Journal of Dedication in Community (JoDiC)
Vol. 02, Issue. 02, Page. 25 – 34
ISSN: 3026-0760

Training in Low-Temperature Stirling Engine Kit Modeling for High School Physics Teachers in the Nganjuk Regency

***Muhammad Nurul Fahmi, Arie Realita, Diah Hari Kusumawati, Tjipto Prastowo, Madlazim, Ni Made Aprillia Sekar Manggartika**
Universitas Negeri Surabaya, Surabaya, Indonesia

Article Info:
Received 18 November 2024
Revised: 18 December 2024
Accepted: 25 December 2024
Published: 28 December 2024

Keywords:
Physics Teacher Training
Low-Temperature Stirling
Project Based Learning
Thermodynamics
Interactive Learning

ABSTRACT

This research examines the difficulties in high school physics education in Nganjuk Regency, Indonesia, specifically the lack of practical teaching tools for successful thermodynamics training. The aim is to assess a community service training program intended to improve the skills of physics instructors via low-temperature Stirling engine modeling kits. The program utilized a descriptive qualitative technique, incorporating preliminary questionnaires, interactive workshops, and practical training sessions in which educators created and employed Stirling engine kits as teaching instruments. Teachers' comments were evaluated using a Likert scale, concentrating on the congruence of training with learning objectives, resources, and student attributes. The results revealed an overall satisfaction score of 89.53%, highlighting notable enhancements in instructors' capacity to engage students and employ project-based learning methodologies. The Stirling engine kits significantly enhanced student engagement and comprehension of thermodynamic fundamentals. The training improved instructors' academic and practical skills while promoting a dynamic and participatory classroom environment. This effort illustrates the capacity of novel teaching tools and collaborative training programs to markedly enhance the quality of physics education, indicating possibilities for scaling to other locations and disciplines. Future proposals involve incorporating these teaching tools into standard curriculum and creating continuous professional development networks for enduring educational progress.

INTRODUCTION

The teaching and learning activities are the main communication channel between teachers and students; they find various materials besides video to communicate ideas (Njọkụ, 2015; Abdulrahman *et al.*, 2020; Mahdi, 2023). Criticos (1996) reveals that teaching aids, which are constructed as one of the basic components in education, are a means for the teachers to inform the students, thus motivating them and encouraging their enthusiasm for education. Instructional aides are the most necessary support that can be provided by teachers to students studying physics so that they acquire good knowledge, and the process of education is mainly deconstructed. Also, the development of media that generates student involvement is a way to create a lively and vibrant learning environment, and suitable teaching technologies and teachers' competencies are the best motivation for students to study physics. The visual materials, the content of instruction, and the methods of teaching are the main things driving the development of cognitive skills, acquiring knowledge, and achieving the learning objectives (Aisami, 2015; Bobek & Tversky, 2016; Abdulrahman *et al.*, 2020) which are shown in Figure 1.

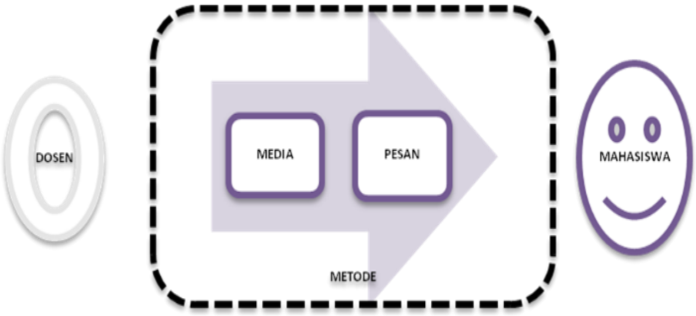

Figure 1. The diagram demonstrates the role of learning media and teaching techniques as conduits for transmitting instructions from lecturers to students during the educational process (Sucahyo *et al.*, 2010).

In the context of high school physics education, conceptual comprehension is essential for the development of meaningful learning experiences for students. Experiential learning, which involves students conducting pertinent laboratory or classroom experiments, can facilitate a comprehensive understanding of physics concepts (Thees *et al.*, 2020; Asad *et al.*, 2021). Students are afforded the opportunity to observe and experience natural phenomena firsthand through physics experiments or practical activities, which render abstract physics concepts more tangible and memorable. However, the implementation of these practical activities in schools frequently encounters obstacles, particularly in the context of resource constraints and inadequate facilities, such as the availability of experiment kits and instructional aides (Haryadi *et al.*, 2019; Karimovna *et al.*, 2020; Farhodovna *et al.*, 2020). On the other hand, for physics instructors, the use of appropriate teaching aids can facilitate the presentation of intricate concepts and motivate students to engage more actively in the learning process.

The training program for low-temperature Stirling engine modeling kits for high school physics educators in Nganjuk Regency is a community service effort designed to improve the quality of physics education in schools. This course emphasizes thermodynamics, specifically the transformation of heat energy into mechanical energy, to provide educators with practical experience and relevant abilities. This training course enables physics educators to comprehend and implement the functionality of low-temperature Stirling engines utilizing straightforward experimental kits as instructional tools in the classroom. Teachers are encouraged to include real-world applications of physics ideas into the curriculum, allowing students to recognize the importance of physics in daily life. This method is expected to stimulate students' interest in physics and enhance their involvement in technology and engineering disciplines.

The partnership between the PKM team and physics educators from the Physics Teachers Working Group (MGMP Fisika) in Nganjuk Regency has led to a consensus to organize a training session focused on low-temperature Stirling engine modelling as a teaching resource. The PKM team is required to provide a meaningful and positive impact on high school physics teachers in Nganjuk through this training session, focusing on improving the effectiveness of physics instruction in classrooms. This training session aims to enhance teachers' abilities in utilizing experimental teaching aids while promoting project-based learning (PBL) that can be applied on a school laboratory scale.

Journal of Dedication in Community (JoDiC)
Vol. 02, Issue. 02, Page. 25 – 34
ISSN: 3026-0760

This project-based approach aims to assist students in cultivating critical thinking skills, enhancing analytical abilities, and achieving a more profound conceptual understanding (Almulla, 2020; Yu, 2024; Buchman, 2024). This partnership acts as a blueprint for adopting creative teaching strategies that enhance students' educational journeys and deepen their understanding of physics concepts through experiential, hands-on activities.

This community service program is designed to enhance the physics teaching and learning process in high schools, with a particular focus on Nganjuk Regency. This training program aims to develop innovative teaching methods that expand teachers' perspectives and establish a dynamic physics learning community involving both teachers and students. The anticipated success of this program aims to inspire the advancement of physics teaching methodologies in various regions and to strengthen the significance of high school physics education in alignment with the skill requirements of the 21st century. This program is designed to support government initiatives aimed at enhancing educational quality by employing innovative, adaptive methods that are pertinent to the progress of science and technology. This initiative is valuable for enhancing teachers' competencies and encouraging students to explore physics in a deeper and more applicable way.

CASE STUDY

A key obstacle to high school physics teaching in Nganjuk Regency is a scarcity of hands-on materials and tools that instructors may utilize to bring courses to life. This initiative seeks to address that issue. Students may struggle to understand concepts such as thermodynamics unless they are provided with visual and interactive tools that make learning more engaging and memorable. Teachers must be able to explain these complicated subjects in simple, practical ways, but inadequate resources make this challenging and affect students' comprehension. To address this, the project focuses on creating a long-term, teacher-centered plan to bridge the gap and improve physics learning experiences throughout the area.

To get an understanding of the requirements and enthusiasm for the program, the project started with a significant amount of preparation, which included conducting surveys and having meetings with local school officials and the MGMP (Subject Teacher Consultation Forum). During their trip to SMAN 1 Nganjuk, the team had a meeting with school officials and representatives from the MGMP to discuss the activities that were planned. Based on their discussion, they concluded that they should proceed with the workshops. It was decided that the PKM action would take place on July 20, 2024, which would provide the crew with sufficient time to complete any further logistics. The crew also put the Stirling engine kits through their paces at this point, ensuring that they were completely put together and ready to be used in the classroom right away. Having successfully tested the kits, the following steps for the team are to adjust the event schedule and make certain that all the resources that are required are adequately prepared.

The first stage was the thorough preparation that consisted of surveys and meetings with local school officials and the MGMP to identify the needs and to determine understanding and engagement. During the visit to SMAN 1 Nganjuk, the team reviewed the planned activities with the school administration and MGMP officials, who then decided on the workshop activities that would take place next. The PKM action will take place on July 20, 2024, giving the crew enough time to cope with any logistical concerns. This phase also featured a test run of the Stirling engine kits, which were successfully constructed and tested, indicating they are suitable for classroom usage. Following the successful trials, the next steps would be to construct a detailed calendar of events and ensure all necessary resources are available.

One of the project's outreach and sustainability methods is to widen and involve stakeholders through workshops, with the results captured through documentation and media coverage. The documentation crew will film each part of the workshop, following the teacher's lead from learning the previous lesson to increasing knowledge with facilitation aid, in order to produce materials for future use. Additionally, we will disseminate the video projects via social media and other platforms to highlight their progress and promote participation in the next initiatives. distributing their findings to other regions enables them to draw inspiration from similar strategies while enhancing the broader initiative for practical and accessible physics educational resources. Through these efforts, the case study will demonstrate the advantages of providing educators with both knowledge and practical skills, eventually improving physics education in Nganjuk and beyond.

METHOD

The program employs a descriptive qualitative methodology to analyze the responses of participants (teachers) regarding the implementation of project-based physics learning in high school configurations. This community service initiative was established in Nganjuk Regency, concentrating on physics educators in senior high schools in the vicinity, and was executed within a designated timeframe as part of Unesa's PKM project.

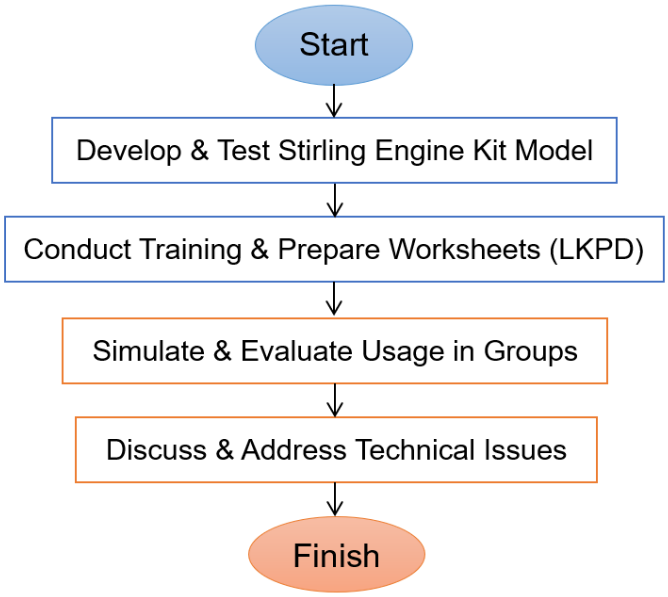

Figure 2. The flowchart for this community service project explains a step-by-step method for assisting high school physics instructors in Nganjuk. The project begins with

building and testing a low-temperature Stirling engine kit and progresses through teacher training, group simulations, and troubleshooting sessions.

The project started with preliminary coordination meetings and a needs assessment, during which the existing obstacles in delivering the physics practical courses, including the utilization of low-temperature Stirling engine models, were highlighted. To address these challenges, the initiative used an interactive, workshop-based paradigm that provided educators with theoretical and practical expertise. The procedural phases of this community service program are delineated in the flowchart presented in Figure 2.

IMPLEMENTATION

To ensure the effective integration of the Stirling engine kit model into classrooms, a community service program for high school physics instructors in Nganjuk was implemented in stages. The PKM team first developed a prototype low-temperature Stirling engine kit and tested it short to see whether it could be utilized as a teaching tool. Worksheets (LKPD) and user manuals were created in response to these results to help instructors successfully incorporate the kit into their physics lectures. The program's subsequent stages were built on the foundation of the initial phase.

The second stage concentrated on educator training, including practical experience with the Stirling engine kit. Educators collaborated in developing the model and jointly produced teaching worksheets that corresponded with the kit's educational objectives. The training culminated with a group simulation, enabling educators to apply the equipment in a classroom environment. This hands-on experience enhanced educators' methodologies and bolstered their confidence in using the gear in their instruction.

In the concluding stage, the program prioritized assessment and critique. Educators engaged in a dialogue to exchange their experiences and pinpoint technical challenges faced during the implementation phase. A survey was administered to evaluate instructors' comprehension and satisfaction with the training, employing a Likert scale to collect quantifiable data (Ketut & I Nyoman 2020; Courey & D. Lee, 2021; Dalka *et al.*, 2022). The results were analyzed descriptively, yielding significant insights to enhance future iterations of the program and secure its long-term success. This study employs the following descriptive form of percentage:

Table 1. Likert scale categories

Score	Description
4	Agree
3	Somewhat Agree
2	Disagree
1	Strongly Disagree

Table 2. Response criteria

Interval for student responses	Criteria
80% ≤ FA ≤ 100%	Highly Positive
60% ≤ FA ≤ 80%	Positive
40% ≤ FA ≤ 60%	Moderately Positive

Journal of Dedication in Community (JoDiC)
Vol. 02, Issue. 02, Page. 25 – 34
ISSN: 3026-0760

Interval for student responses	Criteria
$20\% \leq FA \leq 40\%$	Marginally Positive
$FA \leq 20\%$	Low Positive

The percentage calculation of teacher responses can be performed using equation below (Midoro, *et al.*, 2021):

$$\%P = \frac{\Sigma_x}{\Sigma_i} \times 100\% \tag{1}$$

In this context, FA denotes the final assignment, P signifies the percentage, Σ_x represents the cumulative number of responses for all items, and Σ_i indicates the total ideal score for each item.

RESULT AND DISCUSSION

This study seeks to assess the efficacy of educating high school physics instructors in creating and modeling thermodynamics teaching aids, with a special emphasis on the usage of Stirling engine kits. This curriculum is intended to provide instructors with a more comprehensive grasp of thermodynamic ideas, which should enhance interactive learning methods in the classroom. The Likert scale is the primary technique used to assess the success of training in a variety of areas, including enhancing teacher knowledge and abilities (Darka *et al.*, 2022). Furthermore, this assessment tool identifies opportunities for improvement in the following training session (Martinez-Borregueri *et al.*, 2022; Bhakti *et al.*, 2023). Previous research has found that interactive learning strategies can improve students' comprehension of abstract topics (Bakri *et al.*, 2018).

This analysis involved the distribution of questionnaires during the training, concentrating on four primary assessment aspects: (1) alignment of training with learning objectives; (2) alignment of training with learning materials; (3) alignment of training with student characteristics; and (4) Characteristics of stirling engine teaching aid. This survey assessed 16 criteria, with participants' responses compiled in Table 3, detailing their feedback on each criterion.

This analysis offers a comprehensive overview of the alignment between the training and the anticipated learning outcomes, highlighting areas needing modification to better address participant needs. Furthermore, participants' responses offer valuable insights into their perceptions of the Stirling Engine model as a demonstration tool, serving as a foundation for enhancing its design and implementation in future training sessions. This analysis identifies potential improvements to the training approach, expected to enhance the learning experience of high school Physics teachers.

Tabel 3. Questionnaire on percentage criteria evaluation of the alignment of Stirling engine training programs with educational objectives and student needs.

	Criteria	Score Percentage (%)
A	**Alignment of training with learning objectives**	
1	Enhancing student learning activities and participation	90,00
2	Developing project-based learning	90,00

Journal of Dedication in Community (JoDiC)
Vol. 02, Issue. 02, Page. 25 – 34
ISSN: 3026-0760

	Criteria	Score Percentage (%)
3	Improving teachers' and students' understanding of STEM education with a TPACK approach	87,50
4	Providing a broader role for mentors to support teachers	90,00
B	**Alignment of training with learning materials**	
1	Providing depth and coverage of information	87,50
2	Supporting understanding of relevant physics concepts	87,50
3	Providing concrete examples and factual learning	92,50
4	Offering new knowledge and insights	92,50
C	**Alignment of training with student characteristics**	
1	Capturing interest and increasing learning motivation	95,00
2	Aligning with knowledge and psychological development	90,00
3	Encouraging students to be independent and take initiative	90,00
D	**Characteristics of stirling engine teaching aid**	
1	Relevance between the Stirling Engine teaching aid and related worksheets	87,50
2	Capable of meeting learning objectives	85,00
3	Visually appealing	90,00
4	Easy to assemble	85,00
5	Supporting student-centered learning	92,50
	Overall average percentage	89,53

The results indicated that training had a favorable effect, with an average percentage across all categories of 89.53%. This means that the training is relevant to the demands of secondary school Physics educators. The Stirling Engine presentation tool received the highest rating of 95% in the "Suitability to Student Characteristics" category, demonstrating its effectiveness in stimulating interest and developing students' enthusiasm for learning, particularly in "capturing interest and raising learning motivation." The teachers stated that more realistic and interactive teaching techniques dramatically enhanced students' knowledge of thermodynamic principles that they had previously struggled to grasp through standard lectures. This is confirmed by current research, which shows that activity-based and project-based learning techniques are considerably more engaging for students (Almulla, 2020; Yu, 2024; Buchman, 2024).

Positive survey results indicate that this training significantly enhanced the application of diverse teaching methodologies in the classroom. The training not only improved instructors' comprehension of thermodynamic principles but also facilitated experiential learning through the construction and utilization of the Stirling Engine kit. Consequently, educators can now present physics concepts in a more engaging and comprehensible manner. Additionally, this educational tool enables students to interact with a tangible physical model, thereby augmenting their retention and understanding of the concepts. This study also found that this strategy created a more dynamic classroom environment, which encouraged students to engage in more active learning. Thus, interactive teaching technologies like the Stirling Engine offer a good prospect for widespread use in classroom physics instruction (Almulla, 2020).

Following the discussion of implications for classroom practice, it is crucial to assess the long-term sustainability of this program. The program evaluation indicates that, in the short term, it effectively improved teachers' skills and had a positive effect on their teaching methods (Paolini, 2015; Obilor, 2019). Survey results demonstrate that the program achieved high ratings, especially regarding engagement and alignment with learning objectives. To secure the program's sustained advantages, additional measures are required, including the incorporation of this teaching aid into the school curriculum for regular utilization by educators in the instructional process. Creating a community or practice network among Physics educators can promote continuous collaboration, resource sharing, and collective enhancement of teaching quality. This community serves as a platform for educators to share experiences and engage in discussions regarding innovations in Physics instruction.

CONCLUSION

The Training of High School Physics Teachers on Thermodynamics Teaching Aids and Stirling Engine Experimental Models was carried out in an effective manner and gave considerable benefits in terms of improving the participants' knowledge and practical abilities. This training demonstrated that the methodology that was utilized was able to improve the Physics teaching style, which had previously placed a greater emphasis on theory, to become more relevant and tangible. The average satisfaction score for this training was 89.53%. Through the implementation of this enhancement, it is anticipated that students will be more engaged in the learning process, which will ultimately lead to a better knowledge of the ideas pertaining to Physics. There are potential for other researchers to pursue similar programs, with an emphasis on the use of additional teaching aids or more extensive assessment techniques. These options are made possible by the constraints on the number of participants and the duration of the training.

ACKNOWLEDGMENT

We extend our gratitude to SMAN 1 Nganjuk for their involvement and support in the execution of the 2024 Unesa PKM activity. We extend our heartfelt thanks to the funding supporters who have enabled this activity, along with the supervisors and all parties involved in this research. Special appreciation goes to the research and community service institute, including those who assisted in report preparation, material provision, and logistical support. The involvement and collaboration of everyone are crucial for the success of this training. This collaboration is expected to persist, yielding advantages for all involved and fostering the advancement of education in Indonesia.

REFERENCES

Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N T., Olawo, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O. and Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon, 6*(11) e05312. https://doi.org/10.1016/j.heliyon.2020.e05312

Aisami, R. S. (2015). Learning styles and visual literacy for learning and performance. *Procedia - Social and Behavioral Sciences,* 176, pp. 538-545. https://doi.org/10.1016/j.sbspro.2015.01.508

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) approach as a way to engage students in learning. *Sage Open,* 10(3). https://doi.org/10.1177/2158244020938702

Asad, M.M., Naz, A., Churi, P. and Tahanzadeh, M.M. (2021). Virtual Reality as pedagogical tool to enhance experiential learning: A systematic literature review. *Education Research International,* 2021 (1), 7061623. https://doi.org/10.1155/2021/7061623

Bakri, F., Sunaryo., Irawan, V. F. and Muliyati, D. (2018). E-Learning model for Problem Based Learning on heat and thermodynamic topics in high school, *JPPPF (Jurnal Penelitian dan Pengembangan Pendidikan Fisika),* 4(2). doi.org/10.21009/1.04207

Bhakti, Y. B., Sumarni, R. A., Mayanty, S. and Astuti, I. A. D. (2023). Developing virtual physics practicum module of optic based on guided inquiry to improve students' science process skills. *Journal of Science and Science Education,* 4 (1), pp. 39-49. https://doi.org/10.29303/jossed.v4i1.2329

Buchman, J. C. (2024). Enhancing critical thinking abilities through Project-Based Learning: effects and implementation. *Asia-pacific Journal of Convergent Research Interchange*, 10(9), pp. 545-554. http://dx.doi.org/10.47116/apjcri.2024.09.43

Bobek, E. and Teversky, B (2016). Creating visual explanations improves learning. *Cognitive Research: Principles and Implications*, 1(27). https://doi.org/10.1186/s41235-016-0031-6

Courey, K. A. and D. Lee, M. (2021). A model-based examination of scale effects in student evaluations of teaching. *Sage Open,* 7, pp. 26-30. https://doi.org/10.1177/23328584211040083

Criticos, C. (1996). Media selection. Plomp, T., & Ely, D. P. (Eds.): International Encyclopedia of Educational Technology, 2nd edition. New York: Elsevier Science, Inc.

Dalka, R. P., Sachmpazidi, D., Henderson, C. and Zwolak, J. P. (2022). Network analysis approach to likert-style surveys. *Physical Review Physics Education Research*, 18(2). 10.1103/PhysRevPhysEducRes.18.020113

Farhodovna, A. M., Olimboevich, A, J. and Badriddinovich, K. B. (2020). Innovative pedogogical technologies for training the course of physics. *The American Journal of Interdisciplinary Innovations and Research*, 2(12). https://doi.org/10.37547/tajiir/Volume02Issue12-12

Haryadi, R., Vita, M., Utami, I. S., Ihsanudin, I., Setiani, Y. and Suher,an, A. (2019). Briquettes production as teaching aids physics for improving science process skills. *International Journal of Physics: Conference Series*. 1157(032006). 10.1088/1742-6596/1157/3/032006

Karimovna, N. N., Izzatullaevna, T. Z. and Gayratovna, N. N. (2020). Innovative technologies in physics education. *European Journal of Research and Reflection in Educational Sciences,* 8(10), pp. 19-22. https://doi.org/10.1016/j.chb.2020.106316

Ketut, S. K. & I Nyoman, T. A. P. (2020). Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android. *Jurnal Pendidikan Kimia Indonesia*, 4(1). 10.23887/jpk.v4i1.24981

Mahdi, S. (2023). Effective communication in learning: teacher strategies and their impact on student learning outcomes. *International Journal of Linguistics, Communication, and Broadcasting,* 4(1), pp. 26-30. https://doi.org/10.46336/ijlcb.v1i4.26

Martinez-Borreguero, G., Naranjo-Correa, F. L. and Mateos-Núñez, M. (2022). Cognitive and emotional development of STEM skills in primary school teacher training through practical work. *Education Sciences*, 12(7). https://doi.org/10.3390/educsci12070470

Midroro, J., Prastowo, S. and Nuraini, L. (2021). Analisis respon siswa Sma Plus Al-Azhar Jember terhadap modul fisika digital berbasis *articulate storyline* 3 pokok bahasan Hukum Newton tentang gravitasi. *Jurnal Pembelajaran Fisika*, 10(1). https://doi.org/10.19184/jpf.v10i1.23762

Njọkụ, C. P. U. (2015). Information and communication technologies to raise quality of teaching and learning in higher education institutions. *International Journal of Education and Development using Information and Communication Technology (IJEDICT),* 11(1), pp. 122-147.

Obilor, E. I. (2019). Influence of teaching effectiveness on students' learning outcome. *International Journal of Innovative Social & Science Education Research,* 7(2), pp. 37-48.

Paolini, A. (2015). Enhancing teaching effectiveness and student learning outcomes. *The Journal of Effective Teaching,* 15(1), pp. 20-33. https://files.eric.ed.gov/fulltext/EJ1060429.pdf

Sucahyo I., Rahmawati E. dan Hayati N, 2010, *Pengembangan Bahan Ajar dan Media Pembelajaran Berupa Buku Elektronik untuk Mata Kuliah Elektronika Dasar I*, Laporan Akhir Penelitian DIA-Bermutu TA 2010, Lemlit Unesa. Surabaya

Thees, M., Kapp, S., Strzys, M. P., Beil, F., Lukowicz, P. and Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior,* 108. https://doi.org/10.1016/j.chb.2020.106316

Yu, H. (2024). Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon,* 10(6), e27706. https://doi.org/10.1016/j.heliyon.2024.e27706

*** Muhammad Nurul Fahmi, S.Si., M.Si. (Corresponding Author)**
Physics Study Program, Faculty of Mathematics and Natural Sciences,
State University of Surabaya, Surabaya, Indonesia 60231.
Ketintang Street, C2-C3 Building 1st Floor and 3rd Floor, Surabaya, East Java 60231, Indonesia
Email: muhammadfahmi@unesa.ac.id