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Development of a Practical Module for Mechanical to Heat Energy Conversion: An Exploration with CASSY Lab-Based Experiments

Pengembangan Modul Praktikum untuk Konversi Energi Mekanis menjadi Energi Panas: Eksplorasi Berbasis Eksperimen dengan CASSY Lab

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Abstract: Physics experiments are integral to enhancing students' conceptual understanding, particularly in topics that involve complex quantitative analyses. Traditional teaching methods, however, cannot often effectively develop students' analytical skills. To address this issue, this study introduces a research-based practical module to bridge these gaps. The module focuses on optimizing learning outcomes related to converting mechanical energy to heat energy through experiments conducted with advanced technology-based tools, including Mobile-CASSY. Employing the ADDIE model, the module was systematically developed and implemented. Key components involved designing experiments that utilized NiCr-Ni temperature sensors and advanced data analysis software to validate energy conservation principles. The results from pretests and posttests indicated significant improvements in students' conceptual understanding. Furthermore, feedback from questionnaires underscored the module's efficacy in fostering technology-driven learning environments. These findings contribute substantively to the advancement of physics education by offering a sustainable and practical approach to integrating experimental and theoretical learning at the tertiary level.

Keywords: *Practical module, Mechanics to heat energy conversion, Mobile-CASSY, technology-based physics learning*

Abstrak: Eksperimen fisika merupakan elemen penting dalam meningkatkan pemahaman konseptual mahasiswa, terutama pada topik yang melibatkan analisis kuantitatif kompleks. Metode pengajaran tradisional sering kali kurang efektif dalam mengembangkan keterampilan analitis mahasiswa. Untuk mengatasi masalah ini, penelitian ini memperkenalkan modul praktikum berbasis riset yang bertujuan untuk menjembatani kesenjangan tersebut. Modul ini berfokus pada optimalisasi hasil pembelajaran terkait konversi energi mekanis menjadi energi panas melalui eksperimen yang dilakukan dengan menggunakan alat berbasis teknologi canggih, termasuk Mobile-CASSY. Dengan menggunakan model pengembangan ADDIE, modul ini dikembangkan dan diimplementasikan secara sistematis. Komponen utama melibatkan perancangan eksperimen yang memanfaatkan sensor suhu NiCr-Ni dan perangkat lunak analisis data untuk memvalidasi prinsip konservasi energi. Hasil dari pretest dan posttest menunjukkan peningkatan signifikan dalam pemahaman konseptual mahasiswa. Selain itu, umpan balik dari kuesioner menegaskan efektivitas modul dalam mendukung lingkungan pembelajaran berbasis teknologi. Temuan ini memberikan kontribusi signifikan terhadap pengembangan pendidikan fisika dengan menawarkan pendekatan yang berkelanjutan dan efektif untuk mengintegrasikan pembelajaran eksperimental dan teoretis di tingkat perguruan tinggi.

Kata kunci: *Modul praktikum, konversi energi mekanis ke panas, Mobile-CASSY, pembelajaran fisika berbasis teknologi.*

INTRODUCTION

Understanding the fundamental principles of energy is essential in physics. Mechanical and heat energy, as components of thermodynamics, provide deep insights into the relationship between work and energy. The law of energy conservation, articulated by Hermann von Helmholtz in 1847, has become a cornerstone of modern science and technology (Caneva, 2021).

Physics education at the university level must integrate theory with practical applications to develop students' analytical skills. Hake (1998) found that interactive, experiment-based learning methods were significantly more effective than traditional lecture approaches. Students apply theoretical concepts through direct observation, resulting in deeper comprehension.

However, traditional laboratory tools often pose barriers to effective learning. Conventional calorimeters, for instance, may lack precision and cannot provide real-time data. However, the advent of modern technologies, such as Mobile-CASSY, a portable data acquisition system that enables high-precision measurements and integrated digital data analysis, is transforming the landscape of physics education. These technologies offer transformative solutions, enhancing students' learning experiences and inspiring a new wave of optimism about the future of physics education (Kohl, Rosengrant, & Finkelstein, 2007).

Additionally, the growing demands of the industry require graduates with strong data analysis and technological skills. Integrating technological tools into the curriculum enhances conceptual understanding and prepares students to face professional challenges. Advanced tools in physics education have been shown to improve students' problem-solving abilities (Singh & Marshman, 2015).

Addressing these needs, this research aims to develop a technology-based practical module to enhance students' understanding of converting mechanical energy to heat energy. This module leverages Mobile-CASSY devices and experimental approaches to integrate theory and practice effectively.

METHOD

This study employed the ADDIE model as a systematic framework to guide the practical module's development, implementation, and evaluation. Each phase of ADDIE—Analysis, Design, Development, Implementation, and Evaluation—was rigorously applied to ensure the module was practical, adaptable, and aligned with educational objectives. The model's structured approach facilitated the integration of theoretical concepts with practical applications using advanced technology tools like Mobile-CASSY, directly addressing the learning needs highlighted in the introduction. The ADDIE model is well-recognized in educational research for its structured approach and validity in creating effective instructional designs (Strickland & Strickland, 2012; Kurt, 2017).

The study involved 30 undergraduate students enrolled in physics laboratory courses at Jambi University. These students were selected using stratified sampling to ensure representation across academic performance levels, accounting for variations in prior knowledge, learning styles, and engagement with technology. This comprehensive approach to participant selection ensured that the sample reflected the diverse learning needs highlighted in the introduction, enabling a more comprehensive evaluation of the module's effectiveness and reassuring the audience about its quality and impact.

Key instruments included Mobile-CASSY for real-time data acquisition, NiCr-Ni temperature sensors for precise thermal measurements, and aluminum calorimeters for controlled experimental conditions. The use of Mobile-CASSY directly addressed the limitations of traditional tools, such as the lack of real-time data and precision, as noted in the introduction. These tools provided high accuracy and digital integration, allowing students to effectively validate theoretical principles with empirical data. The CASSY Lab 2 software further enabled students to visualize experimental outcomes and correlate findings with theoretical principles. Mobile applications like Mobile-CASSY are widely regarded as transformative tools in physics education because they enhance student engagement and provide precise real-time data analysis (Kholikov et al., 2021; Thongsi et al., 2020).

The module was developed in iterative stages. Initial drafts were piloted with small groups of students, and feedback was collected through surveys and focus group discussions. Each iteration was designed to align with and integrate advanced technological tools like Mobile-CASSY to create a robust technology-integrated learning environment. Revisions focused on enhancing the instructional content, experimental procedures, and visual aids to support better the theoretical and practical integration highlighted in the introduction. Following this, the refined module was implemented in formal laboratory sessions, where students conducted experiments independently under guided supervision.

Quantitative data from pretest and posttest scores were analyzed using paired t-tests to measure learning gains. Paired t-tests are particularly effective in evaluating changes within the same group over time, making them suitable for assessing the module's impact on students' theoretical understanding and practical application skills. Descriptive statistics were employed to evaluate questionnaire feedback on module usability, clarity, and effectiveness, providing a comprehensive overview of user perceptions. The results were compared against baseline data to identify significant improvements and areas for further enhancement.

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RESULTS AND DISCUSSION

The developed practical module can also be accessed online, providing additional flexibility for educators and students. The integration of accessible digital tools like Mobile-CASSY is consistent with research emphasizing the importance of technology in modern physics education, such as smartphone-assisted modules shown to improve competencies (Fadieny et al., 2022). This feature ensures that the module is available globally for review and implementation. Users can explore the module's content and supplementary materials through the QR code and link provided below:

Figure 1: QR Code for Flipbooks module through access link https://heyzine.com/flip-book/06ab478772.html

The validation process revealed an overall score of 86.93%, underscoring the module's alignment with high educational standards. This score was derived by averaging the ratings across six key aspects: Learning Objectives, Theoretical Relevance, Experiment Guidance, Data Analysis Depth, Logical Structure, and Language Clarity. Each element was evaluated by three reviewers using a consistent scoring framework, and their ratings were averaged to produce the final validation score. These aspects collectively reflect the module's effectiveness in aligning with educational standards and meeting the instructional needs of students in physics education. A detailed summary of the validation findings is provided below:

Table 1. Summary of Validation Scores for Module Effectiveness

Validation Aspect	*Average Score*
Learning Objectives	4.33
Theoretical Relevance	4.17
Experiment Guidance	4.50
Data Analysis Depth	4.00
Logical Structure	4.50
Language Clarity	4.44
Overall Average	4.32

These scores indicate that the module provides clear experimental guidance and maintains a logical structure. This aligns with findings from Rizaldi and Syahwin (2022), which demonstrated the importance of structured e-modules in enhancing students' scientific process skills. However, the relatively lower score for data analysis depth suggests areas for enhancement. Providing students with more detailed instructions on data interpretation, incorporating step-by-step guides for statistical analysis, and including examples of expected results can significantly improve this aspect. Furthermore, integrating interactive tools or software tutorials may bolster students' engagement and analytical capabilities. Enhancing this aspect can improve students' ability to critically analyze outcomes and strengthen their comprehension of the underlying theoretical concepts.

Additionally, reviewer feedback emphasized the need for more diverse and illustrative examples within the module. While the overall scores reflect a robust instructional design, addressing these targeted areas of improvement can elevate the module's effectiveness further. Additionally, pretest and posttest performance data highlighted significant learning gains among participants. Similar results have been reported by Budiman and Permatasari (2019), who emphasized the role of mobile learning platforms in improving students' understanding of physics concepts. A summary of these findings is outlined below:

Table 2. Summary of Pretest and Posttest Performance Metrics

Metric	*Pretest*	*Posttest*	*Improvement*
Average Scores	72.08	88.62	16.54

These outcomes affirm the module's effectiveness in enhancing students’ comprehension of energy principles and integrating theoretical and practical knowledge. Compared to existing literature, such as Hake (1998) and Singh and Marshman (2015), which emphasize the benefits of interactive learning and advanced tools in physics education, this study demonstrates a novel approach by leveraging Mobile-CASSY to bridge experimental and theoretical gaps. This contribution is particularly significant in addressing limitations found in traditional teaching methods, further establishing the module's relevance in modern educational settings. Mobile-CASSY tools facilitated these improvements by providing real-time data and analytical capabilities.

CONCLUSION

The developed module bridges the gap between theoretical and practical physics education, significantly improving students' comprehension of energy concepts and their ability to apply theoretical knowledge in experimental settings. Implementing Mobile-CASSY and other advanced tools has demonstrated the potential to revolutionize physics education by enabling real-time data acquisition and analysis, strengthening students' analytical skills. Additionally, the module's alignment with high educational standards, as reflected in validation scores and learning gains, highlights its effectiveness and relevance. Future research should explore broader applications of this module in interdisciplinary settings, such as engineering and environmental science, to further extend its impact. Furthermore, incorporating feedback mechanisms to refine data analysis instructions and integrating additional interactive elements could enhance the module's adaptability and accessibility for diverse educational contexts.

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The authors emphasize that all suggestions and outputs from the AI tools were carefully reviewed, revised, and incorporated only after thorough verification to align with the study's goals and academic standards.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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