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Development of Student Worksheet for Magnetic Induction Practicum with Real-Time Data Logger Integration

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Abstract

In order to enhance students' conceptual comprehension and practical physics learning abilities, this study intends to create a practicum worksheet on magnetic induction by incorporating data logger technology. Students frequently find the physics concept of magnetic induction to be difficult and abstract. To close the gap between theory and practice, a practical approach utilizing real-time data collection tools is crucial. The ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model is the development model that was employed in this study. The needs of the students and the requirements of the curriculum were determined during the analysis phase. After that, the worksheet was created to help students with experiments involving data loggers based on Arduino that measure variations in magnetic fields brought on by induced currents. Limited trials were carried out in a classroom environment during the implementation phase, and assessments were carried out using student input and expert validation. The findings demonstrated that the worksheet was interactive, well-structured, and successful in encouraging scientific thinking while assisting students in carrying out experiments on their own. Better visualization of magnetic field variations and increased measurement accuracy were made possible by the incorporation of data logger tools. It is anticipated that this practicum worksheet will be a cutting-edge educational tool that promotes purposeful, technologically advanced physics instruction.

Keywords: magnetic induction, physics practicum, student worksheet

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INTRODUCTION

The purpose of learning Physics is basically to lead students to understand the concepts of physics and their interrelationships in solving problems that exist in life (Weber & Wilhelm, 2024). Physics is often said to be complicated because of its abstract concept, this causes students to experience difficulties when studying Physics and solving physics problems (Giovana et al., 2024). To help students understand abstract physics concepts, media is needed in physics learning. The use of learning media has a positive influence on student learning outcomes because it creates interactive learning. Research conducted by Sondermann et al. (2024) concluded by using animation media, students focus on following the learning process, collaboration and interaction between students and teachers can be improved in a conducive classroom environment. Interactive learning is learning that involves active students learning or in other words students become actors in teaching and learning activities. By implementing interactive learning, students can visualize, understand, and conceptualize the material being studied (Errabo & Ongoco, 2024). This allows students to develop a positive attitude, self-confidence, active learning skills, and scientific thinking (Costabile et al., 2024).

Practicum activities as learning are one way that can be done to create active student learning, because it can give students direct experience with using practicum tools, making measurements, making observations, and carrying out predetermined practicum procedures (Wang & Cai, 2023; Skulmowski, 2024). To support the effectiveness of practicum-based learning, it is important to develop well-structured student worksheets that guide students through each phase of the scientific process (Adeyele, 2024). The integration of worksheets into physics practicum particularly those designed for experiments such as magnetic induction enables students to engage in hands-on activities with clarity and purpose (Lichtenberger et al., 2024). A quality worksheet includes clear objectives, procedures, tables for recording observations, and reflective questions to deepen understanding. These worksheets also serve as a bridge between theory and practice, especially when enhanced with modern tools such as data loggers (Lim, 2024). Through this integration, students are not only collecting and analyzing real-time data but are also encouraged to interpret it critically based on guided prompts within the worksheet (Kok & Priemer, 2023; Coscia et al., 2023).

By applying direct learning experience through practicum activities, namely observing, measuring, collecting data, and processing measurement results then drawing conclusions to solve or prove a theory can help achieve conceptual understanding (Alexander & Fuqua, 2024). This allows students to discover scientific concepts and develop a critical attitude. Learning by applying the experimental method or practicum activities results in a better understanding of physics concepts in students compared to students who use the question and answer lecture method (Dostal, 2024). The practicum tools are tools in learning that are used to analyze the characteristics of phenomena in the science learning process and can produce learning effectiveness and increase student learning motivation (Ojetunde & Ramnarain, 2025).

However, Experimental or practicum activities that are carried out often face obstacles, including inadequate supporting facilities, lack of completeness of practicum materials, insufficient time allocation for practicums, lack of preparedness of laboratory assistants in preparing practicum tools and materials, and no laboratory assistants in several schools (Reyes et al., 2024). Insufficient time allocation constraints for practicum can be overcome by using experimental tools equipped with data logger equipment. Data logger is a tool for recording data with sensors and probes with a certain accuracy (Yin et al., 2025). It is a device that combines analog and digital measurements with a programming procedure that detects temperature, relative humidity and other parameters (Mandal et al., 2025). The use of data loggers can be utilized in practical activities. The ability of data loggers to record and store data automatically can make experimental activities faster and more efficient with various physical parameters.

The following table shows a comparison of conventional practicum and practicum with data loggers.

Table 1. Comparison of conventional practicum and practicum using data loggers.

Comparison	Conventional	Data Logger
Implementation	• Manual • Takes more time	• Automatic • Faster
Data Accuracy	Accurate	Very Accurate
Result	• Observations must be carried out carefully • Recording of numerical experiment results	• Data is recorded automatically and in real time • Records can be displayed numerically, graphically, diagrams, or tables

There are many applications of the concept of electromagnetism in everyday life. To fully optimize the benefits of data loggers in practicum activities, the development of corresponding worksheet must also be adapted. Worksheets designed with data logger integration allow students to analyze trends, visualize phenomena, and draw conclusions more efficiently within limited class time. Moreover, when the worksheet includes tasks aligned with higher-order thinking skills, it helps students transition from procedural understanding to conceptual mastery. In this way, combining structured worksheet development with technology-enhanced tools like data loggers supports the goal of modern physics education: fostering independent, analytical, and science-literate learners. However, many students do not understand the concept of electromagnetism properly. This is because the concept of electromagnetism is abstract, so learning media is needed to explain the concept. Based on this description, this study aims to develop a worksheet of magnetic induction practical tool so that it can help students understand one of the concepts of electromagnetism.

METHOD

This research uses research and development methods (R&D), methods referring to the ADDIE development model. There are 5 stages in the ADDIE development model, this is shown in the following figure .

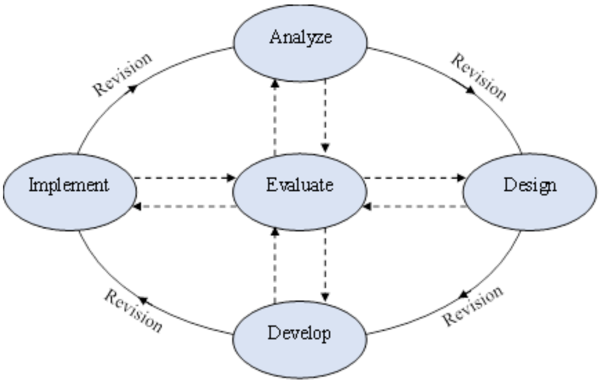


Figure 1. ADDIE Development Model

Analyze

This stage aims to identify possible causes of discrepancies. The analysis phase contains the identification of existing problems in life to determine research objectives, confirm the intended users or audience, and identify the resources needed.

Design

The aim of this stage is to design suitable test steps and methods. The design stages are as follows: perform a task inventory, set performance goals, and create a test strategy.

Development

This stage contains activities to realize the design plan that has been made, namely to produce the product you want to develop, and to test the validity of the product being developed.

Implementation

This stage contains conducting limited product trials to implement products that have been developed in classroom learning.

Evaluate

This stage aims to evaluate each step. At this stage an evaluation of the product being developed is carried out, both before and after implementation.

Research Instrumen and Respondents

The instrument is a non-test questionnaire whose results are obtained in the form of a Likert scale. The feasibility test is carried out by media experts and a product readability test will be carried out by teachers and students.

RESULTS AND DISCUSSION

Analysis

In this stage, the researchers conducted a needs analysis involving both students and teachers regarding the use of practicum-based instructional media. The analysis includes curriculum review, identification of relevant basic competencies related to magnetic induction, and an examination of school laboratory infrastructure. This stage also involves analyzing student characteristics and common problems in conventional practicum implementation, such as time constraints and limited measuring tools. The results of this analysis serve as the foundation for developing a more efficient and technology-integrated practicum worksheet.

Design

At this stage, the structure and content of the practicum worksheet are designed in alignment with inquiry-based or discovery learning models. The worksheet design includes learning objectives, practicum procedures, data observation sheets, and guiding questions for analyzing the results. The research instruments are also prepared, including expert validation forms, practicum implementation observation sheets, and concept mastery tests. The integration of data logger tools is planned to allow students to measure physical quantities such as current and voltage in real time, supporting efficient and accurate data collection.

Development

During the development stage, the initial version of the practicum worksheet is created based on the design phase. The worksheet uses student-friendly language, visual aids, and detailed instructions for using the data logger. Expert validation is carried out involving two experts: a subject matter expert (physics) and a learning media expert. Their suggestions are used to revise and refine the worksheet. Additionally, the functionality of the data logger tools is tested to ensure compatibility with the designed practicum activities.

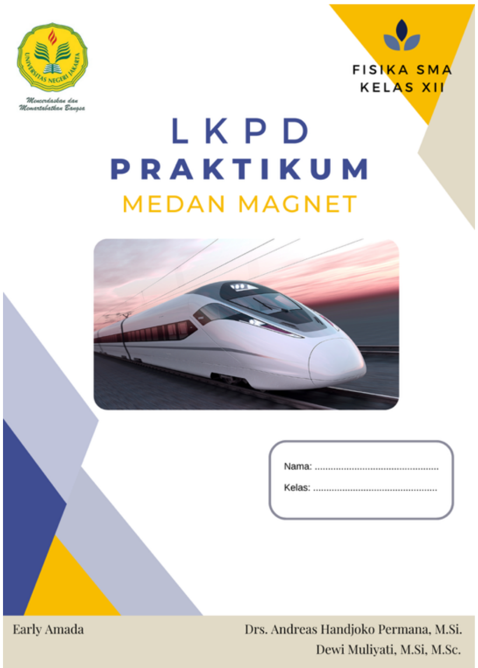
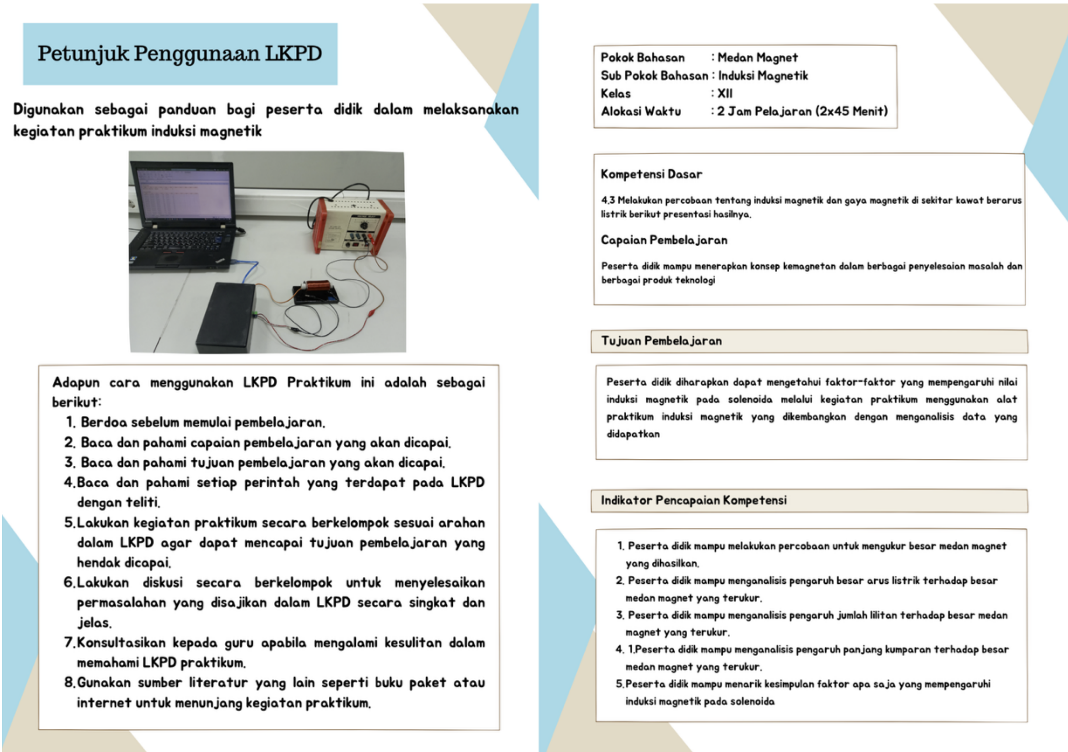


Figure 2. Worksheet Cover



Petunjuk Penggunaan LKPD

Digunakan sebagai panduan bagi peserta didik dalam melaksanakan kegiatan praktikum induksi magnetik

Adapun cara menggunakan LKPD Praktikum ini adalah sebagai berikut:

1. Berdoa sebelum memulai pembelajaran.
2. Baca dan pahami capaian pembelajaran yang akan dicapai.
3. Baca dan pahami tujuan pembelajaran yang akan dicapai.
4. Baca dan pahami setiap perintah yang terdapat pada LKPD dengan teliti.
5. Lakukan kegiatan praktikum secara berkelompok sesuai arahan dalam LKPD agar dapat mencapai tujuan pembelajaran yang hendak dicapai.
6. Lakukan diskusi secara berkelompok untuk menyelesaikan permasalahan yang disajikan dalam LKPD secara singkat dan jelas.
7. Konsultasikan kepada guru apabila mengalami kesulitan dalam memahami LKPD praktikum.
8. Gunakan sumber literatur yang lain seperti buku paket atau internet untuk menunjang kegiatan praktikum.

Pokok Bahasan : Medan Magnet
Sub Pokok Bahasan : Induksi Magnetik
Kelas : XII
Alokasi Waktu : 2 Jam Pelajaran (2x45 Menit)

Kompetensi Dasar

4.3 Melakukan percobaan tentang induksi magnetik dan gaya magnetik di sekitar kawat berarus listrik berikut presentasi hasilnya.

Capaian Pembelajaran

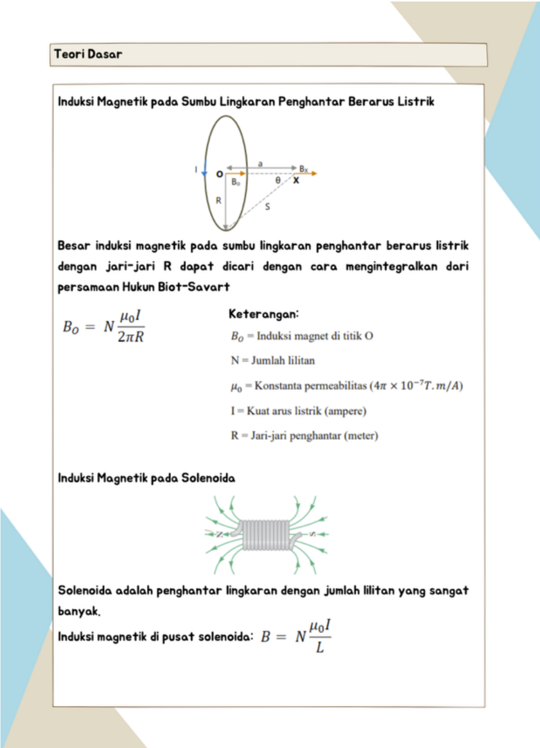
Peserta didik mampu menerapkan konsep kemagnetan dalam berbagai penyelesaian masalah dan berbagai produk teknologi

Tujuan Pembelajaran

Peserta didik diharapkan dapat mengetahui faktor-faktor yang mempengaruhi nilai induksi magnetik pada solenoida melalui kegiatan praktikum menggunakan alat praktikum induksi magnetik yang dikembangkan dengan menganalisis data yang didapatkan

Indikator Pencapaian Kompetensi

1. Peserta didik mampu melakukan percobaan untuk mengukur besar medan magnet yang dihasilkan.
2. Peserta didik mampu menganalisis pengaruh besar arus listrik terhadap besar medan magnet yang terukur.
3. Peserta didik mampu menganalisis pengaruh jumlah lilitan terhadap besar medan magnet yang terukur.
4. 1.Peserta didik mampu menganalisis pengaruh panjang kumparan terhadap besar medan magnet yang terukur.
5. Peserta didik mampu menarik kesimpulan faktor apa saja yang mempengaruhi induksi magnetik pada solenoida



Teori Dasar

Induksi Magnetik pada Sumbu Lingkaran Penghantar Berarus Listrik

Besar induksi magnetik pada sumbu lingkaran penghantar berarus listrik dengan jari-jari R dapat dicari dengan cara mengintegralkan dari persamaan Hukun Biot-Savart

$$B_O = N\frac{\mu_0 I}{2\pi R}$$

Keterangan:

B_O = Induksi magnet di titik O

N = Jumlah lilitan

μ_0 = Konstanta permeabilitas ($4\pi \times 10^{-7} T.m/A$)

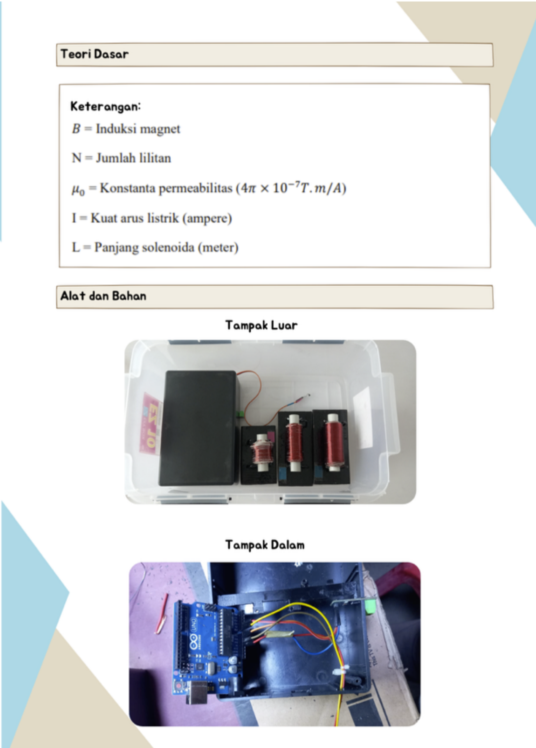
I = Kuat arus listrik (ampere)

R = Jari-jari penghantar (meter)

Induksi Magnetik pada Solenoida

Solenoida adalah penghantar lingkaran dengan jumlah lilitan yang sangat banyak.

Induksi magnetik di pusat solenoida: $B = N\frac{\mu_0 I}{L}$



Teori Dasar

Keterangan:

B = Induksi magnet

N = Jumlah lilitan

μ_0 = Konstanta permeabilitas ($4\pi \times 10^{-7} T.m/A$)

I = Kuat arus listrik (ampere)

L = Panjang solenoida (meter)

Alat dan Bahan

Tampak Luar

Tampak Dalam

Alat dan Bahan

Kumparan solenoida (lilitan)

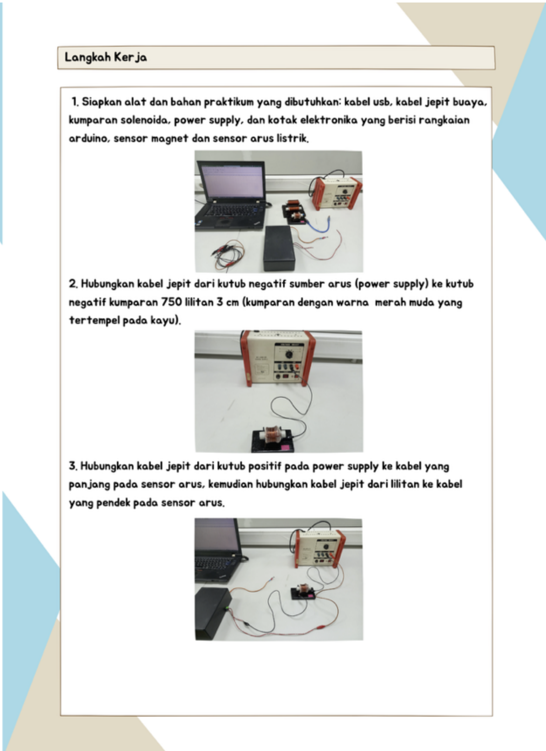
Kumparan lilitan sebanyak 750 lilitan (3 cm dan 6 cm), dan 1300 lilitan (6 cm) untuk dialiri arus listrik dan dideteksi medan magnet.

Power supply analog

Power supply atau catu daya sebagai sumber listrik untuk dialiri pada lilitan.

Kotak elektronika

Kotak elektronika sebagai tempat berisi rangkaian arduino dengan sensor arus dan sensor magnet

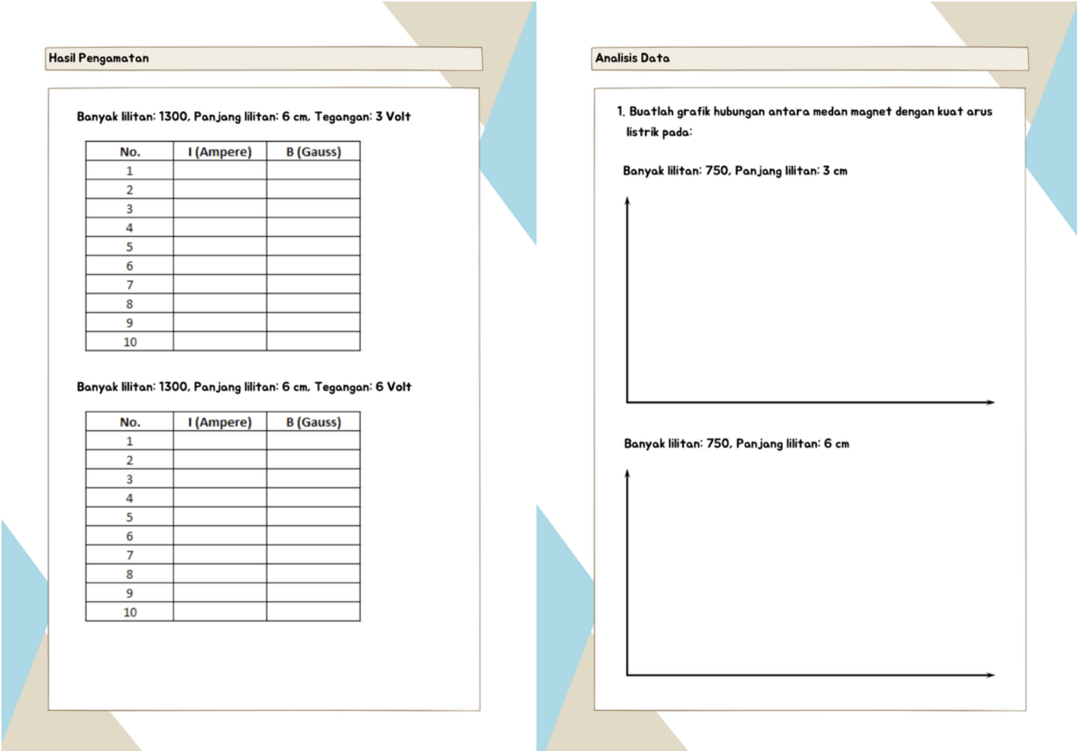


Langkah Kerja

1. Siapkan alat dan bahan praktikum yang dibutuhkan: kabel usb, kabel jepit buaya, kumparan solenoida, power supply, dan kotak elektronika yang berisi rangkaian arduino, sensor magnet dan sensor arus listrik.

2. Hubungkan kabel jepit dari kutub negatif sumber arus (power supply) ke kutub negatif kumparan 750 lilitan 3 cm (kumparan dengan warna merah muda yang tertempel pada kayu).

3. Hubungkan kabel jepit dari kutub positif pada power supply ke kabel yang panjang pada sensor arus, kemudian hubungkan kabel jepit dari lilitan ke kabel yang pendek pada sensor arus.



Hasil Pengamatan

Banyak lilitan: 1300, Panjang lilitan: 6 cm, Tegangan: 3 Volt

No.	I (Ampere)	B (Gauss)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Banyak lilitan: 1300, Panjang lilitan: 6 cm, Tegangan: 6 Volt

No.	I (Ampere)	B (Gauss)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Analisis Data

1. Buatlah grafik hubungan antara medan magnet dengan kuat arus listrik pada:

Banyak lilitan: 750, Panjang lilitan: 3 cm

Banyak lilitan: 750, Panjang lilitan: 6 cm

Figure 3. The content of the worksheet

Implementation

After revision, the worksheet is implemented with a group of students from grade XII at a selected school. The implementation involves a laboratory session where students conduct the magnetic induction experiment using data logger tools while completing the worksheet. The researchers observe the implementation process and collect feedback from both students and teachers regarding the usability and effectiveness of the worksheet in facilitating practicum-based learning.

Figure 4. Implementation in Classroom

Evaluation

The final stage is aimed at evaluating the **validity, practicality, and effectiveness** of the developed worksheet. Formative evaluation is conducted throughout the development process via expert validation and limited trials. Summative evaluation is carried out after implementation through pre-test and post-test results to assess conceptual understanding, observation of student engagement, and questionnaires to gather responses from students and teachers. These evaluations inform further revision and finalization of the product for broader classroom use.

An important advancement in physics education is the creation of a practicum worksheet for magnetic induction that is based on a data logger. Due to the heavy reliance on lectures and textbook materials in traditional physics education, students may find it challenging to fully understand abstract concepts like magnetic induction (Harmer et al., 2024). Through the incorporation of Arduino-based data logging tools into the worksheet, this study offers students the opportunity to observe and analyze real-time magnetic field data during practicum activities, creating a more dynamic and experiential learning environment (Lin et al., 2024). In addition to helping students use the data logger, the worksheet aims to improve their capacity for scientific inquiry. Students are encouraged to create hypotheses, measure things, document their findings, and examine how current, magnetic fields, and the physical setup relate to one another. The ideas of inquiry-based learning, which encourage critical thinking, problem-solving, and active student participation, are well-aligned with this structure.

The practicum worksheet covers important physics learning competencies from a pedagogical standpoint, such as conceptual comprehension, data interpretation, and experimental skills (Kilpeläinen-Pettersson et al., 2025). Additionally, the data logger system's technological integration exposes students to scientific instruments of the twenty-first century, preparing them for advanced

STEM coursework and careers. Automated data collection reduces human error, improves measurement precision, and frees up class time for discussion and introspection. The limited trial's findings demonstrate that students react favorably to the worksheet (Li et al., 2024). They state that the practicum is more engaging and pertinent due to the use of sensors and digital measurement tools, and that the detailed instructions are simple to follow. The organized structure and the way it encourages student independence and teamwork during lab sessions are also valued by teachers.

All things considered, this worksheet serves as a bridge between theoretical knowledge and real-world application in addition to being a learning tool. It encourages a more thorough and enduring comprehension of the subject of magnetic induction by supporting a change in physics education from passive reception to active discovery. To assess long-term learning gains and the product's scalability, more testing with a larger sample is advised.

CONCLUSION

This study has produced a practicum worksheet integrated with an Arduino-based magnetic induction tool aimed at supporting the learning process in physics, particularly to improve students' understanding of magnetic field concepts through hands-on and interactive learning. The development of the worksheet was carried out systematically, beginning with identifying learning needs in the classroom, analyzing students' difficulties in understanding abstract concepts, and recognizing the limited access to effective practicum tools. The worksheet was designed to guide students through structured practicum steps, starting from problem orientation, data collection, to drawing conclusions based on experimental findings. It was developed with attention to clarity, interactivity, and alignment with learning objectives. Through this worksheet, students are encouraged not only to conduct measurements using data logger technology but also to interpret data scientifically and reflect on the underlying physical principles. Overall, this product can be considered as an innovative instructional tool that combines practical skills with conceptual learning. It is expected that this worksheet, when applied more broadly, can contribute positively to the quality of physics education. However, further development and broader implementation are needed to measure its long-term impact and effectiveness in diverse classroom settings.

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