiments in physics learning and the benefits of practice-based learning in improving students' understanding of science concepts. Subsequently, participants were introduced to various experimental simulations and physics teaching aids that illustrate physics concepts in everyday life. The simulations and demonstrations presented included vinegar acid reactions, periscopes, electrostatic concepts, cradle oscillations, hydraulic pumps, balloon cars, fans, projectile motion, magnifying glasses, dispensers, equilibrium of rigid bodies, and simple spray devices. Each demonstration was accompanied by an explanation of the underlying physics principles so that students could connect the theoretical concepts learned in class with the real phenomena observed directly.

After the demonstration activities, students were divided into several groups to carry out hands-on practice and direct observation using the teaching aids provided. In this activity,

students were guided by the community service team and teachers to conduct simple experiments, observe experimental results, and discuss the physics concepts emerging from each demonstration (Girwidz et al., 2022). The evaluation stage was conducted through the distribution of participant response questionnaires and observation of student engagement during the activity to determine the level of enthusiasm, understanding, and perceived benefits of the program (Kassab et al., 2023). The data collected were analyzed descriptively to describe participants' responses to the activity, while documentation in the form of photographs and activity notes served as evidence of implementation and as reflection material for the development of similar programs in the future.

RESULT AND DISCUSSION

The implementation of the community service activity at SMA Negeri 1 Riung Barat on May 23, 2026, proceeded very well and successfully achieved the planned objectives. In the initial stage, the socialization on the importance of experimental methods in science learning was able to broaden the perspectives of both students and teachers regarding the importance of linking classroom theory with real-world phenomena. The introduction of various alternative learning media, such as vinegar acid reaction simulations, periscopes, electrostatic concepts, cradle oscillations, hydraulic pumps, and rigid body equilibrium, became the main attraction for the students. All demonstrations were presented by connecting fundamental physics principles with the use of simple materials and equipment that are easily found in the surrounding environment (Bechinger et al., 2016). This interactive approach proved effective in stimulating students' critical thinking through dynamic question-and-answer sessions from the beginning of the activity.



Figure 1. *Opening of the activity and delivery of materials*

The results of the activity indicated an improvement in students' understanding of physics concepts after participating in the community service program. This improvement demonstrates that the use of experimental simulations and teaching aids can help students understand physics concepts that were previously considered abstract (Banda & Nzabahimana, 2021). In addition, students' experimental skills developed, as reflected in their ability to use teaching aids, observe physical phenomena, conduct simple measurements, and explain the relationship between theory and observational results (Roth & Roychoudhury, 1993). Throughout the activity, students actively participated in group discussions and practical sessions, indicating increased engagement in the learning process (Sartania et al., 2022).

Participants' responses to the activity were also highly positive. Based on the questionnaire distributed at the end of the program, most participants stated that the activity was interesting, easy to understand, and helpful in improving their understanding of physics concepts. Students' enthusiasm was evident from their high level of involvement in question-and-answer sessions, group discussions, and hands-on practice using the teaching aids. In addition to improving students' understanding and skills, this activity also produced several outputs, including a simple experimental module that can be used in physics learning, activity documentation videos as dissemination media, and a user guide for the teaching aids that can

support teachers in implementing physics learning sustainably in schools. The evaluation results are presented in Table 1 below:

Table 1. *Evaluation results of the community service activity*

Evaluated Aspect	Before the Activity	After the Activity	Description
Ability to use teaching aids	low	good	improved
Observation and measurement skills	fair	good	improved
Participants' satisfaction with the activity	–	92% very satisfied	very positive
Student activeness in learning	moderate	high	improved

The utilization of experimental simulations and teaching aids has had a significant impact on improving students' cognitive aspects and science process skills. These findings are consistent with the study conducted by Sumiati Side et al., which found that such approaches are effective in developing students' analytical, interpretative, and representational abilities toward chemical experimental data, and have the potential to be integrated into laboratory activities to strengthen digital science literacy competencies in higher education (Side et al., 2025). Based on the evaluation results, students' ability to use teaching aids showed a noticeable improvement, from the category of "Low" before the activity to "Good" after the activity. This progress was clearly observed when students were divided into small groups to directly practice the use of teaching aids independently under the guidance of the community service team and physics teachers. Through this hands-on involvement, students were not merely passive listeners but active participants who tried, observed, and recorded experimental data. Their motor skills and accuracy in conducting observations and simple measurements also improved, from the category of "Fair" to "Good".



Figure 2. *Vinegar and baking soda simulation (left) and electrostatic simulation (right)*

The presence of these alternative learning media has also been proven effective in overcoming students' psychological barriers, as physics has often been perceived as a difficult and monotonous subject due to its predominantly theoretical instruction (Maharani et al., 2024). By introducing more interactive and experience-based learning approaches, students are gradually able to shift their perception of physics from an abstract and challenging subject into a more engaging and meaningful field of study. The concrete visualization provided by teaching aids, such as hydraulic pumps for Pascal's law or simple pendulums for vibration concepts, has been shown to reduce the abstract nature of physics concepts and make them more accessible to students' cognitive understanding (Damayanti et al., 2015). This transformation from abstract to concrete representations plays a crucial role in strengthening conceptual comprehension, as students can directly observe the relationship between theoretical principles and real-world phenomena (Wu & Puntambekar, 2012).

As a result, this conceptual shift has directly contributed to a significant increase in students' learning motivation in the classroom. Students' activeness during the simulation and

experimental activities increased dramatically from the category of "Moderate" to "High." They appeared highly enthusiastic in group discussions, actively participated in formulating conclusions, and demonstrated greater confidence when presenting their experimental findings in front of the class (Al-Khresheh, 2024). Furthermore, students also showed improved collaboration skills and a stronger willingness to engage in inquiry-based learning processes throughout the activities (Rodríguez et al., 2019; Gillies, 2023).



Figure 3. *Hydraulic pump simulation (left) and simple pendulum simulation (right)*

The success of this community service program is further strengthened by the highly positive responses and outstanding levels of participant satisfaction. Based on the questionnaire data distributed at the end of the activity, 92% of participants stated that they were very satisfied with the implementation of the program. The students emphasized that the materials delivered became much more interesting and easier to understand due to the direct visualizations provided (Siregar, 2024). On the other hand, the sustainability impact of this activity also extends to teachers' professional competencies through the provision of outputs such as a simple experimental module, dissemination video documentation, and a teaching aid usage guide (Symeou et al., 2025). These supporting documents are expected to serve as stimuli for physics teachers at SMA Negeri 1 Riung Barat to independently and sustainably implement practice-based learning, even in the context of limited laboratory facilities.

CONCLUSION

The community service program using experimental simulations and physics teaching aids at SMA Negeri 1 Riung Barat successfully achieved its objectives, namely improving students' understanding of physics concepts, experimental skills, and interest in learning physics. The use of simulations and teaching aids proved effective in making abstract physics concepts more concrete and easier to understand. Evaluation results showed improvements in students' ability to use teaching aids, conduct observations and measurements, as well as increased learning activeness. The 92% participant satisfaction rate indicates that the learning activities were engaging, interactive, and meaningful. The program outputs, including a simple experimental module, documentation videos, and a teaching aid guide, are expected to support the sustainability of physics learning in schools. Therefore, the school is encouraged to continue developing experiment-based learning using simulations and simple teaching aids, while teachers are expected to utilize the provided outputs for more regular and independent practical activities. Continuous support from universities and educational stakeholders is also needed to improve the quality of physics learning despite limited laboratory facilities.

REFERENCES

Ahmad, L. S., Dian Utami, Tessa Zerina Naryamastri, Hari Anggito, & Prahmana, R. C. I. (2024). Dampak Pembelajaran Fisika Menggunakan Alat Peraga Venturimeter pada Materi Fluida Dinamis. *Jurnal Ilmiah Pendidikan Profesi Guru*, *7*(1), 222–234.

https://doi.org/10.23887/jippg.v7i1.69230

Azzahra, N. T., Ali, S. N. L., & Bakar, M. Y. A. (2025). Teori Konstruktivisme dalam Dunia Pembelajaran. *Jurnal Ilmiah Research Student*, *2*(2), 64–75. https://doi.org/10.61722/jirs.v2i2.4762

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. DOI: https://doi.org/10.1103/PhysRevPhysEducRes.17.023108

Barokah, A., Yulistia, A., & Hidayat, S. P. M. (2022). Penerapan Pendekatan Keterampilan Proses Sains Untuk Meningkatkan Pemahaman Konsep Siswa Pada Pembelajaran IPA SD. *Dikoda: Jurnal Pendidikan Sekolah Dasar*, *3*(01), 18–31. https://doi.org/10.37366/jpgsd.v3i01.1061

Bouchée, T., de Putter-Smits, L., Thurlings, M., & Pepin, B. (2022). Towards a better understanding of conceptual difficulties in introductory quantum physics courses. *Studies in Science Education*, *58*(2), 183-202. https://doi.org/10.1080/03057267.2021.1963579

Damayanti, H., Sutikno, & Mastur. (2015). Pembelajaran Hukum Pascal Menggunakan Miniatur Mesin Hidrolik untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Prosiding Seminar Nasional Fisika (E-Journal)*, *4*(2), 15–26. https://journal.unj.ac.id/unj/index.php/prosidingsnf/article/view/4793

Daruwati, I., Sasna Junaidi, N., Genesa Hatika, R., Asra, A., & Syahropi, H. (2024). Pendampingan Pembelajaran Fisika Menggunakan Alat Peraga Sederhana Di SMA Negeri 3 Rambah Hilir. *Mejuajua: Jurnal Pengabdian Pada Masyarakat*, *4*(2), 136–140. https://doi.org/10.52622/mejuajuajabdimas.v4i2.157

Firdausiah, F., Prayogo, M. S., & Prayustin, S. S. E. (2025). Penerapan Pembelajaran Eksperimen untuk Memahami Konsep Perubahan Wujud Benda pada Siswa Kelas V Sekolah Dasar. *Jurnal Bersama Ilmu Pendidikan*, *1*(4), 211–217. https://doi.org/10.55123/didik.v1i4.321

Gillies, R. M. (2023). Using cooperative learning to enhance students' learning and engagement during inquiry-based science. *Education Sciences*, *13*(12), 1242. https://doi.org/10.3390/educsci13121242

Girwidz, R., Theyßen, H., & Widenhorn, R. (2022). Experiments in physics teaching. In *Physics education* (pp. 269-296). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-87391-2_10

Hadi Imam Sutaji, Ali Warsito., & Bernandus. (2025). Konsep Fisika Dan PhET Simulation Sebagai Alternatif Media Pembelajarannya. *ALKHIDMAH: Jurnal Pengabdian Dan Kemitraan Masyarakat*, *3*(2), 69–76. https://doi.org/10.59246/alkhidmah.v3i2.1284

Kalalo, R. R., & Raprap, W. P. (2026). Peran Media Pembelajaran Digital terhadap Minat Belajar Mahasiswa di Era Teknologi. *JURAGAN: JURNAL RAGAM PENGABDIAN DAN PENELITIAN*, *6*(1), 1376–1383. https://doi.org/10.62710/pbs50r15

Kassab, S. E., Al-Eraky, M., El-Sayed, W., Hamdy, H., & Schmidt, H. (2023). Measurement of student engagement in health professions education: a review of literature. *BMC Medical Education*, *23*(1), 354. https://doi.org/10.1186/s12909-023-04344-8

Maharani, A. S., Nasuha, S. U., & Maulida, S. R. (2024). Media Pembelajaran sebagai Alternatif Meningkatkan Gairah Belajar. *Jurnal BIONATURAL*, *11*(1), 76–83. https://doi.org/10.61290/bio.v11i2

Mardiana, A., & Usman, S. (2025). Menganalisis Strategi-Strategi Pembelajaran Eksperimen. *SIPAKATAU: Jurnal Pendidikan Dan Kebudayaan*, *2*(4), 28–36. https://jurnal.staialgazalibone.ac.id/index.php/sipakatau/article/view/94

Maulana, F., & Mutmainah, S. (2025). Meningkatkan Pemahaman Konsep dan Keterampilan Proses Sains Melalui Metode Eksperimen dalam Pembelajaran Fisika. *Multidisciplinary Indonesian Center Journal (MICJO)*, *2*(1), 861–870. https://doi.org/10.62567/micjo.v2i1.560

Mirna, & Annisa, F. (2025). Analisis Keterampilan Proses Sains Peserta Didik Melalui Kegiatan Praktikum Pada Materi Fluida Statis Di Sman Unggul Pidie Jaya. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, *8*(1), 84–94.

https://doi.org/10.29103/relativitas.v8i1.21320

Mitrakas, N., Tsihouridis, C., & Vavougios, D. (2024). Using mixed reality in the educational practice: An inquiry-based process of the fluid expansion–contraction phenomena by pre-service teachers. *Education Sciences*, *14*(7), 754. https://doi.org/10.3390/educsci14070754

Rodríguez, G., Pérez, N., Núñez, G., Baños, J. E., & Carrió, M. (2019). Developing creative and research skills through an open and interprofessional inquiry-based learning course. *BMC medical education*, *19*(1), 134. https://doi.org/10.1186/s12909-019-1563-5

Roth, W. M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of research in science teaching*, *30*(2), 127-152. https://doi.org/10.1002/tea.3660300203

Sartania, N., Sneddon, S., Boyle, J. G., McQuarrie, E., & de Koning, H. P. (2022). Increasing collaborative discussion in case-based learning improves student engagement and knowledge acquisition. *Medical science educator*, *32*(5), 1055-1064. https://doi.org/10.1007/s40670-022-01614-w

Side, S., Djangi, J., Perdana, R., & Cahyani, V. P. (2025). Peningkatan Keterampilan Analisis dan Visualisasi Data Mahasiswa Kimia melalui Pelatihan Penggunaan Software Origin sebagai Upaya Penguatan Literasi Digital Sains. *Jurnal Pengabdian Pada Masyarakat*, *7*(1), 449–460. https://doi.org/10.30605/atjpm.v7i1.7423

Silitonga, S., Sitinjak, E. K., & Sigiro, M. (2025). Pengaruh Model Problem Based Learning Berbantuan Media Amrita Olabs Terhadap Minat Belajar. *JKIP : Jurnal Kajian Ilmu Pendidikan*, *6*(3), 1179–1189. https://doi.org/10.55583/jkip.v6i3.1585

Siregar, R. S. (2024). Students' Preferences for Varied Learning Methods: An Empirical Study of the Effectiveness and Appeal of Diverse Instructional Approaches. *Jurnal Profesi Guru Indonesia*, *1*(2), 140-152. DOI: https://doi.org/10.62945/jpgi.v1i2.679

Susilo, A. (2020). Penggunaan Metode Pembelajaran Eksperimen untuk Meningkatkan Hasil Belajar Fisika Materi Pengukuran Siswa. *Jurnal Ilmiah Pendidikan Profesi Guru*, *3*(3), 542. https://doi.org/10.23887/jippg.v3i3.29861

Symeou, L., Louca, L., Kavadella, A., Mackay, J., Danidou, Y., & Raffay, V. (2025). Development of Evidence-Based Guidelines for the Integration of Generative AI in University Education Through a Multidisciplinary, Consensus-Based Approach. *European Journal of Dental Education*, *29*(2), 285-303. https://doi.org/10.1111/eje.13069

Syuaib, M., Romadhon, M. R., & Zaironi, M. (2026). Teori Konstruktivistik dalam Pembelajaran PAI: YPI Al-Barokah Gondanglegi. *T S A Q O F A H: Jurnal Penelitian Guru Indonesia*, *6*(1), 1141–1153. https://doi.org/10.58578/tsaqofah.v6i1.8477

WIDIARINI, P., RAPI, N. K., SUASTRA, I. W., & SUMA, K. (2024). Studi Pendahuluan: Problematika Pembelajaran Fisika SMA. *SCIENCE : Jurnal Inovasi Pendidikan Matematika Dan IPA*, *5*(1), 131–143. https://doi.org/10.51878/science.v5i1.4430

Wu, H. K., & Puntambekar, S. (2012). Pedagogical affordances of multiple external representations in scientific processes. *Journal of Science Education and Technology*, *21*(6), 754-767. https://doi.org/10.1007/s10956-011-9363-7