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Physics At Home: A Solution to Improve Physics Learning Outcomes during the Covid-19 Pandemic

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Abstract

Physics learning during the COVID-19 pandemic has its challenges. One of them is decreasing student engagement which impacts learning outcomes. Therefore, a learning strategy is needed to overcome this problem. One is implementing a learning strategy that shows physics is a part of daily life. This research was conducted to determine how applying Physics at Home can improve learning outcomes. The design of this research is a quasi-experiment with one group pretest-posttest design. 36 Students of XII IPA 1 SMA Negeri 2 Bandar Lampung received a learning treatment called Physics at Home. The result of this research was the improvement of learning outcomes due to the application of Physics at Home. So it can be concluded that this learning could solve physics learning during the Covid-19 pandemic.

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INTRODUCTION

Physics is still considered a subject that is difficult for students to understand (Aulia & Yuliani, 2022; Khoeriah et al., 2020; Latifa et al., 2021; Mbonyiryivuze et al., 2019). This is indicated by the low average value of their daily assessments. One of the factors that cause this is some physics material that tends to be abstract, where students can only observe phenomena related to the material in the form of pictures or videos without knowing the tangible form or its application in everyday life (Gong et al., 2021; Herayanti et al., 2022). Additionally, the low motivation to learn physics due to its perceived complexity, boredom, and abstractness contributes to the challenge (Cai et al., 2021). The interconnected and hierarchically structured concepts in physics demand a deep understanding, which can be overwhelming for students (Widiasih et al., 2023). The density of physics material, extensive calculations, and lack of contextual learning in the classroom also add to the student's difficulties (Utari et al., 2021). Moreover, the lack of understanding and mastery of specific physics concepts presents a significant challenge to students.

Especially during the COVID-19 pandemic, students carry out physics learning at home (Aziz et al., 2022). Home environments often come with various distractions, such as family members, electronic devices, social media, or noise. These distractions can divert students' attention away from their studies. Besides that, the author feels a decrease in student engagement in learning. Most students are less motivated to follow physics learning, as shown by their delay in attending video conferences and doing assignments given in the Learning Management System (LMS). This decrease in student engagement and motivation ultimately reduced their learning outcomes (Agger & Koenka, 2020; Yu et al., 2020), where the average results of the End of Year Assessment (PAT) for physics subjects for the 2019-2020 Academic Year do not reach the Minimum Completeness Criteria (KKM) that have been set.

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For this reason, learning strategies are needed that can overcome these problems. One of them is by way of learning, which shows that physics is part of their lives (Crouch et al., 2018; Geller et al., 2018, Geller et al., 2019). This strategy has succeeded in increasing student engagement in learning (Makkonen et al., 2021; Wickremasinghe & Kumuduni, 2022), awareness of the impact of science on society and economics, and skills in designing experiments as solutions to problems they face in everyday life (Hestiana & Rosana, 2020; Supahar & Widodo, 2021) which in turn can improve student learning outcomes (Crouch et al., 2018; Geller et al., 2018; Hestiana & Rosana, 2020).

In line with this, learning at home during the COVID-19 pandemic provides opportunities for students to observe and explore physics related to everyday life (Putranta et al., 2021; Yates et al., 2021). Several previous studies have found that physics learning that relates to students' lives can provide more meaningful learning (Oral & Erkilic, 2022; Rahmawati et al., 2022), making students better understand that physics is part of their lives (Hwang & Purba, 2022; Nyirahagenimana et al., 2022), which in turn can improve their understanding of concepts and improve their learning outcomes (Festiyed et al., 2022; Oladejo et al., 2023). However, studies that discussed physics learning strategies by relating problems of daily life during the COVID-19 pandemic, especially to dynamic electrical learning units, have not been carried out much. This was what made researchers develop Physics at Home.

Physics at Home is a learning strategy that the author applies in learning physics class XII science during the COVID-19 pandemic. The author designs learning activities at home on direct current electricity material and its application in everyday life. The implementation of this strategy is expected to be a solution to improve student learning outcomes in the Direct Current Electricity learning unit during the COVID-19 pandemic. This research was conducted to determine how applying Physics at Home can improve learning outcomes.

METHOD

The research was conducted using a quasi-experiment method, with a one-group pretest-posttest design. Where 36 students of grade XII IPA 1 SMA N 2 Bandar Lampung received treatment in the form of learning Physics at home, the design chart of this study can be seen in Table 1.

Table 1. One *Group Pretest-Posttest quasi-experiment design*

O_1	X	O_2
Pretest	***Treatment***	***Posttest***

Physics at Home is implemented in the direct current electricity learning unit (Basic Competencies 3.1 and 4.1 Physics Class XII Senior High School Curriculum 2013 Revised 2017) with indicators in Table 2.

Table 2. Basic Competencies and Learning Indicators of Direct Current Electrical Material

Basic Competencies	Learning Indicators
3.1 Analyze the working principle of unidirectional electrical equipment (DC) and its safety in everyday life.	1. Explain the definition of electrical energy. 2. Explain the definition of electrical power. 3. Calculates the magnitude of replacement resistance in series and parallel resistance circuits. 4. Identify a series of obstacles to the installation of lights in the home. 5. Analyze the amount of electrical resistance and the cost of electricity consumption at home.
4.3 Conducting experiments on the working principle of direct electric circuits (DC) with scientific methods following the presentation of experimental results	1. Designing a house plan and installing lights at home 2. Presenting the results of a significant analysis of electrical resistance and the cost of electricity usage at home

The instruments used are pretest and posttest questions given before and after implementing the Direct Current Electricity learning unit. The questions used are plural choice, with ten questions from Google Forms. This instrument is used to measure the results of learning aspects of knowledge. The second instrument is an observation sheet to observe attitudes and skills. The attitude observed is discipline and responsibility. At the same time, the skills observed are skills in designing house plans and installing lights and skills to present the results of the analysis of significant analyses of electrical resistance and the cost of electricity consumption at home. Guidelines for observing attitudes and skills can be seen in Table 3.

Table 3 Attitude and Skill Observation Guidelines

Aspects	**Variable**	**Criterion**			
		Excellent (4)	**Good (3)**	**Enough (2)**	**Less (1)**
Attitude	Discipline	Always be disciplined in following the learning process.	Often disciplined in following the learning process.	Sometimes discipline in following the learning process.	Never be disciplined in following the learning process.
	Responsibility	Always be responsible in behaving and acting towards teachers and friends.	Often responsible for behaving and acting towards teachers and friends.	Sometimes responsible for behaving and acting towards teachers and friends.	Sometimes responsible for behaving and acting towards teachers and friends.
Skills	Designing house plans and lighting installation	Attractive design, the proportional size of constituent elements, message to be conveyed into the center of attention (all three criteria are met)	Two of the excellent design criteria were met, while one of the criteria was not met.	Only one of the excellent design criteria is met, while two criteria are not met.	Design, size of constituent elements, and center of attention do not indicate good design (all criteria are not met)
	Presenting the results of an extensive analysis of electrical resistance and the cost of electricity usage at home	Messages are straightforward for the audience to capture	Messages are pretty easy for the audience to capture	Messages are complex for audiences to capture	The audience cannot capture the message

Learning was carried out online through Google Classroom by applying the Physics At Home strategy, where students are given instructions to make observations and make floor plans about the installation of lights in their respective homes, identify the type of lamp circuit used, calculate the amount of replacement resistance for all lamps, calculate the amount of electrical power, and calculate the amount of electricity usage based on tariffs Applicable Basic Electricity; The next meeting students were asked to present their assignments at the previous meeting.

RESULTS AND DISCUSSION

Learning outcomes of knowledge aspects are measured using pretest and posttest questions before and after treatment. The pretest and posttest results can be seen in Table 4.

Table 4. Pretest and Posttest Assessment Results

	Pretest	Posttest
Average	66.1	92.2
Number of learners	36 students	
N-gain	0.8	

The data in Table 4 shows an increase in students' average scores before and after implementing the Physics at Home strategy. Based on the calculation of N-gain, the average increase in students' scores is included in the high category, which is 0.8. Improving learning outcomes is one of the impacts of applying Physics at home learning that the author carried out in the classroom. The learning carried out contains physics learning activities relevant to students' daily lives, namely about direct current electric circuits and their application in installing lights in their respective homes.

The author instructs students to observe and make floor plans about the installation of lights in their respective homes, identify the type of lamp circuit used, calculate the amount of replacement resistance for all lamps, calculate the amount of electrical power, and calculate the cost of electricity consumption based on the applicable Basic Electricity Tariff. These activities successfully stimulate students to develop their understanding and apply it to solve the problems given, which in turn can strengthen the mastery of the concepts they learn. In line with this, research conducted (Hartanto et al., 2023) states that incorporating practical, hands-on activities, such as those involving floor plans and electrical calculations, can effectively enhance students' mastery of electrical concepts. In addition, the research (Khan et al., 2021) stated that calculating the amount of electrical power and estimating the cost of using electricity will provide a good understanding for students to understand the practice of electrical circuits and energy use. This follows what was conveyed by (Akben, 2020; Jayadi et al., 2020), which states that science learning outside the classroom will have a significant impact on the cognitive domain of students, where they will experience the process of developing intellectual abilities through the stages of recall, application, analysis, and creating solutions. The results of observations of aspects of attitudes and skills in learning Physics at Home are shown in Table 5.

Table 5. Observation Results of Aspects of Attitudes and Skills

Aspects	Variable	Criterion			
		Excellent (4)	Good (3)	Enough (2)	Less (1)
Attitude	Discipline	28%	55%	17%	-
	Responsibility	28%	72%	-	-
Skills	Designing house plans and lighting installation	14%	44%	33%	9%
	Presenting the results of a significant analysis of electrical resistance and the cost of electricity usage at home	33%	55%	12%	

Observation of student attitudes in learning is focused on two things, namely discipline and responsibility, where both attitudes are closely related to student engagement in learning (Crouch et al., 2018; Geller et al., 2018). As the author previously revealed, physics learning during the COVID-19 pandemic has its challenges, one of which is related to student engagement in learning. In the experience experienced by the author at the beginning of the implementation of learning from home, there was a decrease in student engagement in learning, which was marked by delays in students attending video conferences. The author also often finds delays in students in doing the tasks given, even though there are always students who do not do the task, even though only 1-3 people.

After learning Physics at Home was carried out, the author observed that all students had succeeded in carrying out the task well even though there were still students who submitted assignments late from the given deadline. This shows that the discipline and responsibility attitude of learners tends to be positive. This can be seen in Table 5. The author believes that the learning that has been carried out is something interesting for students so that they can complete tasks well and show engagement in learning. This follows the findings of Ardiansyah & Mu'aminah (2020), which state that students will feel interested and involved in learning by themselves when they understand that the learning, they carry out is part of their daily lives.

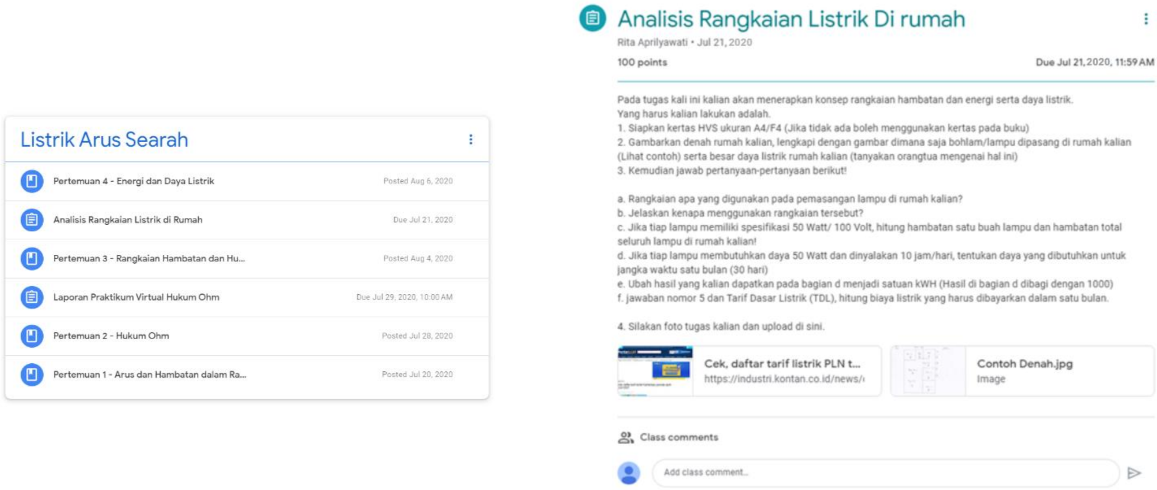

Figure 1. Teacher's instruction in Google Classroom

Meanwhile, for the skill aspect, the author observes the products of students' work in the form of house plans and the location of lighting installations in their respective homes. The author found that most students, namely as many as 44%, could design house plans and the location of lighting installations in their respective homes. They are also primarily able to identify the type of circuit, calculate the amount of resistance and total electrical power of all existing lamps, and calculate the cost of electricity consumption according to electricity tariff. A few students were able to design the floor plan and location of the lamp installation very well (14%) and quite well (33%). The authors also found that as many as 9% of learners still lacked in pouring their observations into pictures. The skill of pouring students' observations into visual form is influenced by their multi-representation ability, which can affect the improvement of their learning outcomes (Sitopu et al., 2019; Suteja & Abdurrahman, 2014). Unfortunately, in this study, the authors did not instruct learners to pay attention to the visual representation they would make.

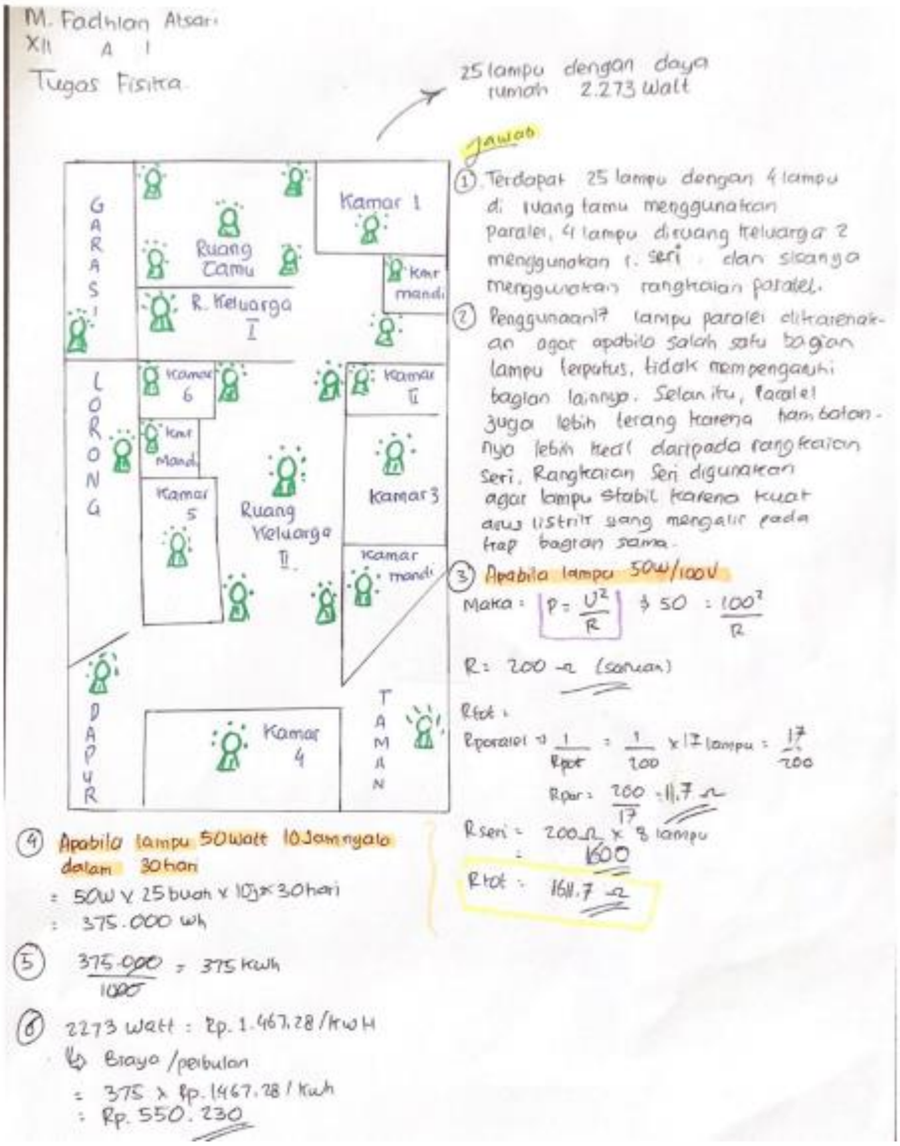

Figure 2. One of the Students' Work

As a result of observations on presentation skills, the authors found that most students could explain their findings well. They also seem enthusiastic and confident, presenting each part of their task in detail. During the discussion, student engagement was also seen. They were very enthusiastic about asking their colleagues who were doing presentations. Especially concerning the amount of electricity consumption costs that vary, which in the end, they realize does not only depend on the amount of electrical power used. Nevertheless, it is also at different TDLs based on the power size used in each house. The increase in enthusiasm and confidence that arises when presenting also impacts the application of science learning outside the classroom. This follows the findings Craciun & Bunoiu,(2019) which revealed that students have an interest in experimental and technology-based learning.

In addition to impacting aspects of knowledge, skills, and attitudes, the application of Physics at Home learning also impacts the reflective thinking of students. Some students conveyed their conclusions and opinions, such as: "Wow, just pay for electricity per month, let alone use other electronic devices."; "So we have to save electricity." The opinions and conclusions conveyed by these learners are also the results of their understanding that physics is part of their daily lives and has an influence on social and economic life so that they will eventually conclude their solutions so that it does not negatively affect their lives (Hestiana & Rosana, 2020).

This research has provided empirical evidence that implementing Physics at Home can improve student learning outcomes. However, researchers have not analyzed with parametric statistics so the conclusions obtained do not represent the entire population. In addition, this research is also limited to direct current electrical learning units, so further analysis is needed to find contextual problems that can bring physics closer to students' daily lives.

LIMITATION

This study is limited to the implementation of the "Physics at Home" strategy in a single school with a small sample size of 36 students, which may affect the generalizability of the findings. Additionally, the research focused solely on the direct current electricity learning unit, leaving room for further exploration of the strategy's application in other physics topics or broader educational contexts. Future studies should involve larger, more diverse samples and a wider range of physics materials to validate and expand upon these findings.

CONCLUSION

The application of Physics at Home can be a solution for learning physics during the COVID-19 pandemic. This learning has succeeded in increasing student engagement in learning. So that, in the end, it can improve student learning outcomes. The application of Physics at Home, like other contextual learning, must have well-structured activities so that students can achieve the expected competencies. The focus is on what students learn, and how and where they learn. In the future, it can be recommended that similar research be conducted in different schools with a larger sample size to increase the generalizability of the study. It also can be recommended that teachers find another contextual problem that can bring physics closer to students' daily lives.

AUTHOR CONTRIBUTIONS

Rita Aprilyawati conceptualized and designed the "Physics at Home" learning strategy, led the research process, and contributed to the analysis and interpretation of data. Ahmad Naufal Umam supported the implementation of the learning strategy, facilitated data collection, and contributed to refining the research framework and manuscript. Both authors collaborated to ensure the study's robustness and its contribution to improving physics education during the COVID-19 pandemic.

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REFERENCES

Agger, C. A., & Koenka, A. C. (2020). Does attending a deeper learning school promote student motivation, engagement, perseverance, and achievement? *Psychology in the Schools*, *57*(4), 627–645. https://doi.org/https://doi.org/10.1002/pits.22347

Akben, N. (2020). Effects of the Problem-Posing Approach on Students' Problem Solving Skills and Metacognitive Awareness in Science Education. *Research in Science Education*, *50*(3), 1143–1165. https://doi.org/10.1007/s11165-018-9726-7

Ardiansyah, A., & Mu'aminah, M. (2020). Analisis Sikap Ilmiah Peserta Didik Pada Praktikum Mandiri Berbasis Proyek Pada Materi Optik Smpn 4 Sojol Di Masa Pandemik. *Koordinat Jurnal MIPA*, *1*(2), 31–38. https://doi.org/10.24239/koordinat.v1i2.17

Aulia, M., & Yuliani, H. (2022). POE-based e-module (predict, observe, and explain): Improving students' critical thinking skills on kinetic theory of gases. *Online Learning In Educational Research*, *2*(2), 57–66.

Aziz, K. G., Faraj, B. M., & Rostam, K. J. (2022). Online and Face-to-Face Learning during COVID-19

Pandemic: A Comparative Analysis of Instructors and Student's Performance. *Online Learning In Educational Research*, *2*(2), 75–83.

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, *52*(1), 235–251. https://doi.org/10.1111/bjet.13020

Craciun, D., & Bunoiu, M. (2019). Learning science outside the classroom: A summer school experience. *AIP Conference Proceedings*, *2071*(January), 0–7. https://doi.org/10.1063/1.5090086

Crouch, C. H., Wisittanawat, P., Cai, M., & Renninger, K. A. (2018). Life science students' attitudes, interest, and performance in introductory physics for life sciences: An exploratory study. *Physical Review Physics Education Research*, *14*(1), 10111. https://doi.org/10.1103/PhysRevPhysEducRes.14.010111

Festiyed, Novitra, F., Yohandri, & Asrizal. (2022). Networked-based Inquiry: An Effective Physics Learning in the New Normal COVID-19 Era in Indonesia. *International Journal of Instruction*, *15*(2), 997–1016. https://doi.org/10.29333/iji.2022.15255a

Geller, B. D., Gouvea, J., Dreyfus, B. W., Sawtelle, V., Turpen, C., & Redish, E. F. (2019). Bridging the gaps: How students seek disciplinary coherence in introductory physics for life science. *Physical Review Physics Education Research*, *15*(2), 20142. https://doi.org/10.1103/PhysRevPhysEducRes.15.020142

Geller, B. D., Turpen, C., & Crouch, C. H. (2018). Sources of student engagement in Introductory Physics for Life Sciences. *Physical Review Physics Education Research*, *14*(1), 10118. https://doi.org/10.1103/PhysRevPhysEducRes.14.010118

Gong, S., Wang, S., Zhu, T., Chen, X., Yang, Z., Buehler, M. J., Shao-Horn, Y., & Grossman, J. C. (2021). Screening and Understanding Li Adsorption on Two-Dimensional Metallic Materials by Learning Physics and Physics-Simplified Learning. *JACS Au*, *1*(11), 1904–1914. https://doi.org/10.1021/jacsau.1c00260

Hartanto, T. J., Dinata, P. A. C., Azizah, N., Qadariah, A., & Pratama, A. (2023). Students' science process skills and understanding on Ohm's law and direct current circuit through virtual laboratory based Predict-Observe-Explain Model. *Jurnal Pendidikan Sains Indonesia*, *11*(1), 113–128. https://doi.org/10.24815/jpsi.v11i1.27477

Herayanti, L., Habibi, H., & Sukroyanti, B. A. (2022). Development of Inquiry-Based Teaching Materials to Improve Physics Teacher's Conseptual Understanding. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 3110–3116. https://doi.org/10.29303/jppipa.v8i6.2543

Hestiana, H., & Rosana, D. (2020). The Effect of Problem Based Learning Based Sosio-Scientific Issues on Scientific Literacy and Problem-Solving Skills of Junior High School Students. *Journal of Science Education Research*, *4*(1), 15–21. https://doi.org/10.21831/jser.v4i1.34234

Hwang, W.-Y., & Purba, S. W. D. (2022). Effects of Ubiquitous-Physics App on Students' Inquiry Behaviors and Learning Achievements. *The Asia-Pacific Education Researcher*, *31*(4), 439–450. https://doi.org/10.1007/s40299-021-00585-7

Jayadi, A., Putri, D. H., & Johan, H. (2020). Identifikasi Pembekalan Keterampilan Abad 21 Pada Aspek Keterampilan Pemecahan Masalah Siswa Sma Kota Bengkulu Dalam Mata Pelajaran Fisika. *Jurnal Kumparan Fisika*, *3*(1), 25–32. https://doi.org/10.33369/jkf.3.1.25-32

Khan, A.-N., Iqbal, N., Rizwan, A., Ahmad, R., & Kim, D.-H. (2021). An Ensemble Energy Consumption Forecasting Model Based on Spatial-Temporal Clustering Analysis in Residential Buildings. *Energies*, *14*(11), 3020. https://doi.org/10.3390/en14113020

Khoeriah, I. H., Abdullah, A. G., & Mulyanti, B. (2020). Reconstruction of vocational high school physics instructional materials. *Momentum: Physics Education Journal*, *4*(2), 85–93. https://doi.org/10.21067/mpej.v4i2.4572

Latifa, B. R. A., Purwaningsih, E., & Sutopo, S. (2021). Identification of students' difficulties in understanding of vector concepts using test of understanding of vector. *Journal of Physics: Conference Series*, *2098*(1). https://doi.org/10.1088/1742-6596/2098/1/012018

Makkonen, T., Tirri, K., & Lavonen, J. (2021). Engagement in Learning Physics Through Project-Based Learning: A Case Study of Gifted Finnish Upper-Secondary-Level Students. *Journal of Advanced Academics*, *32*(4), 501–532. https://doi.org/10.1177/1932202X211018644

Mbonyiryivuze, A., Yadav, L. L., & Amadalo, M. M. (2019). Students' conceptual understanding of electricity and magnetism and its implications: A review. *African Journal of Educational Studies in Mathematics and Sciences*, *15*(2), 55–67. https://doi.org/10.4314/ajesms.v15i2.5

Nyirahagenimana, J., Uwamahoro, J., & Ndihokubwayo, K. (2022). Assessment of Physics Lesson Planning and Teaching based on the 5Es Instruction Model in Rwanda Secondary Schools. *Contemporary Mathematics and Science Education*, *3*(1), ep22004. https://doi.org/10.30935/conmaths/11573

Oladejo, A. I., Okebukola, P. A., Akinola, V. O., Amusa, J. O., Akintoye, H., Owolabi, T., Shabani, J., & Olateju, T. T. (2023). Changing the Narratives of Physics-Learning in Secondary Schools: The Role of Culture, Technology, and Locational Context. *Education Sciences*, *13*(2). https://doi.org/10.3390/educsci13020146

Oral, I., & Erkilic, M. (2022). Investigating the 21st -Century Skills of Undergraduate Students: Physics Success, Attitude, and Perception. *Journal of Turkish Science Education*, *19*(1), 284–301. https://doi.org/10.36681/tused.2022.1122

Putranta, H., Kuswanto, H., Hajaroh, M., Dwiningrum, S. I. A., & Rukiyati. (2021). Strategies of physics learning based on traditional games in senior high schools during the Covid-19 pandemic. *Revista Mexicana de Fisica E*, *19*(1), 1–15. https://doi.org/10.31349/REVMEXFISE.19.010207

Rahmawati, Y., Taylor, E., Taylor, P. C., Ridwan, A., & Mardiah, A. (2022). Students' Engagement in Education as Sustainability: Implementing an Ethical Dilemma-STEAM Teaching Model in Chemistry Learning. *Sustainability (Switzerland)*, *14*(6). https://doi.org/10.3390/su14063554

Sitopu, P. T., Abdurrahman, A., & Herlina, K. (2019). Pengembangan Pengembangan Lembar Kerja Peserta Didik Berbasis Inkuiri Terbimbing untuk Meningkatkan Kemampuan Multirepresentasi pada Materi Hukum II Newton. *Jurnal Inspirasi Pendidikan*, *9*(2), 71–76. https://doi.org/10.21067/jip.v9i2.3261

Supahar, & Widodo, E. (2021). The Effect of Virtual Laboratory Application of Problem-Based Learning Model to Improve Science Literacy and Problem-Solving Skills. *Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)*, *528*(Icriems 2020), 633–640. https://doi.org/10.2991/assehr.k.210305.092

Suteja M, I. M., N, I., & Abdurrahman, A. (2014). Pengembangan Buku Siswa Pembelajaran Fisika Dengan Pendekatan Multirepresentasi Materi Usaha Dan Energi. *Jurnal Pembelajaran Fisika Universitas Lampung*, *2*(4), 116996.

Utari, K., Mulyaningsih, N. N., Astuti, I. A. D., Bhakti, Y. B., & Zulherman, Z. (2021). Physics calculator application with matlab as a learning media to thermodynamics concept. *Momentum: Physics Education Journal*, *5*(2), 101–110. https://doi.org/10.21067/mpej.v5i2.5133

Wickremasinghe, H. T., & Kumuduni, W. Y. (2022). Impact of Physical Learning Environment on University Students' Academic Engagement in an Online Learning Setting during Covid-19: Evidence from a Sri Lankan University. *International Journal of Built Environment and Sustainability*, *9*(3), 35–46. https://doi.org/10.11113/ijbes.v9.n3.953

Widiasih, W., Zakirman, Z., & Ekawati, R. (2023). Development of Augmented Reality Media to Improve Student Understanding of Optical Eyes System Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 912–919. https://doi.org/10.29303/jppipa.v9i2.2858

Yates, A., Starkey, L., Egerton, B., & Flueggen, F. (2021). High school students' experience of online learning during Covid-19: the influence of technology and pedagogy. *Technology, Pedagogy and Education*, *30*(1), 59–73. https://doi.org/10.1080/1475939X.2020.1854337

Yu, Z., Gao, M., & Wang, L. (2020). The Effect of Educational Games on Learning Outcomes, Student Motivation, Engagement and Satisfaction. *Journal of Educational Computing Research*, *59*(3), 522–546. https://doi.org/10.1177/0735633120969214