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Effectiveness of Experimental Tools for Testing the Permeability of Metal Materials to Increase Student Learning Motivation

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ABSTRACT
This study investigates the effectiveness of an experimental apparatus designed to measure the permeability of metal materials as an instructional medium for enhancing the learning motivation of 12th-grade science students on the topic of magnetic fields. The research was conducted at SMAIT Al Fityah Pekanbaru and MA Darul Hikmah Pekanbaru, involving 20 students from each institution. The apparatus was specifically developed to facilitate hands-on exploration of magnetic permeability in various metals. Employing a pre-experimental method, the study adopted a Pretest-Posttest Group Design to assess changes in student motivation. Data were collected using a validated ARCS learning motivation questionnaire, which evaluates four components: Attention, Relevance, Confidence, and Satisfaction. Motivation scores were recorded before and after the intervention, and the results were analyzed descriptively using normalized gain (N-Gain) and its corresponding percentage. The findings revealed a significant improvement in students' motivation following the use of the experimental tool. The N-Gain percentage reached 86%, surpassing the established threshold for effectiveness (>75%). These results indicate that the tool is not only functional but also pedagogically effective in fostering increased motivation in learning physics, particularly in understanding abstract concepts such as magnetic permeability.

Keywords : *effectiveness, experimental tools, metallic materials motivation, testing permeability*

INTRODUCTION

In the context of physics, effectiveness refers to the deliberate and optimal use of resources, tools, and infrastructure to generate energy, force, or transformation within an experimental or educational setting (Sukma, 2021). Effectiveness is commonly defined as the extent to which predetermined objectives are achieved through efficient data use, structured implementation, and time management (Maulida & Kusumaningtyas, 2017). In an educational context, learning effectiveness encompasses the strategies and actions that contribute to student success and the attainment of desired learning outcomes (Saregar et al., 2016).

Physics education is often perceived as challenging due to the abstract nature of the material, which students frequently find confusing and disconnected from real-life contexts (Kanti et al., 2022). Physics involves the study of natural phenomena and their interactions, emphasizing the understanding of facts, concepts, principles, laws, and formulas that must be validated through scientific inquiry such as observation and experimentation. This learning process also requires the cultivation of scientific attitudes—curiosity, openness, honesty, and critical thinking (Khairunnisa et al., 2018). Consequently, many students develop anxiety or aversion toward physics, highlighting the urgent need for effective learning media and pedagogical support (Nurhaniah et al., 2022; Turner & Rapoport, 2016).

Educators play a critical role as cognitive, emotional, and psychomotor facilitators. Their primary responsibility is to foster a conducive and motivating learning environment. Rather than serving as the sole source of knowledge, teachers are expected to engage students actively in the learning process (Ouda & Abdel-Gawwad, 2017). Several interrelated factors—learning materials, classroom atmosphere, media and learning resources, and teacher competence—collectively influence academic achievement. A weakness in any of these areas may hinder learning outcomes. Thus, selecting appropriate teaching tools aligned with learning objectives is essential for effective physics instruction (Anwar & Nurmina, 2019). Given physics' crucial role in helping students interpret and understand the physical world, teachers must be capable of creating learning environments that stimulate curiosity and critical engagement. Effective learning materials can serve as a bridge between theory and application, enabling students to relate abstract concepts to tangible experiences (Wisic & Makiyah, 2021).

Motivation is one of the most influential factors in student engagement and success in science education. It serves as an internal drive that compels students to strive for excellence (Sari & Sunarno, 2018). Motivation energizes students' interest, concentration, and persistence in learning. When engaging tools—such as interactive experiments or multimedia—are introduced, they often increase student motivation and participation, thereby enhancing academic performance (Harahap & Siregar, 2020). Learning outcomes, as indicators of instructional success, are shaped by teacher quality, student characteristics, curriculum design, and learning infrastructure. Outcomes may include cognitive gains, practical skills, and affective development. These can be measured through various assessment methods, such as written tests for theory and performance tasks for skills (Anwar, 2017). Teaching aids have been found to improve both student motivation and cognitive engagement. Their use fosters active participation and critical thinking, making physics instruction more dynamic and meaningful (Yunita & Ilyas, 2019).

Motivation is thus a core component of effective learning. It stimulates curiosity and interest, both of which are closely linked to academic performance (Yusuf et al., 2017). Periodic assessments of student motivation, particularly in physics, are recommended to help educators refine their instructional approaches (Sasmita et al., 2021). Students with higher interest levels are more likely to engage actively and achieve better academic outcomes (Rahma, 2023). Teachers, as facilitators, must go beyond traditional roles to create a supportive learning environment that encourages student exploration and curiosity. Their ability to innovate and adapt teaching strategies is vital to maintaining student interest and improving outcomes (Ernidawati et al., 2021).

Building on this foundation, the present study seeks to evaluate the effectiveness of a newly developed experimental apparatus designed to test the magnetic permeability of metal materials. This study is situated in the context of improving motivation among 12th-grade science students in Pekanbaru. The rationale stems from the pedagogical need to enhance students' understanding of abstract scientific concepts—such as magnetic permeability—through direct experimentation. Unlike traditional resources, the experimental tool introduced in this study allows students to observe and explore scientific phenomena in an interactive manner, thus increasing both engagement and comprehension.

The novelty of this research lies in the creation and implementation of a dedicated tool for testing metal permeability, a topic that is seldom demonstrated in standard classroom settings. Moreover, the study does not merely focus on tool development, but also investigates its influence on student motivation and participation in the physics learning process. By integrating this apparatus into the classroom, educators can offer a more immersive and motivating experience, bridging the gap between theoretical instruction and practical application.

METHODOLOGY

This study was conducted at SMAIT Al Fityah Pekanbaru and Madrasah Aliyah Darul Hikmah Pekanbaru, involving 12th-grade science students during the odd semester of the 2023/2024 academic year. The research employed a pre-experimental design, specifically the One Group Pretest-Posttest Design, which involved a single group of students observed before and after an intervention. In this design, students were first administered a pretest in the form of a learning motivation questionnaire (O1), followed by the implementation of an experimental learning tool (X), and finally given a posttest (O2) using the same questionnaire. This design allowed for the comparison of students' motivation levels before and after the intervention to determine the impact of the experimental tool.

The research subjects consisted of all students from Class XII IPA at SMAIT Al Fityah and MA Darul Hikmah Pekanbaru. Data collection was carried out using a structured learning motivation questionnaire, administered before and after the implementation of the experimental tool designed to measure magnetic permeability. During questionnaire administration, students completed the responses individually in class, and were instructed not to consult or observe their peers' responses to ensure the integrity of the data.

The primary instrument used in this study was a student learning motivation questionnaire based on the ARCS motivational model, which evaluates four components essential to effective learning: Attention (A), Relevance (R), Confidence (C), and Satisfaction (S). The ARCS model is grounded in the principle that effective teaching must capture students' attention, connect content to their lives, build confidence in their abilities, and provide satisfaction through meaningful achievement. As noted by Sugiarti (2022), student attention stems from curiosity, while content relevance supports easier understanding. Confidence is developed through perceived competence, and satisfaction is reinforced through recognition and reward.

The ARCS model was selected for its theoretical rigor and empirical validation in enhancing student engagement and achievement (Afjar et al., 2020). Furthermore, it allows learners to build upon prior knowledge and apply conceptual understanding to problem-solving tasks (Nugroho & Wahyuni, 2018).

The questionnaire employed in this research was adapted from a validated instrument developed by Mulyani Hafidzah (2022) and previously tested for validity and reliability by Umi Mahmudah (2012). The original items were refined and adapted to suit the context of this study, resulting in a 20-item questionnaire focused on student motivation in relation to the use of an experimental tool for testing the magnetic permeability of metal materials. The questionnaire blueprint (pretest version) is presented in Table 1

Table 1. ARCS Motivation Questionnaire Grid Before Treatment (Pretest)

No.	Indicator	Statement Item Number		Amount
		Positive	Negative	
1.	Self-confident	3, 12, 18, 13	8	5
2.	Attention	1, 6, 11, 14	7	5
3.	Relevant	10, 16, 17, 19	5	5
4.	Satisfaction	2, 4, 9, 15	20	5
		Amount		**20**

Based on Table 1, the student learning motivation questionnaire consists of 20 statement items, which are categorized into four indicators corresponding to the ARCS motivational model: Attention, Relevance, Confidence, and Satisfaction. Each indicator comprises five statements, including one negatively worded statement and four positively worded statements, designed to measure various dimensions of students' learning motivation comprehensively. Following the implementation of the experimental tool, students completed the posttest version of the questionnaire. The structure and content of this instrument remained aligned with the pretest to ensure consistency in measurement. The detailed blueprint for the posttest motivation questionnaire is presented in Table 2 below:

Table 2. ARCS Motivation Questionnaire Grid After Treatment (Posttest)

No.	Indicator	Statement Item Number		Amount
		Positive	Negative	
1.	Self-confident	1, 3, 4, 10	2	5
2.	Attention	5, 12, 13, 14	20	5
3.	Satisfaction	11, 15, 16, 18	9	5
4.	Relevant	6, 7, 17, 19	8	5
		Amount		**20**

Based on Table 2, the student learning motivation questionnaire comprises 20 statement items distributed across four indicators of the ARCS motivational model: Attention, Relevance, Confidence, and Satisfaction. Each indicator includes five items, consisting of four positively worded statements and one negatively worded statement, ensuring balanced representation of motivational dimensions. The data analysis technique employed in this study was descriptive analysis. Descriptive analysis is a method used to summarize and interpret data without drawing inferential conclusions or testing hypotheses (Ashari et al., 2017, p. 18). In this research, descriptive statistics were applied to evaluate changes in students' learning motivation before and after the introduction of the experimental tool designed to assess the magnetic permeability of metal materials. The motivational data were obtained through a structured questionnaire and scored using a Likert scale, which measures responses along a continuum of agreement or frequency (Ningsih et al., 2022, p. 3).

RESULT AND DISCUSSION

The experimental tool for testing the permeability of metal materials is a practical device designed to measure the relative magnetic permeability of various metal samples. It serves as a physics learning medium for high school students, specifically within the magnetic field topic, under the subchapter "Magnetic Properties of Materials." This tool aims to support conceptual understanding through hands-on experimentation and visualization of abstract magnetic principles. The physical form and configuration of the tool are illustrated in Figure 1 below.

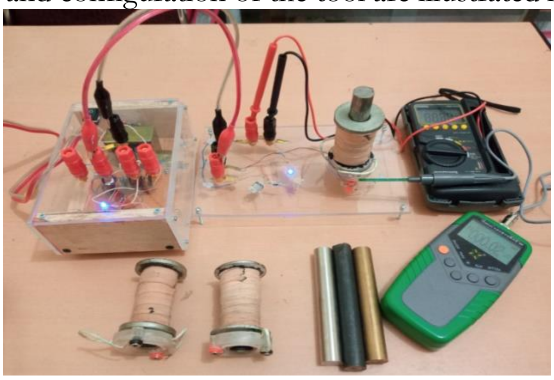

Figure 1. Experimental Tools for Testing The Permeability of Metal Materials

The findings of this study were derived from observations conducted during physics lessons, both before and after the implementation of the experimental tool for testing the magnetic permeability of metal materials. Student motivation levels were assessed using the ARCS learning motivation questionnaire, which provided insights into changes in motivation across the four ARCS components: Attention, Relevance, Confidence, and Satisfaction. The results of the learning motivation assessments for Grade XII Science students at SMAIT Al Fityah Pekanbaru and MA Darul Hikmah Pekanbaru are visually presented in Figure 2 and Figure 3, respectively.

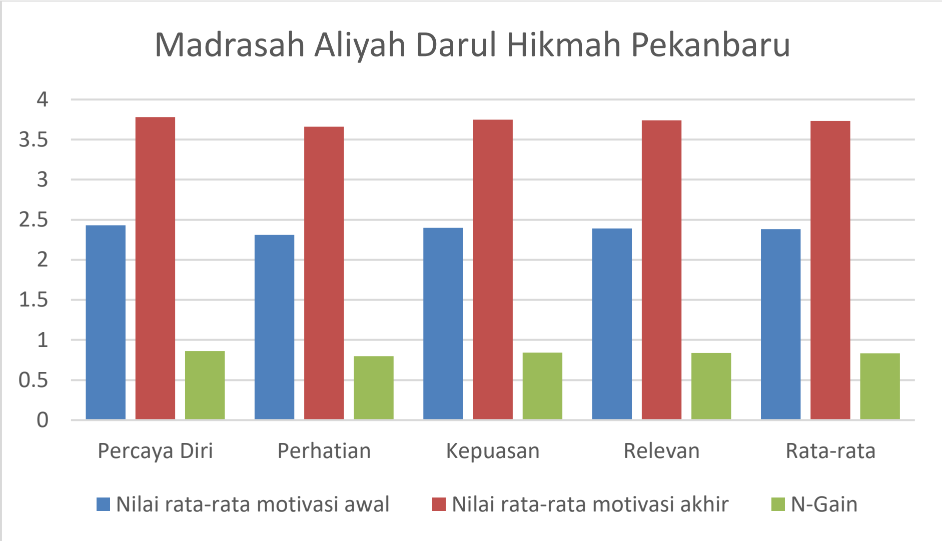

Figure 2. ARCS Madrasah Aliyah Darul Hikmah Pekanbaru Motivational Questionnaire Graphic

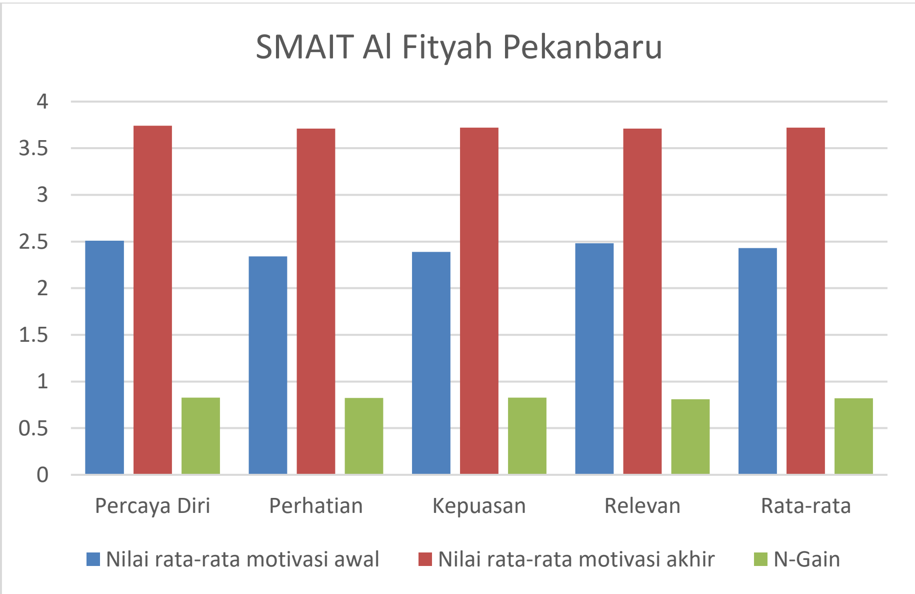

Figure 3. Arcs SMAIT Al Fityah Pekanbaru Motivational Questionnaire Graphic

The Attention, Relevance, Confidence, and Satisfaction (ARCS) model has been shown to effectively enhance both learning motivation and learning outcomes (Asiani & Nugroho, 2017). As illustrated in Figure 2 and Figure 3, there were observable differences in students' motivation scores before and after the implementation of an experimental tool designed to test the permeability of metal materials. These graphs reflect a consistent increase across all four ARCS indicators, indicating an overall improvement in student motivation following the intervention.

A descriptive analysis of students' motivation scores—categorized by each ARCS indicator—further supports this trend. Across all indicators, the average motivation scores increased after students engaged with the experimental tool. These results suggest that the use of the permeability testing apparatus had a positive impact on students' motivation to learn physics, particularly within the topic of magnetic fields. The normalized gain (N-Gain) analysis also confirmed this increase, with values falling into the high category. This finding reinforces the conclusion that the ARCS-based instructional approach, supported by the experimental tool, successfully fostered greater student motivation.

Self-efficacy, defined as an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments, plays a crucial role in learning motivation and academic success. High self-efficacy enables students to tackle challenges with greater confidence and perseverance. In this study, the confidence indicator—aligned with the ARCS model—showed substantial improvement. For students at Madrasah Aliyah Darul Hikmah Pekanbaru, the average motivation score increased from 2.43 (pre-intervention) to 3.78 (post-intervention), yielding an N-Gain of 0.86, categorized as high. Similarly, students at SMAIT Al Fityah Pekanbaru experienced an increase from 2.51 to 3.74, with an N-Gain of 0.83, also within the high category. This improvement can be attributed to students' increased confidence in understanding magnetic field concepts, facilitated by the hands-on learning experience provided by the experimental tool.

The attention indicator, which is closely linked to motivation, also showed significant improvement. Capturing and sustaining students' attention is essential for maintaining high levels of motivation. Effective strategies include providing rewards, stimulating curiosity, and introducing unexpected elements in learning. At Madrasah Aliyah Darul Hikmah Pekanbaru, the attention score improved by 1.35 points, while at SMAIT Al Fityah Pekanbaru, the increase was 1.37 points, with respective N-Gain values of 0.80 and 0.83—both categorized as high. These results indicate that the experimental tool effectively captured students' attention by providing a novel and engaging approach to learning physics, sparking curiosity and encouraging focused participation through group discussions and timely task completion.

The relevance indicator assesses how well students perceive the material as meaningful and applicable to real-life contexts. Students are more likely to be motivated when they see the relevance of the subject matter to their personal experiences, societal needs, or future applications. In this study, Madrasah Aliyah Darul Hikmah students improved from an average motivation score of 2.39 to 3.74 (N-Gain = 0.84), while SMAIT Al Fityah students increased from 2.48 to 3.71 (N-Gain = 0.81). These high gains suggest that students recognized the connections between the physics content and their daily lives, enhancing the perceived value of the learning material.

Finally, the satisfaction indicator reflects students' emotional response to the learning process, which is a crucial determinant of sustained motivation. Satisfaction can be fostered through opportunities for active participation, question-and-answer sessions, and collaborative problem-solving. When students are engaged and feel their contributions are valued, they tend to compete constructively and derive fulfillment from the learning experience. The high satisfaction scores observed in this study demonstrate that the experimental tool not only facilitated conceptual understanding but also made the learning experience more enjoyable and rewarding for students.

The data analysis reveals that the average initial motivation score for students at Madrasah Aliyah Darul Hikmah Pekanbaru was 2.40, while the final average motivation score increased to 3.75, resulting in an N-Gain score of 0.84, categorized as high. For SMAIT Al Fityah Pekanbaru, the average initial motivation score was 2.39, with the final score reaching 3.72, yielding an N-Gain score of 0.83, also in the high category. These results suggest that the experimental tool designed for testing the permeability of metal materials was effective in enhancing students' motivation. The tool's design was not only visually appealing but also user-friendly, which helped sustain students' enthusiasm throughout the learning process. As a result, students remained engaged and curious, avoiding boredom and becoming more eager to explore the subject matter further.

Further analysis of the initial and final learning motivation scores for both Madrasah Aliyah Darul Hikmah Pekanbaru and SMAIT Al Fityah Pekanbaru confirms that the use of the experimental tool significantly increased student motivation. Specifically, the N-Gain for class XII Science students at Madrasah Aliyah Darul Hikmah Pekanbaru was 0.84, while the N-Gain for class XII Science students at SMAIT Al Fityah Pekanbaru was 0.82. These findings indicate that the experimental tool for testing the permeability of metal materials had a positive impact on student motivation. In terms of the N-Gain percentage, the results were 84% for Madrasah Aliyah Darul Hikmah Pekanbaru and 82% for SMAIT Al Fityah Pekanbaru. According to the established criteria, an N-Gain percentage greater than 75% indicates that the experimental tool was highly effective in increasing student learning motivation.

CONCLUSION

Based on the analysis of the research data, it can be concluded that the use of experimental tools for testing the permeability of metal materials significantly enhances the motivation to learn physics among class XII Science students at SMAIT Al Fityah Pekanbaru and Madrasah Aliyah Darul Hikmah Pekanbaru. The experimental tool, when employed as a learning medium, effectively fosters greater engagement and enthusiasm for physics learning. As such, this experimental tool presents a viable alternative method for enhancing the learning experience in physics education.

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