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Integrating Simulation-Based and Hands-On Experiments: A Guided Inquiry Learning Packet on Magnetic Induction

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ABSTRACT

Students often struggle with magnetic induction due to its abstract nature and complex relationships between flux, emf, and current. Simulations are known to be effective tools in enhancing understanding complex and abstract physics concepts. But simulations alone limit the complete development of procedural skills of students during physical experiments. On the other hand, guided inquiry learning promotes scientific literacy among learners as it encourages exploration, formulation of hypotheses, and analyzing evidence. Combining guided inquiry-based learning with simulations and hands-on activities can furtherly enhance understanding and achievement by promoting exploration and active engagement. This study developed a guided inquiry learning packet that integrates simulation-based and hands-on activities to enhance student understanding and academic performance on Magnetic Induction. The packet combines PhET simulations with hands-on activities to provide a comprehensive learning experience. The developmental research design supported by both qualitative and quantitative approaches was employed to investigate the effect of this integrated approach on students' conceptual gain and academic performance. The overall evaluation confirmed that the learning packet meets high standards of validity and acceptance, with the overall mean score reflecting an excellent rating. The impact of the guided inquiry learning packet on students' academic performance was assessed using the devised achievement tests, activities, and problem sets. The results from the six sections that used the learning packet revealed that students' academic performance significantly improved and the average class gain across all sections ranged from 0.48 to 0.62, reflecting a notable improvement in academic performance.

Keywords: Guided Inquiry-based learning, Magnetic Induction, PhET Simulations, Hands-on activities, Academic performance.

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1. INTRODUCTION

Physics education is essential for developing scientific literacy, problem-solving, and critical thinking skills. However, many students struggle with electromagnetism, particularly magnetic induction, due to its abstract nature and the limited availability of hands-on learning opportunities (Balila et al., 2024; Shodiqin et al., 2024). The phenomena of magnetic induction creates very complex relationships between its different parameters like the changing magnetic flux, electromotive force, and current flow. All these concepts are complex and tedious to visualize and apply (Haertel, 2018). Traditional instruction is heavily laden with mathematical formulations and passive learning. It normally reinforces misconceptions and conceptual understanding is limited (Berger & Lensing, 2023; Bentayao & Ilagan, 2024).

Guided inquiry-based learning has been an efficient tool in improving comprehension and scientific reasoning among students by encouraging exploration, generating hypotheses, and analyzing evidence under the guidance of a teacher

(Kuhlthau et al., 2015; Demirtas & Cayir, 2021). Instead of allowing students to passively listen to lectures, GIBL enables the student to actively engage through a structured learning process, thereby helping them construct knowledge and inculcate deep reflection and analysis (Soysal, 2022; Constantinou et al., 2018).

GIBL, when integrated with simulation-based learning, may further enhance the understanding of complex phenomena. Interactive programs, such as PhET, allow learners to change parameters, get responses, and see animated actions in real time. This greatly enhances their understanding of difficult concepts such as magnetic induction (Banda & Nzabahimana, 2022; Diab et al., 2024). However, the full development of procedural skills associated with performing manipulations with the real object during a physical experiment cannot be fully provided by the simulation (Rayan et al., 2023). Combining sim

Integrating simulation-based and hands-on learning within a guided inquiry approach focuses on making learning comprehensive, enhancing understanding, and strengthening the acquired practical skills. There is no doubt about the advantages of GIBL and simulations working in harmony, however, there remains little research on its application for teaching magnetic induction (Kapici et al., 2022; Husnaini & Chen, 2019).

This study intends to develop and assess the efficacy of the guided inquiry learning packet which integrates simulation-based and hands-on activities for teaching magnetic induction with grade 12 STEM students.

2. METHODS

2.1 Research Design

This research employed developmental research (Richey et al., 2004) supported by both qualitative and quantitative approaches. The researcher adopted this methodology to develop and evaluate a guided inquiry-based lesson packet on magnetic induction. A survey achievement test was administered before and after the application of the guided inquiry lesson packet to determine its effect on students' conceptual gain and academic performance. Other quantitative data including students' written works from the learning packet, such as quizzes, problem sets, and worksheets were also collected. The qualitative data were derived from students' learning reflections and summaries, as well as from the insights and feedback survey questionnaire filled by the Grade 12 STEM students and the teacher-implementer.

2.2 Research Subjects and Participants

The subjects of the study included all six sections of Grade 12 STEM students in a private institution officially enrolled for the S.Y. 2024–2025, with a total population of 257 students. To ensure a diverse mix of academic backgrounds and abilities, the sections were heterogeneously grouped. The purposive sampling method was selected for this study which enabled the selection of participants that met the study's predefined criteria to comprehensively portray the target population. This method, along with involving the entire population, helped to eliminate sampling bias and increase the validity of the study by capturing a wide range of views from the Grade 12 STEM population. For the selection of the eleven (11) physics experts who assessed, evaluated, and provided objective feedback on the inquiry-based lesson packet, convenience sampling was employed. These were students or graduates with a Master of Science in Education, majoring in Physics, and/or in-service teachers of physics with over three years of teaching experience.

2.3 Data Gathering Procedure (Successive Approximation Model)

The Successive Approximation Model (SAM) developed by Dr. Michael W. Allen in 2012, is an effective instructional design model consisting of three steps: preparation, iterative design, and iterative development phases that focuses on iterative development, reducing the time between initial concepts and final programs (Kuzmina, 2024). The model was employed for rapid prototyping, feedback for continuous improvement, and testing, making it easier to assess a product than an idea. Its recursive nature enabled continuous adjustments and improvements of the developed learning packet based on honest feedback, ensuring an optimal course structure for a specific audience type. The learning packet was first evaluated by eleven (11) physics experts using the developed rubric by Fitzgerald and Byers

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(2002) along with their feedback which was used to refine the material. It was then implemented with Grade 12 STEM students, where students engaged with the activities and problem sets incorporated in the packet. A pretest and posttest was also administered before and after the exposure to measure the class gain. Continuous observations and content analysis of students feedback further informed final adjustments.

2.3.1 Preparation Phase

During the preparation phase of the study, the researcher gathered relevant information and resources to establish a solid foundation for the subsequent stages. A review of literature on guided inquiry-based learning was conducted to identify research gaps, support the study's methodology, and build a strong theoretical framework. Furthermore, a literature review on the underachievement of Grade 12 STEM students in magnetic induction was done to analyze the contributing factors and identify existing interventions. The researcher reviewed the K-12 Science Curriculum Guide and the Most Essential Learning Competencies (MELCs) to verify whether the activities, achievement tests, problem sets, and quizzes included in the learning packet met the requisite academic standards and objectives of the instructional materials.

2.3.2 Iterative Design, Development and Validation of the Guided Inquiry-Based Learning Packet

With the purpose of meeting the goals of the study and the requirements of the curriculum, the researcher first collected and chose virtual simulations from PhET along with hands-on laboratory activities on the magnetic induction topic. With regards to the adopted simulations and hands-on activities, activity sheets and the achievement test were prepared in compliance with the K-12 Science Curriculum Guide and the Most Essential Learning Competencies (MELCs). Subsequently, the researcher designed the guided inquiry learning packet by organizing the selected PhET simulations and laboratory activities into a structured format that promoted exploration and critical thinking. The guided inquiry based learning packet consists of three (3) activities—two (2) simulation-based activities and one (1) hands-on activity along with two (2) problem sets designed to guide students through key concepts using both virtual and physical experiments to enhance understanding and academic performance.

An iterative feedback and revision process followed, where the packet was reviewed and refined based on feedback from the adviser, panelists, and eleven (11) physics experts. The study adapted, modified, and utilized the developed *Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials* by Mary Ann Fitzgerald and Al Byers in 2002 to assess the validity of developed guided inquiry-based learning packet. Comments and suggestions were also gathered and considered in the made adjustments to improve clarity, content accuracy, and overall instructional quality. After revising the packet, additional feedback was gathered to assess the effectiveness of the changes and ensure that the final version addressed identified gaps and enhanced student learning.

2.4 Data Analysis

The researcher analyzed the data using both quantitative and qualitative methods. Normalized gain was computed using Hake's (1998) criteria to measure the improvement in student conceptual gain between the pretest and posttest, calculated through Google Sheets to assess the effectiveness of the guided inquiry lesson packet in enhancing conceptual understanding. Item analysis was conducted to evaluate the quality of test items based on difficulty and discrimination indices, following Magno and Ouano (2010) interpretation guidelines. A cross-tabulation table from Dela Peña et al. (2011) guided the decision to retain, revise, or reject items, with poor discrimination items rejected and others revised or retained based on performance. The researcher also computed the mean scores from the physics experts' evaluation to assess the packet's clarity, relevance, and alignment with learning objectives, guiding further revisions. For qualitative data, responses from open-ended questionnaires and interviews were transcribed, translated if necessary, and analyzed using content analysis (Saldana, 2021). Important fragments of text were analyzed and assigned codes through thematic analysis through iterative coding, with cross-checking ensuring consistency and accuracy in identifying key patterns and insights.

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3.RESULTS AND DISCUSSIONS

3.1 Preparation Phase

The researcher conducted a literature review to establish a strong foundation for the study on guided inquiry-based learning for Grade 12 STEM students. The review aimed to define gaps in previous research and devise supporting methodology. Additionally, the researcher looked into other studies done on the students' low achievement in magnetic induction to identify contributing factors and assess current interventions. The achievement test, activities, problem sets, and quizzes in the learning packet were integrated following the K-12 Science Curriculum guide and the Most Essential Learning Competencies (MELCs) to ensure that the learning experiences addressed specific learning outcomes and provided teachers with a clear framework for designing effective instructional strategies and assessments to meet educational goals (Holland, 2023).

Table 1 Aligning the Guided Inquiry Learning Packet with the DepEd K-12 Identified Standards and Competencies

Content Standard *The learners demonstrate an understanding of the concepts…*	Performance Standard *The learners should be able to…*	Most Essential Learning Competencies & K-12 CG Code	Duration	Guided Inquiry Learning Packet Objectives *By the end of this Guided Inquiry Learning Packet, learners should be able to…*
Magnetic induction Faraday's Law Alternating current, LC circuits, and other applications of magnetic induction		Identify the factors that affect the magnitude of the induced emf and the magnitude and direction of the induced current (Faraday's Law) (STEM_GP12EMIVa-1). Compare and contrast electrostatic electric field and non electrostatic/induced electric field (STEM_GP12EMIVa-3). Calculate the induced emf in a closed loop due to a time-varying magnetic flux using Faraday's Law (STEM_GP12EMIVa-4). Describe the direction of the induced electric field, magnetic field, and current on a conducting/non conducting loop using Lenz's Law (STEM_GP12EMIVa-5).	Week 1-3	- explain the principles of magnetic induction, including Faraday's Law, Lenz's Law, and their relationship to magnetic flux and induced emf; - calculate the induced emf using Faraday's Law and analyze how changes in magnetic field, coil turns, and motion affect it; and - appreciate the significance of magnetic induction in modern technology and everyday applications.

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		Compare and contrast alternating current (AC) and direct current (DC) (STEM_GP12EMIVb-6). Characterize the properties (stored energy and time-dependence of charges, currents, and voltages) of an LC circuit (STEM_GP12EMIVb-8).		

3.2 Iterative Design, Development and Validation of the Guided Inquiry-Based Learning Packet

The researcher designed a guided inquiry learning packet in paper format on magnetic induction which contained two PhET simulations and one hands-on activity along with two problem sets to meet the study's aims and curriculum standards. The packet was developed in such a way as to allow for exploration and higher-order thinking while fulfilling the K-12 Science Curriculum Guide and MELCs requirements. The developed learning packet went through thorough evaluation by eleven (11) physics experts which led to its revision and increased accuracy and instructional quality. The validity of the packet was measured with the adapted and modified *Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials* by Fitzgerald & Byers (2002).

Figure 1. Changes in the Guided Inquiry-Based Learning Packet (Version 1)

The initial design of the developed guided inquiry-based learning packet has three versions before its implementation. Figure 1 shows the first version of the developed learning packet. This version has undergone face validation from physics experts. Comments and suggestions were gathered for the refinement of the material. Version 1, although contains details and activities of the learning packet, other details and questions have to be improved.

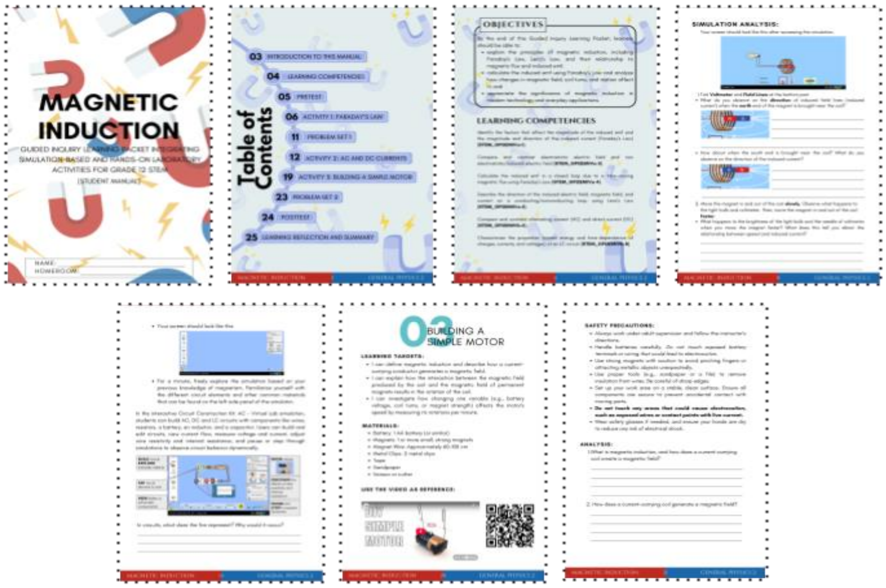

Figure 2. Changes in the Guided Inquiry-Based Learning Packet (Version 2)

Figure 2 shows the version 2 of the developed learning packet. In Version 2, the cover page texts were rearranged for better presentation. The word *student manual* was made part of the main header. Objectives of the learning packet were also added before the Learning Competencies for better emphasis of the goal of the material. The questions for both Activity 1 and 2 were enhanced with more illustrations shown to further guide the students in exploring and learning Magnetic Induction using the guided inquiry-based learning packet. Activity 3 was changed from *Building a Generator* to *Building a Simple Motor*. This change was made due to the level of achievability of the activity within the scheduled time period. Safety Precautions was also added for the safety of the students while performing the activity. This version of the packet has undergone evaluation using the adapted and modified *Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials* by Fitzgerald & Byers (2002).

Finally, on Version 3, the general theme and content of the learning packet was settled. The graphics, content, including the questions arrangement and the way they were presented were enhanced accordingly and consistency in the font styles and colors were observed. It took several versions of the manual to achieve the appropriate visual representation for the guided inquiry-based learning packet.

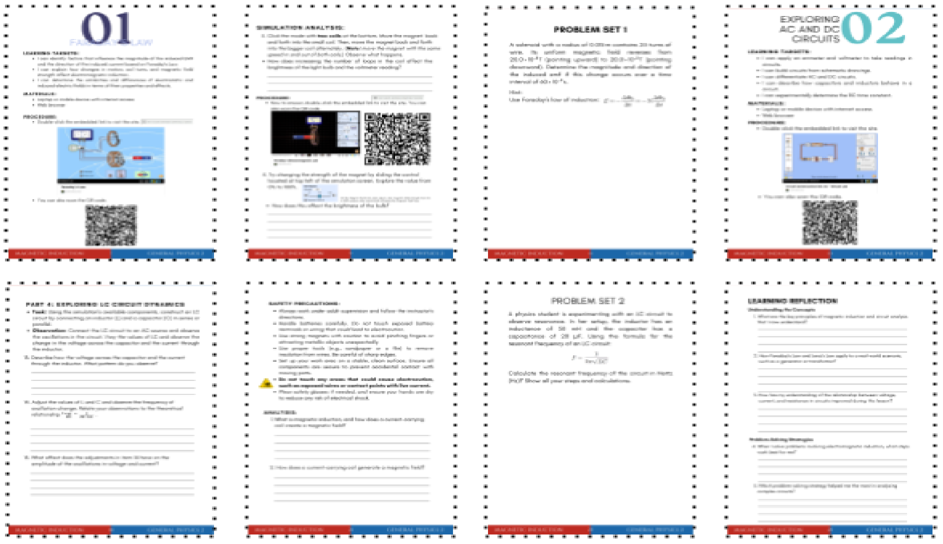

Figure 3. Changes in the Guided Inquiry-Based Learning Packet (Version 3)

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Table 2. Evaluation Rating Result

Statements	**Mean Rating**	**Description**
A. Increase their understanding of the science subject matter investigated		
A1. Content		
A1a. The material provides content aligned with national, state, or local standards.	3.82	Excellent
A1b. The material provides an opportunity to develop an enduring understanding of subject matter content.	3.73	Excellent
A1c. The material contains accurate content.	3.91	Excellent
B. Gain an understanding of how students explore the natural world.		
B1. Understanding of how students work		
B1a. The material provides an opportunity to learn how different kinds of questions—based on what students already know—can lead to different kinds of investigations.	3.73	Excellent
B1b. The material provides an opportunity to learn that students conduct investigation for a variety of reasons.	3.64	Excellent
B1c. The material provides an opportunity to learn that students use a variety of tools, technology, and methods to extend the senses and observations.	3.55	Excellent
B1d. The material provides an opportunity to learn that students use evidence, logic, and current knowledge to propose explanations.	3.73	Excellent
B1e. The material provides an opportunity to learn that students collaborate and communicate with each other in a variety of ways to reach well-supported explanations.	3.73	Excellent
C. Develop the ability to conduct investigations		
C1. Posing scientifically oriented questions		
C1a. The material provides an opportunity to ask questions that can be answered through scientific investigations.	3.91	Excellent
C2. Designing and conducting investigations		
C2a. The material engages learners in planning investigations to gather evidence in response to questions.	3.73	Excellent
C2b. The material engages learners in conducting the investigation.	3.64	Excellent
C2c. The material engages learners in the use of analytical skills.	3.55	Excellent

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C3. Proposing answers		
C3a. The material engages learners in proposing answers and explanations to questions.	3.82	Excellent
C4. Comparing explanations with current scientific knowledge		
C4a. The material engages learners in the consideration of alternative explanations.	3.45	Excellent
C4b. The material engages learners in linking explanations with scientific knowledge.	3.82	Excellent
C5. Communicating and justifying results		
C5a. The material engages learners in the communication of scientific procedures and explanations.	3.82	Excellent
C5b. The material engages learners in appropriately responding to critical comments.	3.64	Excellent
C5c. The material engages learners in raising additional questions.	3.64	Excellent
D. Develop the habits of mind associated with science		
D1a. The material promotes the questioning of assumptions (skepticism).	3.55	Excellent
D1b. The material presents science as open and subject to modification based on communication of new knowledge and methods (openness).	3.91	Excellent
D1c. The material promotes longing to know and understand (curiosity).	3.91	Excellent
D1d. The material promotes respect for data (honesty).	3.64	Excellent
OVERALL MEAN	**3.72**	**Excellent**

Legend: Excellent 3.24-4.00; Moderate 2.50-3.24; Basic 1.75-2.49; Needs Improvement 1.00-1.74

Table 2 presents the evaluation results of the learning packet, which was comprehensively assessed by a panel of 11 physics experts using a set of 22 statements. The feedback was overwhelmingly positive, with all statements receiving an excellent rating, which underscores the high quality and effectiveness of the content. In addition to the ratings, the overall evaluation confirmed that the learning packet meets high standards of validity and acceptance, with the overall mean score reflecting an excellent rating. Importantly, the detailed comments and suggestions provided by the experts were carefully reviewed and incorporated into the final version of the packet for implementation, ensuring continuous improvement and alignment with expert expectations in physics education.

The learning packet was implemented with Grade 12 STEM students to enhance their understanding of magnetic induction. Initially, a pretest was administered to assess baseline knowledge, followed by the integration of the packet into the teaching strategy. During the intervention, continuous observations and feedback from both the teacher and students helped to identify areas for improvement. Post-intervention, a posttest was conducted, and the normalized class gain score indicated a moderate improvement and students' improved academic performance measured from all the written work scores of the students demonstrated a positive impact. Additionally, a content analysis of students' insights and feedback revealed recurring themes that provided further insights into their learning experiences. This comprehensive evaluation informed final adjustments to enhance the packet’s effectiveness and instructional quality, ultimately contributing to improved learning outcomes.

4. CONCLUSION AND RECOMMENDATION

The learning packet on magnetic induction which consists of both simulation-based and hands-on activities integrated within guided inquiry learning was found to be effective. An expert appraisal performed by 11 physics experts was exceedingly positive which confirmed the accuracy of the packet's content and instructional design. Its implementation with Grade 12 STEM students resulted in moderate learning gains and enhanced academic performance, as evidenced by pretest and posttest comparisons, written work scores, and qualitative feedback from both students and the teacher implementer. Through sustained scrutiny and qualitative content analysis of student learning reflection, the iterative design process has not only improved the packet but has also enhanced the content for other instructional purposes. This multifaceted technique underlines the strength of a guided inquiry-based learning approach in the teaching of physics while noting the need for further improvements and research. The study suggests modifications to the learning packet by adding more simulations and hands-on activities, offering instructional training for teachers about guided inquiry, and using continuous iterative feedback to further refine the material and investigate its application to other difficult topics in physics.

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