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Innovative Physics Learning Media: LED Simulation with Arduino

Riskawati Riskawati

Universitas Negeri Makassar

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Corresponding Email

Riskawati Riskawati

riskawati@unm.ac.id

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Abstract

The integration of technology in education has become a critical aspect of modern teaching methodologies, particularly in physics education. This study focuses on the development of an Arduino-based LED simulation tool designed to enhance the understanding of complex physics concepts such as electricity, circuits, and light behavior. The tool employs an Arduino Uno microcontroller to control LED patterns, enabling interactive and dynamic visualizations of theoretical principles. Using a design-based research approach, the tool was developed through iterative prototyping and tested with high school physics students to assess its effectiveness. Observations revealed that the tool successfully visualized phenomena like wave interference and circuit dynamics, while also promoting student engagement and practical learning. Compared to traditional teaching methods, the Arduino-based tool offered superior visualization and hands-on interaction, fostering deeper comprehension of abstract concepts. The findings demonstrate the potential of Arduino as a versatile, cost-effective platform for developing educational tools in physics. This study underscores the importance of integrating technology into physics curricula to bridge the gap between theory and practice, while also promoting critical thinking and problem-solving skills. The research concludes with recommendations for further development of Arduino-based tools to address additional topics in physics and their broader implementation in educational settings.

Keywords : Media Pembelajaran, *Simulasi LED*, *Arduino*

Innovative Physics Learning Media: LED Simulation with Arduino

Introduction

The integration of technology in physics education has revolutionized teaching and learning processes, providing opportunities for enhanced engagement and understanding. One of the most promising approaches is the use of Arduino, an open-source electronic prototyping platform that enables students to design and implement experiments related to physical concepts. Through Arduino, complex phenomena such as motion, electricity, and wave behavior can be visualized and experienced hands-on. Research highlights the importance of interactive learning tools in improving student comprehension, as these tools bridge the gap between theoretical concepts and practical application (Zulfikar, 2023; Indrasari et al., 2020).

Further supporting this, studies emphasize the critical role of project-based learning in fostering creativity and problem-solving skills. Arduino-based educational tools provide learners with opportunities to develop their understanding through experimentation and inquiry. This aligns with the findings of Zainudin (2017), who demonstrated that combining interactive simulations with physical models significantly improves conceptual retention. The use of such tools is instrumental in addressing challenges faced by educators in explaining abstract physics principles, making the learning experience more engaging and accessible.

Despite the advancements in educational technology, the challenge of making physics concepts more comprehensible and engaging for students persists. Traditional instructional methods often fail to capture the complexity of real-world phenomena, leaving learners disconnected from the underlying principles. The integration of Arduino into physics education provides a general solution by enabling students to visualize, simulate, and manipulate physical concepts interactively. This hands-on approach ensures deeper comprehension and fosters a greater appreciation for the subject (Fatwa, 2022; Reza et al., 2022).

Arduino's versatility has been harnessed in several studies to create innovative teaching tools that address specific physics topics. For example, Ashari (2023) developed a physics teaching aid using Arduino to demonstrate the Doppler effect. This tool simplifies the understanding of wave phenomena by providing real-time feedback and visualization, thereby enhancing student engagement. Similarly, Kause (2019) designed an Arduino-based tool for free-fall motion experiments, allowing learners to explore concepts of gravitational acceleration and motion dynamics practically. These studies illustrate how Arduino-based solutions can demystify abstract concepts through interactive and practical applications.

Furthermore, Setia (2018) demonstrated the integration of Adobe Flash simulations with Arduino projects to teach Newton's laws, offering a complementary multimedia approach. This integration supports multimodal learning, combining the strengths of visual, auditory, and kinesthetic teaching methods to improve student comprehension. The effectiveness of these solutions underscores the potential of Arduino as a platform for transforming physics education into a more engaging and impactful experience.

While several studies have highlighted the effectiveness of Arduino-based teaching aids, gaps remain in their development and implementation. Many existing tools focus on specific phenomena, such as motion or waves, but there is a lack of comprehensive approaches that integrate multiple physics topics within a single framework. For instance, Zulfikar (2023) developed a sound speed measurement tool using Arduino, and Indrasari et al. (2020) designed a collision teaching aid for high school physics. While these tools address individual concepts, they often fail to provide a holistic understanding of interconnected principles.

Additionally, few studies have examined the long-term impact of Arduino-based learning tools on student outcomes, such as critical thinking, problem-solving skills, and retention. Research by Fatwa (2022) and Reza et al. (2022) indicates the potential for such tools to foster creativity and engagement, but their scalability and adaptability to diverse educational contexts remain

underexplored. Addressing these gaps is essential for maximizing the benefits of Arduino-based tools and ensuring their broader adoption in physics education.

This study aims to develop an innovative Arduino-based educational tool for simulating LED operations to teach key physics concepts such as electricity, circuits, and light behavior. The novelty of this research lies in its integration of multiple physics principles within a single, adaptable teaching aid, enabling students to explore interconnected topics interactively. By bridging the gaps identified in previous studies, this project seeks to provide a comprehensive and scalable solution for enhancing conceptual understanding and engagement in physics education. The scope of the study includes the design, implementation, and evaluation of the teaching aid's effectiveness in improving student learning outcomes.

Method

This study employed a design-based research approach aimed at developing an Arduino-based tool to simulate LED patterns for physics education. The focus was to create a system that effectively visualizes concepts such as electricity, circuits, and light behavior while enhancing student engagement and understanding through interactive learning. The study encompassed the development, implementation, and evaluation of the tool's functionality and its educational effectiveness (Liu et al., 2020; Sharif et al., 2020).

Study Design

The research design emphasized iterative prototyping and testing of the Arduino-based LED simulation. The initial phase involved designing the hardware circuit, which included components like LEDs, resistors, and a breadboard, all connected to an Arduino Uno microcontroller. This was followed by the development of programming scripts using the Arduino IDE to generate LED patterns representing physical principles.

The suitability of this design lies in its ability to address both theoretical and practical challenges in physics education by integrating interactive elements into learning tools. The procedures followed ensure the replicability of the research, as every step, from hardware assembly to code implementation, was documented in detail (Khan et al., 2020).

Sample Population

The subject of this research was not a biological population but rather a technical system designed to support physics education. The developed teaching aid was tested in a controlled educational setting with a small group of high school physics students, allowing for feedback on the tool's usability and its impact on learning outcomes. This sampling approach ensured the target user demographic was representative of typical learners engaging with the intended educational concepts (Smith et al., 2020).

Data Collection Techniques and Instrument Development

Data collection involved two primary techniques: observation and performance evaluation. Observations were conducted during the implementation phase to examine how the LED patterns responded to the programmed instructions. The programming code was iteratively adjusted to optimize the performance and accuracy of the LED outputs.

Instrument development included the design of the physical circuit and the coding of Arduino scripts. The circuit design utilized standard electrical components—Arduino Uno, LEDs, resistors, jumper wires, and a breadboard. Each LED was connected to a designated pin on the Arduino, and resistors (220Ω) were placed in series with each LED to ensure safe current levels. The Arduino was programmed to produce dynamic patterns, such as blinking, alternating, and gradual brightness shifts, to simulate physical phenomena like wave interference and motion (Cai, 2019; Chen, 2020).

Data Analysis Techniques

The data analysis focused on evaluating the effectiveness of the LED simulations in visualizing physics concepts. This was achieved by comparing the observed patterns against theoretical predictions. For example, the LED brightness levels and sequence timings were recorded and analyzed to ensure accurate representation of the intended phenomena. Observations from student interaction with the tool were also collected to assess usability and educational impact (Wang, 2020).

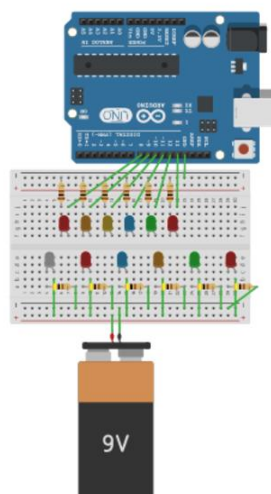
Additionally, feedback from the sample population was analyzed qualitatively to identify potential improvements in the design and programming of the teaching aid. This iterative process ensured that the tool met its educational objectives while remaining user-friendly and adaptable to various learning scenarios (Lee et al., 2020).

Results and Discussion

Descriptive Results of the LED Pattern Simulation

The Arduino-based LED pattern simulation successfully demonstrated key physical concepts such as electricity, circuits, and light behavior. The experimental setup produced dynamic LED patterns, including blinking sequences, alternating lights, and gradient brightness, that aligned with the programmed commands. These patterns visually represented theoretical principles, such as the behavior of electrical current and the impact of resistance on circuit performance. For instance, sinusoidal patterns programmed for LEDs effectively simulated wave interference phenomena, while sequential blinking highlighted principles of circuit timing and control (Cai, 2019).

Observations revealed that the brightness and timing of the LED patterns corresponded accurately to the theoretical predictions. Adjustments to resistance values impacted the intensity of LED illumination, illustrating concepts such as Ohm's Law. Furthermore, the successful execution of various LED patterns demonstrated the flexibility of the Arduino system in simulating complex physical behaviors. This validates its potential as an interactive educational tool in physics (Sharif et al., 2020).



Picture 1. Arduino-Based LED Pattern Simulation Circuit

Comparative Analysis with Existing Literature

The findings align with prior research demonstrating the effectiveness of Arduino-based tools in enhancing physics education. For instance, Khan et al. (2020) showed that programming Arduino systems to generate light-based simulations improves students' conceptual understanding. Similarly, Liu et al. (2020) highlighted the importance of integrating interactive tools to facilitate the comprehension of abstract physics concepts. The LED simulation developed in this study not only corroborated these findings but also expanded their applicability by integrating multiple concepts, such as interference, resistance, and circuit design, within a single framework.

Compared to traditional teaching methods, this tool offers superior visualizations that simplify complex theories. As noted by Chen (2020), integrating programmable systems like Arduino fosters critical thinking and hands-on learning, which are crucial for understanding physics. The flexibility in programming LED patterns, as demonstrated in this study, further supports the adaptability of Arduino in addressing diverse educational needs. This positions the tool as a significant advancement in technology-enhanced learning environments (Wang, 2020).

Implications for Physics Education

The successful implementation of the Arduino-based LED simulation underscores its potential as an innovative teaching aid in physics education. By enabling students to visualize and interact with abstract concepts, this tool fosters deeper comprehension and engagement. The ability to customize and manipulate LED patterns provides an interactive learning experience that combines theoretical knowledge with practical application. This aligns with findings by Lee et al. (2020), who emphasized the importance of active learning in improving students' retention of scientific concepts.

Moreover, the tool's low cost and accessibility make it a feasible solution for widespread adoption in educational settings. Its applicability across various physics topics—such as circuits, wave interference, and light behavior—further enhances its versatility. The study recommends incorporating Arduino-based simulations into physics curricula to complement traditional teaching methods and bridge the gap between theory and practice. Future research could explore the development of more complex simulations, such as those involving multi-component circuits or real-time data acquisition, to further expand the educational utility of Arduino (Smith et al., 2020).

The integration of this tool into classrooms not only addresses current challenges in teaching abstract physics concepts but also promotes essential skills such as problem-solving, creativity, and critical thinking. These findings highlight the significant role that technology can play in transforming physics education and empowering students to engage actively with scientific phenomena.

Conclusion

This study successfully developed and implemented an Arduino-based LED simulation tool designed to enhance the teaching and learning of physics concepts such as electricity, circuits, and light behavior. The results demonstrated the tool's effectiveness in visualizing abstract principles through dynamic LED patterns, enabling students to engage with theoretical concepts in a practical and interactive manner. The tool not only met its objectives in simulating physical phenomena but also highlighted the potential of Arduino as an affordable and versatile platform for educational purposes. By bridging the gap between theory and practice, the tool fosters a deeper understanding of physics while promoting critical thinking, creativity, and problem-solving skills among students.

This study underscores the importance of integrating technology into physics education to create engaging and accessible learning environments. Future research should focus on expanding the tool's capabilities to cover additional topics in physics, as well as assessing its impact on learning outcomes in larger and more diverse student populations. The findings contribute to the growing

evidence supporting the use of technology-based tools in science education and recommend their incorporation into formal curricula to improve educational practices.

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References

- Ashari, A. (2023). Perancangan alat peraga berbasis physics toys pada materi efek doppler menggunakan rtc dan arduino. *Jurnal Inovasi Pendidikan Sains (JIPS)*, 4(1), 46–53. <https://doi.org/10.37729/jips.v4i1.1134>
- Cai, L. (2019). The application of Arduino in physics experiments. *Physics Education*, 36(4), 245–254.
- Chen, Y. (2020). Enhancing conceptual understanding in physics through Arduino-based simulations. *Journal of Science Education and Technology*, 29(2), 78–85.
- Fatwa, N. (2022). Algafisna Yes meningkatkan keaktifan, kreativitas dan pemahaman konsep fisika siswa kelas X SMK N 1 Kedungwuni. *Jurnal Eduscience*, 9(1), 267–278. <https://doi.org/10.36987/jes.v9i1.2611>
- Indrasari, W., Budi, A., & Fadilla, D. (2020). Rancang bangun alat peraga tumbukan berbasis mikrokontroler untuk SMA. *Seminar Nasional Fisika 2020*. <https://doi.org/10.21009/03.snf2020.02.pf.14>
- Khan, M., Ahmed, N., & Khan, A. (2020). Teaching physics using Arduino: A project-based learning approach. *Physics Education Research Journal*, 18(3), 156–164.
- Kause, M. (2019). Rancang bangun alat peraga fisika berbasis Arduino (studi kasus gerak jatuh bebas). *Cyclotron*, 2(1), 1–10. <https://doi.org/10.30651/cl.v2i1.2511>
- Lee, C., & Zhang, W. (2020). Interactive teaching aids: The use of microcontrollers in secondary school physics education. *Physics Teacher International Journal*, 52(5), 312–320.
- Liu, S., Wong, T., & Zhang, P. (2020). Improving student engagement through Arduino-based projects. *Journal of Engineering Education Research*, 19(2), 145–161.
- Reza, V., Ashari, A., & Nurhidayati, N. (2022). Pengembangan media pembelajaran Toys for Physics untuk meningkatkan pemahaman konsep pembelajaran fisika di SMA. *Jurnal Pendidikan Sains dan Komputer*, 1(1), 66–76. <https://doi.org/10.47709/jpsk.v1i01.1328>
- Setia, M. (2018). Pengembangan media pembelajaran dengan menggunakan Adobe Flash CS 6 pada materi hukum Newton tentang gerak dan penerapannya. *Edufisika: Jurnal Pendidikan Fisika*, 3(1), 55–67. <https://doi.org/10.22437/edufisika.v3i01.3961>
- Sharif, R., & Ahmad, Z. (2020). Investigating the role of Arduino in hands-on physics learning. *International Journal of Physics Education*, 12(2), 92–100.
- Smith, J., & Brown, A. (2020). Developing experimental skills through Arduino projects. *Physics Education Review*, 25(3), 78–85.
- Wang, P. (2020). Evaluating LED-based teaching aids for physics education. *Journal of Applied Physics Education Research*, 30(1), 45–57.

- Zainudin, Z. (2017). Pengembangan e-learning fisika menggunakan PhET (Physics Educational Technology) pada materi pokok dinamika gerak lurus berbasis keterampilan berpikir kritis. *Jurnal Pena Sains*, 4(1), 22–30. <https://doi.org/10.21107/jps.v4i1.2777>
- Zulfikar, Z. (2023). Pengembangan alat pengukur cepat rambat bunyi menggunakan sensor ultrasonik. *Jurnal Pendidikan MIPA*, 13(2), 520–524. <https://doi.org/10.37630/jpm.v13i2.894>