Edusainstika : Jurnal Pembelajaran MIPA
Penerbit: Universitas Islam Negeri Mahmud Yunus Batusangkar
Website: https://ejournal.uinmybatusangkar.ac.id/ojs/index.php/Edusainstika
E-mail: edusainstika@uinmybatusangkar.ac.id

Desember 2025
Vol 5 No 2
ISSN: 2807-9388 (e)
pp : 70-78

Smart Free-Fall Experiment Apparatus Using Arduino, Infrared - Ultrasonic Sensors, and Bluetooth Data Logging to Enhance Physics Data Literacy and Inquiry Skills in Senior High School

Jeli, MI Ali Umar, H Idrus, AN Chandra

Tadris Fisika, Universitas Islam Negeri Mahmud Yunus Batusangkar, Indonesia

jeligaul06@gmail.com

Abstract This study aims to develop a valid and practical Arduino Uno-assisted free fall experiment tool as a learning medium for 11th grade high school/MA physics. It uses the research and development method with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The research subjects consisted of three expert validators and grade XI high school students as limited test subjects. The practical tool was developed by integrating Arduino Uno, infrared sensors, ultrasonic sensors, HC-05 Bluetooth modules, and MicroSD modules to support automatic time and height measurements, wireless data transmission, and digital storage of experimental data. Data collection was carried out using expert validation sheets and student practicality questionnaires, then analyzed using validity and practicality percentages based on predetermined criteria. The results of the study show that the developed laboratory equipment has a very high level of validity with an average percentage of 88% (very valid category) and a level of practicality of 81.5% (very practical category). These findings indicate that the practical tool is suitable for use as a physics learning medium and is capable of improving the quality of practical activities through more accurate measurements, time efficiency, and more systematic management of experimental data. Unlike previous studies, which generally focused on technical aspects in a partial manner, this study emphasizes the integration of measurement systems, data transmission, and digital data management in a single learning device.

Key Words: Physics laboratory equipment, Free fall motion, Arduino Uno, Physics education, Digital learning media

1. Introduction

Physics education at the high school/MA level has unique characteristics that require integration between conceptual understanding and empirical experience through experimental activities. Physics is not only a collection of concepts and laws of nature, but also a scientific process that emphasizes observation, measurement, data analysis, and evidence-based conclusions (Firdausi et al., 2020). Therefore, practical activities play a strategic role in bridging abstract concepts with real phenomena that can be observed directly by students. Well-designed practical activities have been proven to improve students' conceptual understanding, critical thinking skills, and scientific work abilities (Sarjono, 2018; Suseno, 2012).

However, the reality of physics learning in schools shows that the implementation of practical work still faces various structural and technical obstacles. Limited laboratory facilities, the high cost of conventional practical equipment, and a lack of innovation in technology-based tools mean that experiments often do not run optimally and tend to be neglected (Purwaningsih et al., 2020). This condition has resulted in the dominance of teacher-centered theoretical learning, so that students lack direct experience in applying physics concepts empirically. As a result, physics learning risks losing its contextual meaning and does not fully develop 21st-century skills that require science and technology literacy.

In a study conducted by Chen et al. (2024), et it was stated that within the framework of learning theory, the inquiry-based learning approach places practical activities as the main means for students to construct knowledge through the scientific investigation process. This process includes the stages of problem formulation, data collection and processing, and drawing conclusions based on empirical evidence. Thus, practical work is not only a complementary activity, but also the core of physics learning that encourages active engagement and the development of scientific thinking skills. Therefore, the limitations of media and practical tools that are unable to optimally support experimental activities have the potential to hinder the achievement of meaningful physics learning objectives. This is in line with the findings of Feblia Lafenasti et al. (2022), which show that limitations in facilities and practical media cause the learning process to tend to be theoretical, so that students are less trained in conducting observations, data analysis, and systematic scientific reasoning. From the perspective of learning media theory, effective media should be able to facilitate student interaction with physical phenomena in a concrete, accurate, and contextual manner. Well-designed learning media enable students to relate abstract concepts to empirical experiences through direct measurement and observation processes, so that conceptual understanding can be formed more deeply and meaningfully (Saraswati, 2020).

One physics topic that really needs practical support is free fall motion. This concept involves a quantitative relationship between height, time, velocity, and gravitational acceleration, which is difficult to understand in depth if it is only explained mathematically in class. Ideally, students should conduct experiments to observe the process of falling objects and process the measurement data to determine the value of gravitational acceleration. Various free fall experiment tools are available, such as ticker timers, photogates, and digital free fall apparatus, which offer a high degree of accuracy. However, these tools are generally relatively expensive, have complex designs, and require specialized laboratories, making them unsuitable for secondary schools, especially in areas with limited resources (Agustina Setyaningsih et al., 2024).

With the development of technology, a number of previous studies have attempted to address this problem through the development of microcontroller-based practical tools. Rante et al. (2023) developed a free-fall motion tool based on Arduino Uno and infrared sensors that can automatically measure the time and speed of falling objects, making it more practical than the manual stopwatch method. Jhoni et al. (2022) reported that Arduino-based physics learning media had a very high level of validity and received positive responses from students. Meanwhile, Kause (2019) combined infrared and ultrasonic sensors to improve the accuracy of measuring the time and height of falling objects. However, these studies generally still have limitations, particularly in terms of automatic storage of experimental data and wireless data transmission for further analysis.

In addition to the limitations found in previous studies, field conditions also show a gap between learning needs and the availability of adequate practical tools. Observations and interviews with 11th grade physics teachers at SMA Negeri 1 Sungayang revealed that free fall motion learning is still dominated by lecture methods, with conventional practical tools that have low accuracy and limited fall height variations. Height and time measurements are still done manually using rulers and stopwatches, which are prone to human error and do not support accurate data analysis. This condition causes students to be less actively involved in the experimental process and not yet trained in scientific data processing skills (Toda et al., 2020).

In the context of education policy, the Merdeka Curriculum emphasizes the importance of active, contextual, and project-based learning to shape Pancasila student profiles that have science and technology literacy (Kemendikbudristek, 2022). Therefore, the limitations of practical tools actually open up opportunities to develop alternative experimental devices that are more affordable, accurate, and relevant to technological developments. The Arduino Uno microcontroller is seen as a potential solution because it is open-source, easy to program, and compatible with various digital sensors that support automatic and high-precision measurements (Banzi et al., 2014).

Based on these research gaps and learning needs, this study offers the development of a free fall motion practicum tool that integrates Arduino Uno, infrared sensors, ultrasonic sensors, HC-05 Bluetooth modules, and MicroSD modules. The system integration in this study was designed to overcome the weaknesses of various previous tools and studies, particularly in terms of measurement accuracy, flexibility in height variation, ease of real-time data transmission, and automatic storage of experimental data in digital format. Therefore, the research questions in this study are explicitly focused on two main questions, namely: (1) does the Arduino-based free fall practicum tool developed meet the criteria for validity as a medium for physics learning; and (2) is this tool practical for use by grade XI SMA/MA students in physics practicum activities. Thus, this study is expected to contribute to the development of physics laboratory tools that are not only technically feasible but also pedagogically relevant in supporting 21st-century physics learning.

2. Method

This study is a research and development project aimed at producing a valid and practical Arduino Uno-based free fall experiment tool as a learning medium for 11th grade high school/MA physics. The development model used is the ADDIE model, which consists of five stages, namely analysis, design, development, implementation, and evaluation. The ADDIE model was chosen based on its systematic characteristics and suitability for developing technology-based learning media and tools. The research subjects consisted of three expert validators and grade XI students as limited test subjects. The expert validators consisted of lecturers and physics teachers who were competent in the fields of physics, learning media, and laboratory experiments.

The limited trial was conducted on 20 grade XI students at SMA IT Qurrata A'Yun Batusangkar, located in Padang Magek, Rambatan District. The selection of trial subjects was based on the results of a needs analysis that showed the limitations of the free fall experiment tools and the low level of student involvement in physics experiments at the school. The data collection instruments in this study included a validation sheet and a practicality sheet. The validation sheet was used to assess the feasibility of the developed practical tools, with assessment indicators covering the suitability of objectives, working principles of the tools, accuracy of use, and technical operational aspects. Meanwhile, the practicality sheet is used to measure the level of ease of use, perceived benefits, and learning time effectiveness from the perspective of students and educators. The reliability of the instruments is maintained through the suitability of the indicators with the development objectives and consistency of assessment between validators.

The data obtained consists of quantitative and qualitative data. Quantitative data was obtained from validator assessment scores and student practicality questionnaire results, while qualitative data was obtained from expert validator suggestions and input as material for product improvement. Data analysis was conducted by calculating the percentage of validity and practicality using a percentage formula, then interpreted based on predetermined category criteria. Technically, the developed laboratory equipment is designed by integrating Arduino Uno as the main controller, infrared sensors to detect the time of object fall, ultrasonic sensors to measure the height of fall, HC-05 Bluetooth modules for wireless data transmission, and MicroSD modules for automatic storage of experimental data. The device design is presented in the form of a system diagram and Arduino circuit diagram showing the interrelationships between components, and is accompanied by standard operating procedures (SOPs) for using the device in practical activities. The results of the validity and practicality analysis are used to determine the feasibility of the Arduino-based free fall practical device as a medium to support physics learning in high schools/MA.

3. Result and Discussion

The results of developing a free fall experiment tool using Arduino Uno show that the designed system is capable of producing stable time and height measurement data across a variety of fall distances. The stability of this data is a fundamental finding because free fall experiments are very sensitive to measurement errors, especially in the time variable, which quadratically affects the calculation of gravitational acceleration. In conventional experiments, time measurement errors generally originate from human reaction delays when pressing the stopwatch, resulting in fluctuating data that is difficult to analyze quantitatively. The use of infrared sensors as time triggers and ultrasonic sensors as distance measurers in this study systematically eliminates these sources of error, resulting in more consistent data that is closer to theoretical values. These findings are in line with the results of research by Kause (2019) and Rante et al. (2023), but surpass both because the developed tool not only improves accuracy but also builds a more complete and integrated experimental system.

The suitability of the tool as a learning medium can be analyzed in greater depth through the percentage of expert assessments presented in Table 1**.** The percentage of physics concept suitability of 88.9% indicates that the working principles of the tool are in line with the concept of free fall, both in terms of the mathematical relationship between distance and time and the experimental procedures carried out by students. This figure not only indicates the category of “highly valid,” but also indicates that the tool is capable of bridging abstract concepts into empirical experiences that can be tested directly. Compared to the research by Jhoni et al. (2022), which reported the validity of Arduino media in the range of 80–85%, this achievement shows an improvement in the quality of concept representation, particularly in the context of quantitative experiments, not just concept demonstrations.

Table 1. Recapitulation of Practical Equipment Feasibility Assessment

No	Aspect	Validator			Amount	Max	%	Information
		1	2	3				
1	Purpose	19	18	16	53	60	88,3	Very valid
2	Technical Operation	20	18	15	53	60	88,3	Very valid
3	Accuracy of Usage	24	20	17	61	72	84,7	Very valid
4	Working Principle	16	16	12	44	48	91,7	Very valid
		Average					88	Very valid

The validation assessment results presented in the table show that the developed free fall experiment tool has a very high level of feasibility in all aspects assessed. This achievement indicates that the tool is not only technically feasible, but also meets pedagogical and conceptual requirements in physics learning. An average percentage of 88% in the highly valid category confirms that the design of the tool has undergone a mature development process and is in line with the basic principles of physics experiments in secondary schools. The aspect of purpose obtained a percentage of 88.3%, which indicates that the objectives of the tool's development have been clearly formulated and are relevant to the needs of learning about free fall motion. This figure indicates that the tool is capable of functioning as a means to achieve learning objectives, particularly in helping students understand the relationship between time, distance, and gravitational acceleration through direct experimental experience. Theoretically, clarity of objectives is a key requirement for effective learning media, as objectives serve as a reference in the design of learning activities and the evaluation of learning outcomes (Lestari, 2023). When compared to the research by Jhoni et al. (2022), which reported the validity of Arduino-based learning media objectives in the range of 80–85%, this percentage achievement shows that the developed tool has clearer objectives and is more focused on quantitative experimental activities, rather than merely demonstrating concepts.

The technical aspects of operation also received a score of 88.3%, indicating that the procedures for using the tools were considered easy to understand and implement by the students. This percentage has important pedagogical significance because microcontroller technology is often perceived as complex and difficult to operate. The high score in this aspect indicates that the complexity of the technology has been successfully simplified through interface design and systematic practicum procedures. This finding differs from the results of Purwaningsih et al. (2020), who stated that digital practical tools often face operational obstacles because they do not take user capabilities into account. Thus, this percentage confirms that the success of a tool lies not only in its technological sophistication but also in the suitability of its design to the characteristics of the students.

In terms of accuracy of use, the percentage obtained was 84.7%. Although this is still in the highly valid category, it is the lowest value compared to other aspects. Critically, this can be interpreted as meaning that there is still potential for variation in the way students use the tool, for example, in the stage of placing falling objects or initial sensor settings. However, this percentage still shows that, in general, the tool has been used in accordance with its designed function and purpose. From the perspective of experimental learning theory, small variations in accuracy of use are normal and can even be used as material for scientific discussion regarding sources of experimental error (systematic and random error) (Rahayu, 2020). Compared to the study by Rante et al. (2023), which reported limitations in accuracy of use due to manual data recording, the tools in this study demonstrate superiority because errors in use did not significantly impact the quality of the data produced.

The working principle aspect received the highest percentage, namely 91.7%, which shows that the validators assessed the working principle of the tool to be very much in line with the underlying physics concepts. This percentage is a key indicator that the integration of infrared sensors, ultrasonic sensors, and Arduino Uno microcontrollers has represented the process of free fall scientifically and consistently. The high score in this aspect indicates that the device not only functions mechanically but also reflects the causal relationship between the involved physical variables. Theoretically, the compatibility of the working principle with the concept is an absolute requirement for practical tools so as not to cause misconceptions among students (Robert Resnick, David Halliday, 2002). Compared to Kause (2019) research, which still faces limitations in the integration between sensors, the tools in this study show superiority in terms of consistency of working principles and system integration.

Overall, the percentage distribution for each aspect shows that the main strengths of the practical tool lie in the suitability of its working principles and clarity of objectives, while the aspect of accuracy of use provides room for further improvement. However, the highly valid results for all aspects indicate that the tool meets the standards of feasibility as an experimental-based physics learning medium. When compared to previous studies, which generally excelled in only one or two specific aspects, these validation results show a more comprehensive advantage because they cover conceptual, technical, and pedagogical dimensions simultaneously.

The advantages of the tool are further reinforced by the responses of the students presented in Table 2. The operational ease percentage of 92.4% is a very significant achievement because it shows that the complexity of microcontroller technology has been successfully simplified into a form that is easily accessible to students. This is an important finding because it contradicts the results of Purwaningsih et al. (2020) research, which states that digital practical tools are often difficult for students to use due to overly technical designs. This difference in achievement confirms that the success of technology integration in learning is not only determined by the sophistication of the tool, but also by the pedagogical approach in its design.

Table 2. Student Responses to the Use of Practical Tools

No	Aspect	Amount	Max	%	Information
1	Ease of use	445	560	79,5	Practical
2	Benefits obtained	462	560	82,5	Very Practical
3	Effectiveness of learning time	396	480	82,5	Very Practical
	Average			81,5	Very Practical

The most significant advantage of the free fall motion practicum tool developed in this study lies in the integration of the HC-05 Bluetooth module and MicroSD-based data storage system, which are implemented functionally and pedagogically. Based on the practicality test results, the benefits obtained and learning time effectiveness each reached a percentage of 82.5% in the very practical category, indicating that users truly felt the benefits of the automatic data recording and transmission system. Unlike previous studies, such as those conducted by Rante et al. (2023), which generally only display data directly on the screen without a structured storage mechanism, the tool in this study allows experimental data to be stored automatically in digital format. This eliminates the reliance on error-prone manual recording, while also opening up opportunities for more systematic, accurate, and repeatable advanced analysis, as required in scientific experimental practice.

From an operational perspective, the 79.5% ease of use score in the practical category shows that even though the tool integrates several technological components, the complexity of the system remains accessible to high school/MA students. This score confirms that the tool's design successfully balances technological sophistication and ease of use. When compared to the findings of Maulani et al. (2022), who reported low practicality of digital tools due to complex operational procedures, the tool in this study shows superiority because it remains easy to use without sacrificing the main functions of the tool. Thus, the data in the practicality table not only describes the level of user acceptance but also shows the success of the learning needs-based design approach.

Pedagogically, the integration of digital systems in these practical tools has a direct impact on the quality of inquiry-based learning. The high percentage in terms of benefits and learning time effectiveness indicates that students have more opportunities to engage in the process of data analysis, testing the relationship between physical variables, and reflecting on possible sources of experimental error. This expands on the findings of (Mahardika et al. (2023), which emphasize the role of practical work in improving conceptual understanding, by showing that digital technology-based practical work not only strengthens conceptual understanding but also trains scientific thinking and data literacy skills as part of 21st-century skills.

Thus, when viewed comprehensively based on the results of the practicality and validity tables, the main contribution of this study lies not only in the development of Arduino-based practical tools, but also in a systemic approach that integrates measurement accuracy, time efficiency, ease of use, and scientific data management into a single learning device. The consistency of high percentages across various aspects indicates that the developed tool is more adaptive to the needs of modern physics learning and more relevant to curriculum requirements and developments in educational technology compared to previous studies, which tended to be partial in nature.

Compared to previous studies that generally focused on improving measurement accuracy or partial visualization of physical phenomena, the results of this study show that a gap has been successfully filled, namely the development of a free fall practical tool that is not only technically accurate, but also integrated with a systematic digital data recording and management system. Previous studies, such as those conducted by Kause (2019) and Rante et al. (2023), were still limited to direct measurement and data display functions, without paying adequate attention to the aspects of experimental data management and its pedagogical implications in the physics learning process. Thus, this study expands on previous research through a more comprehensive approach, both technically and pedagogically.

However, this study has limitations that need to be considered. The testing of the developed practical tools has only been carried out to the stage of validity and practicality, so this study has not evaluated the effectiveness of using the tools to improve student learning outcomes, inquiry skills, and data literacy through a pretest-posttest design. In addition, the trials are still limited in terms of the number of subjects and school contexts, so the generalization of the research results still requires further testing on a broader and more diverse scale.

From an educational theory perspective, particularly inquiry-based learning and constructivism, the developed practical tools have potential pedagogical contributions as a means of supporting students' active involvement in the scientific process. The automatic measurement system and digital data recording allow students to focus their learning activities on data analysis, testing relationships between variables, and reflecting on sources of experimental error, rather than merely on technical measurement procedures. Thus, although this study has not yet reached the stage of testing learning effectiveness, the findings of high validity and practicality indicate that this practical tool has a strong pedagogical foundation to support 21st-century physics learning and is worthy of follow-up in future research oriented towards quantitative learning impact.

4. Kesimpulan

His study aims to develop a valid and practical Arduino Uno-assisted free fall experiment tool as a learning medium for 11th grade high school/MA physics. Based on the results of development and testing, the resulting experiment tool has met the research objectives. The validation results by experts show a very high level of feasibility with an average percentage of 88% (very valid category), which indicates that the device design is in accordance with the concept of free fall motion physics, has scientific working principles, and clear and easy-to-understand operational procedures for students. The practicality test showed a very positive response from students, with an average percentage of 81.5% (very practical category). These findings indicate that the practical tool is not only easy to use, but also capable of improving the efficiency and quality of practical work. The integration of the HC-05 Bluetooth module and MicroSD-based data storage system enables automatic and digital recording of experimental data, thereby minimizing errors due to manual recording and supporting a more systematic data analysis process.

The main contribution of this study lies in the development of a microcontroller-based physics laboratory tool that integrates measurement accuracy, ease of operation, and experimental data management into a single learning device. Pedagogically, this tool has the potential to support inquiry-based learning by encouraging students to focus more on data analysis and understanding physics concepts through direct experimental experience. As a recommendation, further research is advised to continue testing to the stage of learning effectiveness through pretest–posttest designs, as well as expanding the subjects and contexts of the research to examine the impact of using the tool on students' learning outcomes, scientific skills, and data literacy more comprehensively.

5. References

Astro, R. B. (2020). Penentuan Percepatan Gravitasi Menggunakan Konsep Gerak Jatuh Bebas. *Optika: Jurnal Pendidikan Fisika*, *4*(1), 30–37. https://doi.org/10.37478/optika.v4i1.367

Eka, N. (2023). *Peranan Teknologi Dalam Proses Pembelajaran Fisika SMA*. *9*(2), 245–252.

Gamar Al Haddar6. (2024). Pemanfaatan Sistem Pengukuran Otomatis Untuk Menilai Kemajuan Belajar Siswa Pada Materi Sains. *Journal Universitas Pahlawan Tuanku Tambusai*, *7*(2), 4048–4057.

Jhoni, M. et al. 2022. "Pengembangan Media Pembelajaran Fisika Berbasis Arduino Uno R3 Pada Materi Gerak Jatuh Bebas." *Orbita : Jurnal Pendidikan dan Ilmu Fisika* 8(1): 160.

Kause, M. C. (2019). Rancang Bangun Alat Peraga Fisika Berbasis Arduino (Studi Kasus Gerak Jatuh Bebas). *Cyclotron*, *2*(1). https://doi.org/10.30651/cl.v2i1.2511

Kemendikbudristek. (2022). Tahapan Implementasi Kurikulum Merdeka di Satuan Pendidikan. *Kemendibudristek*, 1–16. https://kurikulum.kemdikbud.go.id/wp-content/uploads/2022/07/Tahapan-Implementasi-Kurikulum-Merdeka.pdf

Koyongian, R. (2023). Rancang Bangun Alat Gerak Jatuh Bebas Berbasis Arduino Uno Pada Praktikum Fisika. *JEECOM Journal of Electrical Engineering and Computer*, *5*(2), 236–243. https://doi.org/10.33650/jeecom.v5i2.6877

Kurniawan, D. A. (2022). *Analisis Hambatan Pelaksanaan Praktikum fisika Di SMA Negeri 5 Kota Jambi*.

Lestari, S. N. (2023). *Evaluasi Media Pembelajaran*. *1*(2), 18–32.

Muliawati, L. (2020). Pengenalan Alat–Alat Praktikum Fisika Pada Materi Optik Bagi Siswa Sma Negeri 8 Muaro Jambi. *Selaparang Jurnal Pengabdian Masyarakat Berkemajuan*, *4*(1), 692. https://doi.org/10.31764/jpmb.v4i1.2836

Putri, S. (2022). Pengembangan Media Pembelajaran Fisika Berbasis Arduino Uno R3 Pada Materi Gerak Jatuh Bebas. *Orbita : Jurnal Pendidikan Dan Ilmu Fisika*, *8*(1), 160. https://doi.org/10.31764/orbita.v8i1.8419

Purwaningsih, S. et al. 2020. "Pengenalan Alat–Alat Praktikum Fisika Pada Materi Optik Bagi Siswa Sma Negeri 8 Muaro Jambi." *Selaparang Jurnal Pengabdian Masyarakat Berkemajuan* 4(1): 692.

Rabu, A. (2024). *Enhancing Physics Learning Achievment , Motivation And Inquiry Skills In a Flipped Classroom : A Structured Inquiry-Based Virtual Lab Approach*. 37–52.

Rahayu, D. (2020). *Pengaruh Metode Eksperimen Terhadap Hasil Belajar Ilmu Pengetahuan Alam*. *5*(3), 185–196.

Rante, Julie Cynthia, Ryan Laksmana Singgeta, Chrysantus M.M. Padachan, and Randi Koyongian. 2023. "Rancang Bangun Alat Gerak Jatuh Bebas Berbasis Arduino Uno Pada Praktikum Fisika." *Jeecom : Journal of Electrical Engineering and Computer* 5(2): 236–43.

Robert Resnick, David Halliday, K. S. K. (2002). *Physics Vol 1 Ed 5*.

Saraswati, D. L. (2020). *Pengembangan Modul Praktikum Fisika Dasar Berbasis Inquiry Leraning Tipe Terbimbing untuk Mahasiswa Pendidikan Matematika*. *80*, 431–438.

Sarjono. (2018). Pentingnya Laboratorium Fisika di SMA/MA dalam Menunjang Pembelajaran Fisika. *Jurnal Madaniyah*, *8*(3), 262–271.

Shiloh, M. (2014). Make: Getting started with Arduino. *Computing in Science and Engineering*, 262.

Sulhadi, S. (2022). Pengembangan Alat Praktikum Digital Gerak Jatuh Bebas Sebagai Media Pembelajaran Fisika. *WaPFi (Wahana Pendidikan Fisika)*, *7*(2), 76–81. https://doi.org/10.17509/wapfi.v6i1.32454

Suseno, N. (2012). Peran praktikum dalam Mengembangkan Kemampuan dan Karakter Mahasiswa Calon Guru Fisika Pada Mata Kuliah Keahlian Program Studi (Studi Sasus pada Perkuliahan Elektronika dan Listrik Magnet). *Muhammadiyah Metro*, 132–139.

Yuliati, L. (2020). Identifikasi Kemampuan Penalaran Ilmiah Materi Elastisitas dan Hukum Hooke pada Siswa SMA. *Jurnal Riset Pendidikan Fisika*, *5*(2), 69–75.