Effects of Hands-on Laboratory Approach on Academic Performance and Learning Engagement in Grade 11 Earth and Life Science

Haniyah S. Lazim

Bukidnon State University

DOI: https://doi.org/10.47772/IJRISS.2026.100400602

Received: 28 April 2026; Accepted: 04 May 2026; Published: 20 May 2026

INTRODUCTION

In today's rapidly evolving educational landscape, fostering active student engagement and improving academic performance remain critical priorities, particularly in the sciences. Earth and Life Science, a core subject in the grade 11 curriculum, presents complex concepts that often challenge learners' understanding when taught solely through traditional, lecture-based instruction. When students are encouraged to connect classroom lessons with practical experiments, they develop a richer appreciation for science and its real-world applications. Introducing hands-on laboratory not only makes the learning environment more dynamic and interactive but also helps students gain a firmer grasp of topics in earth and life sciences. This engaging approach can boost their confidence, spark curiosity, and ultimately lead to improved academic performance.

Considering this necessity, it is important to adopt appropriate strategies that can improve educational practices, particularly in Grade 11 Earth and Life Science. The use of innovative laboratory instructional materials can bring life to the often abstract and textbook-centered nature of theoretical science, making lessons more engaging and interactive for students (Gericke et al., 2022). These materials allow learners to perform and observe experiments or scientific phenomena that may be difficult to demonstrate in a conventional classroom environment.

The lack of engaging, context-sensitive instructional resources widens this gap. The conventional method of teaching, which mostly relies on lectures and teacher-led discussions, has several drawbacks that can limit learners' learning. In this approach, students often act as passive listeners, simply receiving information rather than actively participating, which can lead to a shallow understanding and difficulty in remembering concepts over time (Deslauriers et al., 2019). This becomes even more challenging in subjects like Earth and Life Science, where topics such as rocks and minerals can be abstract and hard to imagine without actual experience (Orion & Hofstein, 2022).

Moreover, this method often results in low student engagement, as learners may lose interest due to limited interaction and involvement. It also does not strongly support the development of higher-level thinking skills like analysis, problem-solving, and critical thinking, since the focus is usually on memorization rather than application (Hattie, 2017). In addition, students may struggle to see how what they learn connects to real-life situations.

Globally, science education faces challenges such as unequal access to laboratory facilities, and a shortage of well-trained teachers, particularly in developing countries. While wealthier nations are integrating digital learning tools, virtual labs, and hands-on teaching strategies, many schools worldwide still rely on conventional way of teaching, making science less engaging for learners. In the Philippines, these global challenges are also evident, particularly in public schools where inadequate laboratory facilities and limited resources hinder practical learning. Additionally, large class sizes, teacher workload, and outdated learning materials further impact the quality of instruction.

Learners, in the researcher's participating school, encounter certain challenges when it comes to fully engaging in practical science education. One notable concern is the limited access to fully equipped laboratory facilities, which can limit opportunities for students to participate in hands-on laboratories essential to understanding Earth and Life Science. As a result, instruction often leans heavily on theoretical approaches, which can make it more difficult for learners to visualize and connect scientific concepts to real-life applications (Pareek, 2019).

Addressing the challenge of teaching complex scientific concepts in grade 11 Earth and Life Science would be highly effective through hands-on laboratory activities. Utilizing these resources not only provides variety but also wraps learners in an active learning environment. With access to the scientific method, learners put this data to use by exploring practical experiments demonstrating essential concepts of earth and life sciences, like ecosystems and geological processes, animal care, and the interdependence of all life forms (Ifqiren et al., 2023).

Through such activities, learners can advance from rote memory to the development of critical thinking and problem solving. Participating directly in activities that enable them to witness, question, and explore scientific phenomena firsthand has been shown to increase students' excitement and comprehension. Such a paradigm shift not only leads to a better understanding of complex scientific concepts but also helps instill learners' curiosity and desire for knowledge (Bae & Lai, 2020).

While several studies have emphasized the benefits of laboratory-based instruction in science education, the present study introduces a contextualized hands-on laboratory approach specifically designed for grade 11 Earth and Life Science learners using locally available materials and simplified experimental procedures. Unlike many previous studies that relied on fully equipped laboratory facilities, this study implemented practical activities that can be conducted even in resource-limited classroom settings. The approach integrates real-world environmental samples, direct observation, and collaborative experimentation, enabling learners to explore Earth and Life Science concepts such as rocks, minerals, and environmental processes through tangible experiences.

Furthermore, this study does not only measure students' academic performance, but also examines multidimensional learning engagement such as cognitive, emotional, and behavioral engagement which are often overlooked in earlier research. By combining experiential laboratory activities with engagement-focused assessment, the study aims to a more comprehensive understanding of how hands-on laboratory instruction influences both students' learning outcomes and their active engagement in science learning.

Framework of the Study

Training theories that emphasize active learning and experiential education, as well as process-based constructivism, are at the foundation of hands-on laboratory in teaching grade 11 Earth and Life Science. Some of them are the Kolb's experiential learning theory, Dewey's theory of learning by doing and constructivist theory of Vygotsky and Piaget.

As seen in Kolb's experiential learning cycle, concrete experiences are essential to effective teaching strategies, such as when a grade 11 Earth and Life Science educator needs to employ effective teaching strategies. It has a particular design which consist of four key stages; this includes concrete experience, reflective observation, abstract conceptualization and active experimentation. The goal of each stage is to capture a full learning journey that resonates with how deeply learners develop an understanding of the content (David A. Kolb, 1984; Alice Y. Kolb & Kolb, 2005).

One critical approach to teaching science is the use of hands-on laboratory that engage learners with authentic hands-on experiments based on Earth and Life Science contexts. Examples include soil analysis, ecosystem observation, or tracking pollution on local wildlife. These concrete experiences are no random occurrences, they have been carefully structured to afford learners a chance to watch what is going on around them, reconsider their prior beliefs, and combine challenging scientific principles (Nir Orion & Avi Hofstein, 2022). Such approaches allow students to actively construct knowledge through direct interaction with their environment, leading to deeper understanding and improved learning outcomes.

Kolb's cycle also encourages learners to reflect on their experiences as they move through the stages. This process of reflection enables them to think about what they learned during the hands-on activities they did, and how the lessons apply to wider environmental and biological rules. Transition into the stage of abstract conceptualization means learners must use their observations to create theories or models, which can lead to more substantial comprehension (Kolb, 2015).

The implementation of Kolb's experiential learning cycle in laboratory-based instruction materials brings additional depth into the pedagogy of grade 11 Earth and Life Science. Educators can also foster critical thinking by incorporating experiential learning opportunities into their curriculum; above all, learners can explore the concepts behind the science, thus leaving a more profound integration with the knowledge. This comprehensive approach broadens learners' educational experiences while providing a basis for lifelong learning and interest in the natural world (Jerome Bruner, 1961).

Dewey's theory of learning by doing (1896) emphasizes that education should be grounded in real-world experiences and that active engagement in the learning process leads to deeper understanding and retention of knowledge. He argued against traditional methods that relied heavily on rote memorization and passive learning, advocating instead for a hands-on, experiential approach to education that fosters critical thinking and problem-solving skill. This philosophy has significantly influenced modern educational practices, promoting the idea that learners learn best when they are actively involved in their own learning experiences. This approach enhances academic performance while supporting social, emotional, and intellectual growth.

Furthermore, Piaget's cognitive constructivism focuses on how individuals build knowledge through developmental stages. According to Piaget, learning is a process of adapting mental models through assimilation and accommodation, progressing through stages such as the sensorimotor, preoperational, concrete operational, and formal operational stages. He emphasized the importance of hands-on discovery and individual exploration in learning (Piaget, 1972).

On the other hand, Vygotsky's social constructivism highlights the role of social interaction, language, and culture in cognitive development. Vygotsky introduced the concept of the Zone of Proximal Development (ZPD), which is the difference between what a learner can do independently and what they can achieve with guidance from a more knowledgeable other (MKO). He also introduced scaffolding as a teaching method where support is gradually removed as learners gain independence (Vygotsky, 1978). Together, Piaget and Vygotsky's perspectives offer a comprehensive understanding of how knowledge is constructed both individually and socially under the constructivist framework.

In addition to experiential learning theory, this study is also grounded in student engagement theory, particularly the multidimensional model of engagement proposed by Jennifer A. Fredricks, Phyllis C. Blumenfeld, and Alison H. Paris (2014). This theory explains that effective learning occurs when students are actively involved in the learning process through behavioral, emotional, and cognitive engagement. Rather than viewing engagement as a single construct, the model emphasizes that meaningful learning emerges from the interaction of these three dimensions, each contributing uniquely to how students participate in and internalize knowledge.

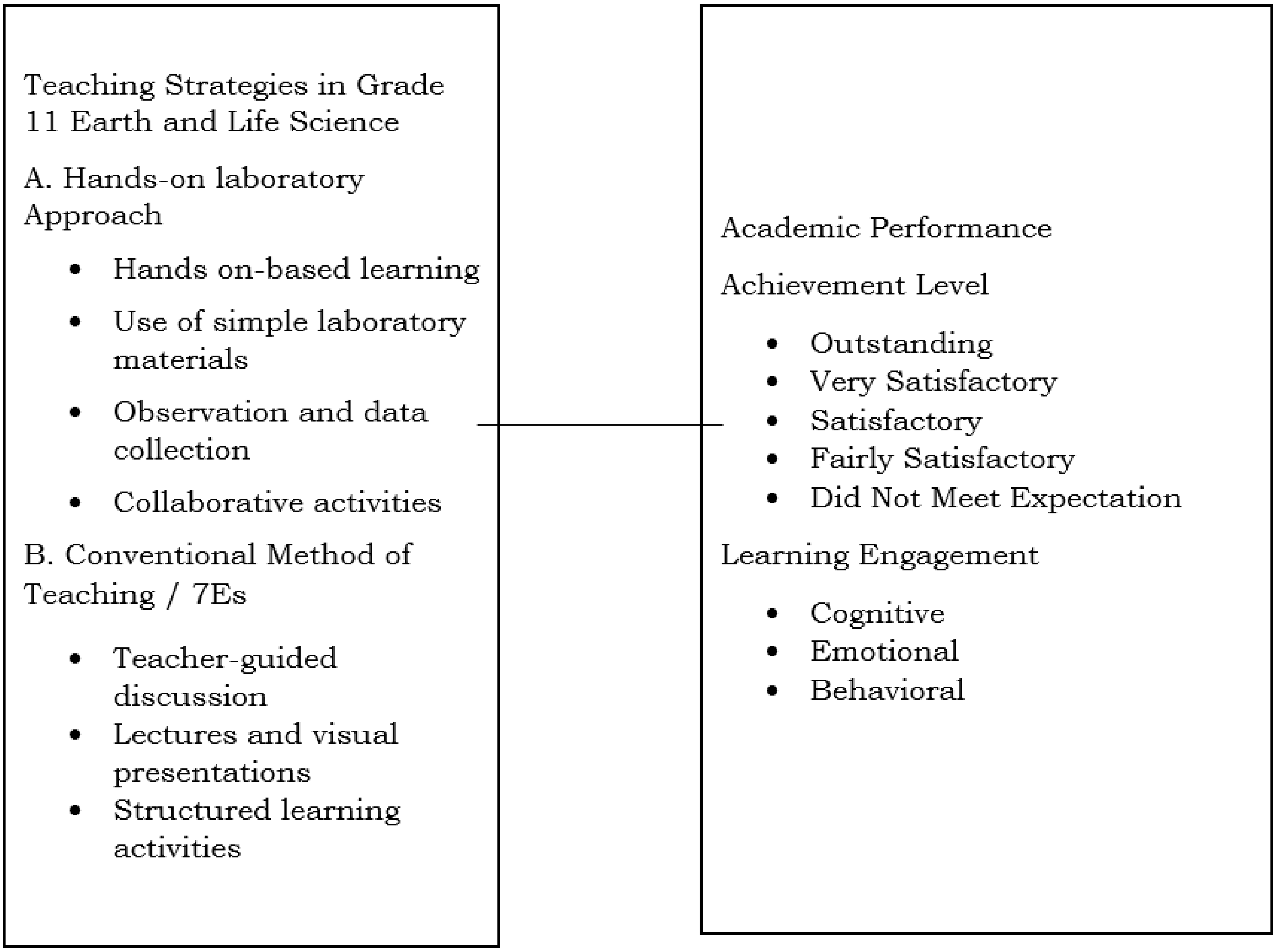
In the context of this study, the hands-on laboratory approach is expected to enhance student engagement by allowing learners to actively perform experiments, collaborate with peers, and explore scientific concepts through real experiences. These activities can stimulate students' curiosity and motivation, thereby strengthening behavioral, emotional, and cognitive engagement. Increased engagement may consequently contribute to improved academic performance in Earth and Life Science.

The diagram presented in Figure 1 illustrates the conceptual framework for this research. It illustrates the relationship between the teaching strategies used in grade 11 Earth and Life Science and the students' academic outcomes. The independent variable of the study is the teaching strategy, which consists of two instructional approaches: the hands-on laboratory approach and the conventional method of teaching using the 7Es model.

The hands-on laboratory approach involves experiment-based learning, the use of simple laboratory materials, observation and data collection, and collaborative activities that allow students to actively engage in scientific investigation. In contrast, the conventional teaching method primarily involves teacher-guided discussions, lectures with visual presentations, and structured learning activities.

These instructional strategies are expected to influence the dependent variables, namely academic performance and learning engagement. Academic performance is measured through students' achievement levels, categorized as *outstanding, very satisfactory, satisfactory, fairly satisfactory, and did not meet expectations*.

Figure 1 Schematic Diagram of the Conceptual Framework of the Study



Learning engagement is examined through three dimensions: cognitive, emotional, and behavioral engagement. The framework therefore proposes that the type of teaching strategy employed in the classroom may affect students' level of achievement and engagement in learning Earth and Life Science.

Statement of the Problem

The purpose of the study is to evaluate the effect of using hands-on laboratory approach in improving the academic performance and learning engagement of grade 11 learners under the Earth and Life Science. Using a quasi-experimental research design, the study aims to answer the following specific questions:

1. What is the academic performance of grade 11 learners in Earth and Life Science when exposed to the hands-on laboratory approach and when exposed to the conventional approach?
2. What is the level of engagement of grade 11 learners in Earth and Life Science when exposed to the hands-on laboratory approach and when exposed to the conventional approach in terms of:

a. cognitive;

b. emotional; and,

c. behavioral?

3. Is there a significant difference in the academic performance of learners of grade 11 when exposed to the hands-on laboratory approach and when exposed to the conventional approach?
4. Is there a significant difference in the learning engagement of learners of grade 11 who are exposed to hands-on laboratory and those who are not exposed?

Null Hypothesis

H_o1. There is no significant difference in the academic performance of grade 11 learners in Earth and Life Science when exposed to the hands-on laboratory approach and when exposed to the conventional approach.

H_o2. There is no significant difference in the learning engagement of grade 11 learners in Earth and Life Science who are exposed to hands-on laboratory and those who are not exposed to it.

Significance of the Study

The conduct of this study focusing on the effects of students' exposure or non-exposure to hands-on laboratory is deemed beneficial to various groups. Specifically, the results of this study is significant to the following:

Hands-on laboratory activities can enhance *students'* understanding and retention of scientific concepts by allowing them to experience firsthand the principles they are learning. This could lead to improved academic performance as students are more likely to retain information when they physically engage in the learning process. Furthermore, such activities encourage active participation and critical thinking, enabling students to connect theoretical knowledge with real-world applications. They also promote deeper conceptual understanding by allowing learners to observe, experiment, and reflect on scientific phenomena.

The study provides *teachers* with valuable insights into the effectiveness of hands-on learning. It helps teachers understand how such methods can be integrated into the curriculum to improve students' academic outcomes and engagement. Additionally, it guides teachers in designing more interactive and student-centered instructional strategies that cater to diverse learning styles. This can lead to a more dynamic classroom environment where students are motivated to participate and explore.

The study provides evidence on the value of incorporating hands-on labs into the educational framework. *DepEd administrators* can use this data to advocate for and support the inclusion of more interactive, lab-based activities in the curriculum for Earth and Life Science. Moreover, the findings can assist in policy-making decisions regarding resource allocation, teacher training, and facility improvements. This ensures that schools are better equipped to implement effective experiential learning strategies.

The findings of this study can serve as a basis for *Curriculum Developers* in designing more effective and engaging science programs. By incorporating hands-on laboratory activities into the curriculum, developers can ensure that learning experiences are aligned with students' needs and promote deeper understanding of scientific concepts. Additionally, the study can guide the integration of experiential learning approaches that emphasize inquiry, exploration, and application of knowledge. This can result in a more balanced curriculum that combines both theoretical and practical components of learning.

This study provides a foundation for *future researchers* who are interested in exploring the impact of hands-on learning in science education. It offers relevant data, methodologies, and insights that can be used as references for further studies in similar or different educational contexts. Moreover, future researchers may expand this study by examining other variables such as students' attitudes, motivation, or long-term retention of knowledge. This can contribute to the continuous improvement of teaching strategies and educational practices in science learning.

Delimitation of the Study

This study focused on assessing the effect of the hands-on laboratory approach in teaching grade 11 Earth and Life Science, particularly on the topic of Rocks and Minerals. The participants of the study consisted of Grade 11 learners from Datu Mamintal Adiong Sr. Memorial National High School in the Division of Lanao del Sur I, with a total of 80 learners divided into two groups: a control group and an experimental group, each comprising 40 learners.

The study was conducted within the said school during the second semester of the academic year 2025–2026. In terms of subject area, the research focused on Earth and Life Science, particularly on selected topics under Rocks and Minerals, including the identification of common rock-forming minerals, classification of rocks (igneous, sedimentary, and metamorphic), and the basic properties and uses of rocks and minerals. The variables of the study were limited to the use of hands-on laboratory activities as the independent variable, and learners' academic performance and engagement as the dependent variables.

The research employed a quasi-experimental design, specifically utilizing a control and experimental group to compare the effectiveness of the instructional approaches. The duration of the study was confined to the period in which the selected lessons were taught during the second semester.

Furthermore, the intervention scope was limited to the use of hands-on laboratory instructional materials developed by the researcher, applied only to the selected lessons in Rocks and Minerals. Other topics in Earth and Life Science and alternative teaching strategies were not included. Lastly, the instruments used in the study were limited to researcher-developed assessment tools and engagement measures designed to evaluate students' academic performance and level of engagement within the specified scope of the study.

Definition of Terms

Terms are crucial to understanding a study. To this end, the following terms were defined theoretically and conceptually:

Hands-on Laboratory Approach. The hands-on laboratory approach refers to an instructional strategy grounded in experiential learning theory, which emphasizes learning through direct experience and active participation (Kolb, 1984). It allows learners to construct knowledge by manipulating materials, conducting experiments, and observing scientific phenomena firsthand. This approach promotes deeper conceptual understanding by connecting theory with practical application. In this study, the hands-on laboratory approach referred to the structured laboratory-based activities implemented in grade 11 Earth and Life Science lessons on Rocks and Minerals, where students manipulated rock and mineral samples, used basic laboratory tools, conducted observations and simple experiments, recorded data, and drew conclusions as part of the learning process.

Academic Performance. It refers to the level of achievement demonstrated by students in relation to specific learning objectives and academic tasks (York et al., 2015). It reflects how well learners acquire knowledge, develop skills, and demonstrate understanding of the subject matter through formal assessments and classroom tasks. In this study, academic performance referred to the students' level of achievement in Earth and Life Science as measured through their scores in the researcher-developed pretest and posttest covering the topic of Rocks and Minerals.

Learning Engagement. It refers to the extent to which students are actively involved in the learning process through their behavioral participation, emotional interest, and cognitive investment in learning tasks (Fredricks et al., 2004). It includes students' willingness to participate in classroom activities, their enthusiasm toward learning, and their effort to understand academic content. In this study, learning engagement referred to the students' level of behavioral, emotional, and cognitive involvement during the implementation of the hands-on laboratory approach, measured through a validated student engagement questionnaire focusing on participation, interest, and effort in Earth and Life Science learning activities.

METHODOLOGY

This chapter presents the research design, study locale, participants, research instruments, data collection procedures, and statistical tools used to analyze the data for the study titled Development of Hands-on laboratory in Teaching Grade 11 Earth and Life Science.

Research Design

This study employed a quasi-experimental research design, specifically the pretest–posttest control group design, to determine the effect of the hands-on laboratory approach on the academic performance and learning engagement of grade 11 learners in Earth and Life Science. A quasi-experimental design is commonly used in educational research when random assignment of participants is not possible but the researcher still aims to examine the causal effect of an intervention on selected variables. This design allows the researcher to compare the outcomes of two groups, an experimental group that receives the intervention and a control group that follows the conventional instructional approach.

Research Locale

This study was conducted at a public secondary school located in Bubong, Lanao del Sur, Philippines. The school serves learners from surrounding semi-rural and agricultural communities in the municipality and nearby areas. Due to its accessible location, the school accommodates students from several neighboring barangays and municipalities. Situated in the province of Lanao del Sur, which is part of the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), the school operates within a predominantly Muslim cultural and religious context. It offers both junior high school and senior high school programs, providing educational opportunities for learners in the local community.

While the school has functional classrooms and supports science instruction, some learning spaces and resources are shared among different academic programs. For example, the science laboratory room is sometimes utilized alongside other facilities, such as the computer laboratory, to maximize available space. As a result, laboratory activities are occasionally conducted in alternative spaces such as classrooms or designated activity areas. Despite these conditions, teachers continue to integrate hands-on activities and demonstrations whenever possible to provide learners with meaningful learning experiences.

The school provides basic laboratory equipment and materials that support science instruction. Teachers often supplement available resources with improvised materials and creative demonstrations to help illustrate scientific concepts. Through these strategies, learners are still able to participate in experimental activities, observe scientific processes, and engage in discussions that enhance their understanding of the lesson. The teachers also participate in professional development activities when opportunities are available, which helps them improve their instructional practices and adopt appropriate teaching strategies for science education.

By conducting the research at Datu Mamintal Adiong Sr. Memorial National High School, the findings of the study can be interpreted within the specific geographical, cultural, and educational context of a semi-rural public high school in the Bangsamoro region of the Philippines. The setting provides a relevant environment for examining how hands-on laboratory approaches may support the academic performance and learning engagement of grade 11 learners in Earth and Life Science, particularly in topics related to Rocks and Minerals.

Participants of the Study

The participants of this study were grade 11 learners enrolled in the Earth and Life Science classes during the academic year 2025–2026. The learners were typically between 16 and 18 years old, which is the common age range for senior high school students in the Philippines. These learners were selected because Earth and Life Science is a core subject in the senior high school curriculum where laboratory activities are commonly integrated to support conceptual understanding of scientific topics.

The study involved two grade 11 sections, namely GAS 11-A and ABM 11-A, with 40 students in each section, resulting in a total of 80 participants. These sections were purposively selected based on several considerations. First, both sections were enrolled in the same Earth and Life Science course and were handled by the same subject teacher, ensuring consistency in instructional delivery. Second, school academic records indicated that the two sections had comparable academic performance levels, which allowed for a more balanced comparison between the experimental and control groups. The selection of these sections also ensured that the participants were available during the scheduled class periods when the intervention was implemented.

The inclusion criteria consisted of learners who were currently enrolled in the Earth and Life Science course, regularly attending classes, and willing to participate in the study. On the other hand, students who had excessive absences, transferred to another school during the conduct of the study, or required specialized instructional accommodations that might affect the uniform implementation of the intervention were excluded from the participant group.

The researcher conducted the instructional intervention during the implementation of the study. Although the researcher delivered the lessons and facilitated the class, the researcher was not the regular classroom teacher of the participating sections. The instructional sessions were conducted with the permission and coordination of the assigned Earth and Life Science teacher. The researcher administered the pretest and posttest, implemented the hands-on laboratory activities, and observed students' learning engagement during the intervention period. Data on students' academic performance and engagement were then collected and analyzed to determine the effect of the hands-on laboratory approach on grade 11 learners in Earth and Life Science.

Sampling Procedure

The 80 participants were selected through purposive sampling, focusing on grade 11 learners who were enrolled in the Earth and Life Science classes during the academic year 2025–2026. This sampling technique was used because the study specifically aimed to examine the effect of the hands-on laboratory approach within the Earth and Life Science subject, making it necessary to select learners who were currently taking the course. Purposive sampling allowed the researcher to include participants who were directly relevant to the objectives of the study.

The participants were drawn from two existing grade 11 sections, GAS 11-A and ABM 11-A, which were chosen based on their comparable academic performance levels and similar class size. School academic records and previous subject performance were considered to ensure that the two groups had relatively similar learning backgrounds prior to the implementation of the intervention. One section was designated as the experimental group, which was exposed to the hands-on laboratory approach, while the other section served as the control group, which received the conventional method of instruction.

Since the participants came from intact class sections, random assignment of individual students was not conducted. However, the use of two sections with comparable academic performance helped establish a balanced comparison between the experimental and control groups. This grouping allowed the researcher to examine the effect of the hands-on laboratory approach on students' academic performance and learning engagement in Earth and Life Science.

Research Instruments

To measure the academic performance of the learners, the researcher utilized a researcher-made academic achievement test based on the content, performance standards, and learning competencies specified in the K to 12 Curriculum for Earth and Life Science. The test consisted of 50 multiple-choice items designed to assess learners' understanding of the selected topics, particularly Rocks and Minerals. The researcher developed the test items to ensure alignment with the learning objectives of the lesson. Prior to its administration, the instrument underwent pilot testing and item analysis to determine the validity and reliability of the test items. The researcher-made academic achievement test was administered as both a pretest and posttest to measure learners' knowledge before and after the implementation of the hands-on laboratory approach. The results of the pretest and posttest served as the basis for evaluating the effect of the laboratory-based instruction on learners' academic performance.

To assess learners' level of engagement in the learning process, the researcher used a Student Engagement Questionnaire (SEQ) that was adapted from established engagement frameworks, particularly the model of Fredricks et al. (2004) on multidimensional student engagement. The questionnaire also incorporated elements inspired by engagement indicators used in educational research instruments such as the National Survey of Student Engagement (NSSE) and learning engagement indicators aligned with DepEd learning outcomes in science education. The adapted instrument consisted of 45 items designed to measure three major dimensions of student engagement: cognitive, emotional, and behavioral engagement.

Cognitive engagement assessed the extent to which learners invested effort in understanding the lesson and applying critical thinking during learning activities. Emotional engagement examined students' level of interest and positive feelings toward the learning process, while behavioral engagement measured their participation, attentiveness, and involvement in classroom tasks and activities. The Student Engagement Questionnaire (SEQ) was administered before and after the implementation of the intervention to determine changes in the learners' level of engagement during the learning process. The responses gathered from the instrument provided quantitative data that helped identify whether the hands-on laboratory approach influenced students' cognitive, emotional, and behavioral engagement in learning Earth and Life Science.

Scoring Procedure

This section presents scoring procedure specific to academic performance and learning engagement. It aided the researcher to interpret the data gathered.

Scoring Procedure for Academic Performance

For the academic performance, the scoring procedure followed DepEd Order no. 8, s. 2015. The total score of the learners after the pretest and posttest were interpreted based on this DO, which is the implementation of Enhanced Basic Education Act of 2013 (Republic Act No. 10533), outlining the Policy Guidelines on Classroom Assessment for K-12 Basic Education Program. Under these guidelines, the following scale was used to interpret the learners' scores:

Score Range and Descriptive Interpretation of Academic Performance

Score Range (Items)	Percentage Equivalent (%)	Descriptive Equivalent	Qualifying Statement
45–50	90–100	Outstanding	Demonstrates excellent understanding of Earth and Life Science concepts and can apply knowledge accurately and independently
43–44	85–89	Very Satisfactory	Demonstrates a very good understanding of the concepts with minimal errors in application and explanation
40–42	80–84	Satisfactory	Demonstrates adequate understanding of the concepts but may require some guidance in applying scientific ideas
38–39	75–79	Fairly Satisfactory	Demonstrates basic understanding of the concepts but shows difficulty in applying knowledge consistently
Below 38	Below 75	Did Not Meet Expectations	Demonstrates limited understanding of the concepts and requires additional support to achieve the expected learning competencies

This interpretation was applied to determine the effect of the intervention by comparing the learners' academic performance before and after the exposure to hands-on laboratory.

Scoring Procedure for Learning Engagement

The weighted mean scores were interpreted using the engagement levels presented below. Each range corresponds to a specific qualitative description and Likert response, indicating the level of learners' engagement in classroom activities.

Mean Score Interpretation for Student Engagement

Engagement Level	Weighted Mean Range	Likert Response	Cognitive Engagement	Emotional Engagement	Behavioral Engagement
Highly Engaged	4.21 – 5.00	Strongly Agree (SA)	Learners consistently invest strong effort in understanding concepts, applying critical thinking, and solving complex tasks independently.	Learners demonstrate strong interest, enthusiasm, and positive feelings toward learning activities.	Learners actively participate in discussions, experiments, and collaborative tasks with sustained involvement.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

Engaged	3.41 – 4.20	Agree (A)	Learners generally attempt to understand concepts and apply thinking skills but may occasionally need guidance.	Learners show interest in the lesson, although enthusiasm may vary depending on the activity.	Learners participate regularly in class activities but may not always maintain active involvement.
Moderately Engaged	2.61 – 3.40	Neutral (N)	Learners demonstrate moderate effort in understanding the lesson but may rely on surface-level learning.	Learners display neutral feelings toward learning activities with occasional interest.	Learners participate occasionally but often remain passive during class activities.
Slightly Engaged	1.81 – 2.60	Disagree (D)	Learners show limited effort in analyzing concepts or applying critical thinking.	Learners show low interest or weak emotional connection to the learning activities.	Learners rarely participate and require frequent prompting to engage in tasks.
Not Engaged	1.00 – 1.80	Strongly Disagree (SD)	Learners demonstrate minimal effort in understanding concepts and rarely attempt to solve problems.	Learners show little or no interest in the lesson and may feel disconnected from the learning process.	Learners show very minimal participation and often avoid involvement in classroom activities.

The learners' responses to the Student Engagement Questionnaire (SEQ) were analyzed using the weighted mean method. Each item in the questionnaire was rated on a five-point Likert scale, and the responses were grouped according to three engagement dimensions: cognitive engagement, emotional engagement, and behavioral engagement. Cognitive engagement refers to the effort learners invest in understanding the lesson and applying critical thinking skills. Emotional engagement reflects the learners' level of interest and feelings toward the learning activities, while behavioral engagement measures their participation and involvement in classroom tasks.

The weighted mean score for each category and overall engagement level will be interpreted using standardized engagement ranges to reflect the learners' degree of involvement in classroom activities. This scoring framework provided both quantitative and qualitative insight into student engagement. It allowed the researcher to pinpoint which specific areas such as the cognitive, emotional, or behavioral require attention and which aspects reflect strong engagement. This diagnostic approach helps educators design more targeted and responsive interventions.

A higher weighted mean indicates greater student involvement in laboratory-based instructional activities. Comparing mean scores across categories helps determine which aspect (cognitive, emotional, or behavioral) is most or least engaged.

Data Gathering Procedure

The gathering of data was conducted during the second semester of the academic year 2025–2026. Prior to the implementation, a pilot test was conducted at a school in Bayabao among their grade 12 students. After run statistically, and finalized the questionnaire the researcher seek approval from the school administration and informed the participants about the purpose and ethical considerations of the study, including the use of consent and assent forms. The school administration was involved collaboratively, particularly in the implementation and evaluation phases of the study. This includes coordinating schedules, assisting in class assignments, and supporting the monitoring of instructional delivery and learners participation to ensure the smooth and ethical conduct of the research.

The participants were selected using purposive sampling and grouped into two: the experimental group and the control group. Both groups were given a pretest to determine their baseline knowledge and engagement level. The experimental group was taught using hands-on laboratory approach, while the control group was taught using the conventional lecture method. Both groups covered the same topic in Earth and Life Science, specifically Rocks and Minerals, within a two-week instructional period. The posttest and the Student Engagement Questionnaire (SEQ) was administered after the intervention to measure academic performance and engagement outcomes. All instruments was pilot-tested beforehand and undergone item analysis to ensure reliability and validity.

Class management followed standard DepEd classroom routines. The same teacher-researcher handled both the experimental and control groups to ensure consistency in teaching delivery. To avoid bias, both groups were oriented on the study without revealing which method was considered innovative. Learners were encouraged to participate actively, and any learning materials needed were provided equally.

Figure 2. Procedural Framework of the Study

REC Approval
⬇
Permission from School Administration
⬇
Orientation of Participants and Distribution of Consent/Assent Forms
⬇
Pilot Testing of Research Instruments
⬇
Item Analysis and Finalization of Instruments
⬇
Selection of Participants (Purposive Sampling)
⬇
Administration of Pretest and Student Engagement Questionnaire (SEQ)
⬇
Implementation of Instruction (2 Weeks)

• Experimental Group – Hands-on Laboratory Approach

• Control Group – Conventional Lecture Method
⬇
Administration of Posttest and Student Engagement Questionnaire (SEQ)
⬇
Data Collection, Encoding, and Tabulation
⬇
Statistical Analysis (Mean, SD, t-test, ANCOVA)
⬇
Interpretation of Results

The data were encoded and stored confidentially. Descriptive and inferential statistics such as mean, standard deviation, and ANCOVA were applied to analyze the outcomes in relation to the study's research questions.

Data Analysis

The data collected in this study were analyzed using both descriptive and inferential statistical methods in accordance with the specific statements of the problem (SOPs).

For problems 1 and 2, which sought to determine the academic performance of the control and experimental groups before and after the intervention, the mean and standard deviation were computed. The mean was used to determine the average score of the learners in the pretest and posttest, while the standard deviation was used to determine the variability of the learners' scores within each group.

For research problem 3, which aimed to determine whether there is a significant difference in the academic performance of the control and experimental groups after the intervention, Analysis of Covariance (ANCOVA) was used. The pretest scores served as the covariate to control for any initial differences between the groups, allowing for a more accurate comparison of the posttest results.

For research problem 4, which sought to determine whether there is a significant difference in the level of learning engagement between the control and experimental groups, Analysis of Covariance (ANCOVA) was also utilized. The pre-intervention engagement scores served as the covariate, while the post-intervention engagement scores were used to determine the effect of the hands-on laboratory approach on learners' engagement.

All inferential statistical tests were conducted using a 0.05 level of significance ($\alpha = 0.05$). These were used to determine whether the differences observed between the groups were statistically significant.

Ethical Considerations

This study adhered to established ethical standards to ensure the protection of participants and the integrity of the research process. Prior to the conduct of the study, ethical clearance was secured from the Research Ethics Committee (REC) to ensure compliance with ethical guidelines for research involving human participants. After obtaining REC approval, permission to conduct the study was requested from the administration of a public secondary school in Lanao del Sur.

Before the data gathering phase, the researcher explained the purpose, procedures, and expected outcomes of the study to the participants. Informed consent was obtained from parents or guardians, while assent forms were secured from the participating learners to confirm their voluntary participation. Participants were clearly informed about their rights, including the option to withdraw from the study at any time without any academic or personal consequences.

To ensure the validity and reliability of the research instruments, the researcher-made academic achievement test and the adapted Student Engagement Questionnaire (SEQ) underwent expert validation prior to implementation. The validation process involved several phases, including content validation, clarity review, and pilot testing. The instruments were evaluated by experts in science education, educational research, and measurement and evaluation. The validators reviewed the alignment of the items with the K to 12 Earth and Life Science curriculum, the clarity of instructions, and the appropriateness of the test items and engagement indicators. Based on the validators' feedback, minor revisions were made to improve item clarity and alignment with the learning competencies before the instruments were finalized and administered.

Confidentiality and anonymity of participants were strictly maintained throughout the research process. The identity of the school and the participants was protected using pseudonyms and coded identifiers in all research documents and reports. All collected data were stored securely in password-protected digital files accessible only to the researcher. The data will be retained solely for academic purposes related to this study and will be safely disposed of after the completion of the research and required retention period through permanent deletion of digital files and shredding of printed materials.

Measures were also taken to minimize potential bias and conflicts of interest during the conduct of the study. Although the researcher facilitated the implementation of the intervention, the participating classes were not directly handled by the researcher as their regular classroom teacher. The study was conducted in coordination with the assigned subject teacher to ensure that instructional delivery remained consistent with regular classroom practices. Both the control and experimental groups received equal instructional time, learning materials, and opportunities to participate in class activities. Furthermore, participants were not informed which instructional method was considered the experimental intervention to reduce possible expectancy effects.

Participation in the study was entirely voluntary. The researcher ensured that learners were not pressured to participate and that their responses would not affect their academic standing. To acknowledge their participation and cooperation, learners received non-monetary tokens of appreciation, such as certificates of participation or school supplies, in accordance with ethical research practices.

Throughout the research process, the researcher remained attentive to any ethical concerns that might arise and ensured that appropriate measures were taken to address them responsibly and in accordance with established ethical standards.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

Presentation of Data, Analysis, and Interpretation

This chapter presents, analyzes, and interprets the data collected for this study. The findings are systematically arranged to directly answer the research questions of the study and to assess the effect of the hands-on laboratory exercises on the academic achievement and learning engagement of grade 11 Earth and Life Science students.

Academic Performance of the Learners

Table 1 presents the pretest and posttest mean scores and standard deviations of the grade 11 learners' academic performance in Earth and Life Science, comparing the control group (conventional approach) and the experimental group (hands-on laboratory approach). Scores were interpreted using the study's descriptive scale with a perfect score of 50, allowing a clear comparison of performance levels before and after the intervention.

The results in the pretest indicate that both groups were classified under the *did not meet expectations*, indicating that learners demonstrated limited understanding of Earth and Life Science concepts and required further improvement. The comparable performance of the two groups at the beginning of the study suggests that the participants had not yet developed sufficient mastery of the Earth and Life Science concepts covered in the test.

Table 1 Pre-test and Posttest Mean and Standard Deviation of the Academic Performance of Grade 11 Learners in Earth and Life Science

Groups	N	Pretest			Posttest		
		Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
Control	40	15.13	5.538	Did Not Meet Expectations	29.00	6.344	Did Not Meet Expectations
Experimental	40	14.83	5.377	Did Not Meet Expectations	38.50	4.957	Fairly Satisfactory
Perfect Score: 50							

Such results are common in science classes where students encounter abstract concepts that are difficult to understand through theoretical discussion alone. The classification of both groups under *did not meet expectations* implies that learners may have had limited opportunities to actively engage in practical activities that could strengthen their conceptual understanding.

In the posttest results, both groups improved, but the experimental group showed a noticeably higher level of performance. The control group remained within the *did not meet expectations*, which indicates that learners still demonstrated limited mastery of the concepts. In contrast, the experimental group reached the *fairly satisfactory*, indicating that learners demonstrated basic understanding of the concepts but still require improvement in applying scientific knowledge.

The pattern in Table 1 suggests that hands-on laboratory instruction is associated with greater academic gains in Earth and Life Science compared with traditional teaching methods. From a learning perspective, this improvement is consistent with the idea that students learn science more effectively when they are actively engaged in doing scientific tasks, such as observing, measuring, recording data, and drawing conclusions, because these activities help learners connect abstract concepts to concrete experiences. The experimental group's shift from *did not meet expectations* in the pretest to *fairly satisfactory* in the posttest implies that the intervention may have supported deeper understanding and better retention of Earth and Life Science concepts. Meanwhile, the control group's improvement without a change in descriptive category suggests that conventional instruction may promote progress but may be less effective in producing performance gains large enough to meet expected standards within the same period.

The slight improvement observed in the control group may be attributed to regular classroom instruction, teacher explanations, and exposure to learning materials during the lesson. These instructional strategies may help learners gradually improve their understanding of the topic. However, the improvement observed in the experimental group appears to be greater because learners were able to actively participate in laboratory activities that required them to observe, manipulate materials, and record their findings. Such experiences may help learners connect theoretical concepts to practical situations, which can enhance understanding and retention.

Overall, Table 1 indicates that both groups benefitted from instruction over time, but learners who experienced the hands-on laboratory approach demonstrated a more substantial rise in achievement and reached a higher descriptive level of academic performance. This descriptive evidence sets the foundation for further statistical testing in later tables to determine whether the observed difference between groups is statistically significant.

The findings of this study are supported by Orion (2018), who reported that students exposed to fieldwork and laboratory simulations exhibited improved spatial thinking skills and a deeper understanding of Earth Science concepts. These experiential learning opportunities allowed learners to link theoretical concepts with real-world geological phenomena, which contributed to better concept retention and improved academic performance. In the same way, King (2021) emphasized that the use of concrete learning materials such as rock samples and mineral identification kits enhances students' ability to classify, analyze, and differentiate geological specimens, leading to stronger performance in science-related assessments.

Additionally, the significant improvement of the experimental group's academic achievement aligns with the foundational perspectives on experiential science learning. Taranikanti et al. (2022) stated that laboratory-based instruction improves scientific literacy by allowing students to physically interact with observable phenomena versus relying on theoretical explanations. This real-world experience allows for enhanced conceptual understanding and retention of knowledge; therefore, this experimental group's experience moves them from *did not meet expectations* to *fairly satisfactory*.

Dessie et al. (2023) argued that an experimental approach to teaching enhances critical thinking and problem-solving capabilities and results in measurable improvements in academic performance by pairing practical experiments with interactive teaching style. This marked improvement in posttest scores within the experimental group indicates that students in this group connected more effectively to link Earth and Life Sciences theory including processes of rock formation and mineral identification to real-world laboratory activities.

This view is supported by empirical findings of Abdurakil et al. (2024), who found that STEM students who participated in structured laboratory activities performed significantly better on science tasks compared to their peers with instruction as usual. Similarly, Pols and Dekkers (2024) demonstrated how specifically reimagined lab classes reinforce both cognitive and procedural capacity, emphasizing the importance of both structure and inquiry in lab activities.

Additionally, Mihret et al. (2023) showed that integrated lab work fosters understanding of science theories and fosters analysis using a combination of laboratory skills along with solid science ideas.

Learning Engagement of the Learners

The learning engagement of the learners was measured before and after intervention. Their engagement in their Earth and Life Science was determined along cognitive, emotional, and behavioral dimensions. The succeeding sections thoroughly present, analyze, and interpret the data.

Learning Engagement of the Learners Before Intervention

Cognitive Engagement

Table 2 presents the pre-test results on students' learning engagement in Earth and Life Science for the control and experimental groups prior to the implementation of the hands-on laboratory approach. The table reports the mean scores and standard deviations for each indicator, along with the corresponding descriptive level, providing a baseline profile of how engaged learners were before any instructional intervention was applied.

The Table reveals that the overall cognitive engagement of both the control and experimental groups was classified as *moderately engaged*, indicating that learners demonstrated a reasonable level of effort in understanding the lesson but still required further opportunities to deepen their conceptual understanding.

Among the indicators, the three highest indicators reflected learners' ability to connect lesson concepts with practical situations and recall previously learned science topics. These indicators suggest that learners were able to relate scientific information to familiar experiences and previous knowledge.

Table 2 Mean and Standard Deviation of the Students' Engagement Pre-test Scores in Earth and Life Science in Terms of Cognitive Engagement

Indicator	Control			Experimental		
	Mean	**SD**	**Descriptive Level**	**Mean**	**SD**	**Descriptive Level**
I try to understand the characteristics and types of rocks deeply.	2.63	0.586	Moderately Engaged	2.73	0.716	Moderately Engaged
I relate mineral properties to real-life applications.	2.95	0.597	Moderately Engaged	2.68	0.572	Moderately Engaged
I make connections between rock formation and Earth processes.	2.43	0.501	Slightly Engaged	2.70	0.648	Moderately Engaged
I use strategies like notetaking and diagrams to understand rock cycles.	2.70	0.564	Moderately Engaged	2.68	0.572	Moderately Engaged
I analyze the differences among igneous, sedimentary, and metamorphic rocks.	2.53	0.506	Slightly Engaged	2.63	0.628	Moderately Engaged
I ask questions when rock and mineral topics confuse me.	2.50	0.641	Slightly Engaged	2.70	0.608	Moderately Engaged
I review rock cycle processes to reinforce my learning.	2.68	0.694	Moderately Engaged	2.88	0.563	Moderately Engaged
I apply scientific terms correctly when discussing rocks and minerals.	2.68	0.474	Moderately Engaged	2.40	0.672	Slightly Engaged
I use various learning materials to study Earth materials.	2.75	0.670	Moderately Engaged	2.68	0.526	Moderately Engaged
I can explain how minerals are identified by their properties.	2.43	0.594	Slightly Engaged	2.68	0.616	Moderately Engaged
I try to recall lessons related to plate tectonics and rock formation.	2.90	0.304	Moderately Engaged	2.78	0.480	Moderately Engaged
I find it interesting to compare different rock samples.	2.85	0.736	Moderately Engaged	2.28	0.751	Moderately Engaged
I reflect on how geologic processes impact the environment.	2.20	0.405	Slightly Engaged	2.80	0.648	Moderately Engaged
I connect past science topics to the current discussion of rocks.	2.73	0.506	Moderately Engaged	2.88	0.335	Moderately Engaged
I enjoy solving problems related to Earth's geologic materials.	2.85	0.533	Moderately Engaged	2.33	0.526	Slightly Engaged
Sub-mean	**2.65**	**0.592**	**Moderately Engaged**	**2.65**	**0.617**	**Moderately Engaged**

On the other hand, the three lowest indicators were related to deeper reflection and higher-order thinking tasks such as reflecting on the environmental implications of geologic processes, analyzing rock formation processes, and applying concepts in problem-solving situations. These results indicate that learners initially had limited opportunities to engage in analytical and reflective thinking activities.

The moderate level of cognitive engagement observed in both groups suggests that learners were capable of following classroom discussions and understanding basic concepts. However, deeper cognitive processes such as analysis, reflection, and problem solving appeared less evident prior to the intervention. This pattern may be explained by the traditional structure of classroom instruction, where learners often receive information through lectures and textbook explanations rather than through direct exploration of scientific phenomena. Without opportunities to manipulate materials or investigate scientific processes, learners may struggle to develop deeper conceptual understanding.

These findings align with the observations of Fredricks et al. (2016), who explained that cognitive engagement develops when learners are challenged to analyze concepts, apply appropriate learning strategies, and solve problems actively. In the context of this study, the hands-on laboratory approach provided learners with opportunities to think critically, make observations, compare rock and mineral samples, and draw conclusions based on evidence. Such activities required students not only to recall information but also to process, interpret, and apply scientific concepts in meaningful ways. This supports the idea that when learners are intellectually involved in the learning process, their understanding becomes deeper and more lasting.

Similarly, Gericke et al. (2022) emphasized that laboratory-based instruction promotes cognitive engagement because it allows learners to investigate scientific ideas directly rather than passively receiving information from the teacher. Through actual manipulation of materials, observation of physical properties, classification tasks, and guided inquiry, students become active participants in constructing knowledge. In relation to the present study, the use of hands-on laboratory activities in teaching Rocks and Minerals helped learners connect abstract concepts with concrete experiences. This direct engagement with learning materials may have contributed to their improved academic performance, as students were able to better understand, retain, and apply the lesson concepts.

Emotional Engagement

Table 3 presents the emotional engagement of the learners prior to the implementation of the instructional intervention. Emotional engagement refers to the learners' affective responses toward the learning process, including their interest, enjoyment, curiosity, motivation, and sense of confidence while studying Earth and Life Science.

Moreover, Table 3 reflects how learners emotionally connect with the lesson content, classroom activities, and learning environment. When learners demonstrate positive emotional engagement, they are more likely to show enthusiasm for the subject, develop curiosity about scientific concepts, and maintain a favorable attitude toward participating in learning tasks. Furthermore, the results indicate that both groups were generally classified as *slightly engaged*, suggesting that learners demonstrated only modest levels of interest, curiosity, and emotional connection toward the topic.

Table 3 Mean and Standard Deviation of the Students' Engagement Pre-test Scores in Earth and Life Science in Terms of Emotional Engagement

Indicator	**Control**			**Experimental**		
	Mean	**SD**	**Descriptive Level**	**Mean**	**SD**	**Descriptive Level**
I feel excited when identifying rock and mineral samples.	2.73	0.716	Moderately Engaged	2.75	0.927	Moderately Engaged
I enjoy doing hands-on activities like testing mineral hardness.	2.58	0.594	Slightly Engaged	2.60	0.632	Slightly Engaged
I find the rock cycle visually and conceptually interesting.	2.50	0.716	Slightly Engaged	2.35	0.533	Slightly Engaged
I feel confident during discussions on Earth materials.	2.43	0.712	Slightly Engaged	2.83	0.385	Moderately Engaged
I am interested in how rocks are formed and transformed.	2.40	0.709	Slightly Engaged	2.88	0.822	Moderately Engaged
I look forward to activities about minerals and the Earth's crust.	2.58	0.594	Slightly Engaged	2.28	0.452	Slightly Engaged
I feel accomplished when I understand geologic processes.	2.55	0.677	Slightly Engaged	2.78	0.698	Moderately Engaged
I enjoy watching videos or simulations of volcanic rock formation.	2.20	0.564	Slightly Engaged	2.45	0.552	Slightly Engaged
I like sharing facts about rocks and minerals with my peers.	2.40	0.591	Slightly Engaged	3.13	0.853	Moderately Engaged
I feel curious about how rocks affect human activities and history.	2.58	0.712	Slightly Engaged	2.75	0.494	Moderately Engaged
I find mineral identification tasks engaging.	2.63	0.540	Moderately Engaged	2.75	0.670	Moderately Engaged
I am motivated to learn when the topic involves Earth's layers.	2.20	0.723	Slightly Engaged	2.70	0.516	Moderately Engaged
I appreciate the value of rocks and minerals in daily life.	2.63	0.628	Moderately Engaged	2.43	0.501	Slightly Engaged
I enjoy drawing or interpreting diagrams of the rock cycle.	2.73	0.554	Moderately Engaged	2.48	0.506	Slightly Engaged
I feel more interested in science because of this topic.	2.33	0.526	Slightly Engaged	2.78	0.832	Moderately Engaged
Sub-mean	**2.50**	**0.654**	**Slightly Engaged**	**2.66**	**0.675**	**Moderately Engaged**

The three highest indicators were associated with learners' curiosity about rock formation and their willingness to share knowledge with peers. These responses suggest that learners had some interest in the topic and were open to discussing scientific ideas with classmates. Conversely, the three lowest indicators involved activities requiring deeper emotional investment, such as sustained interest in visual learning resources and enthusiasm

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

toward science-related topics. These findings indicate that some learners had not yet developed strong emotional attachment to the subject matter.

The slightly engaged classification suggests that learners initially viewed the lesson topics as moderately interesting but not strongly motivating. Without active participation in experiments or discovery-based activities, students may find it difficult to develop strong curiosity and enthusiasm toward scientific concepts.

According to Ellen Skinner et al. (2017), when students feel comfortable, interested, and supported in the classroom, they are more willing to participate and continue working on their tasks. When learners enjoy the activities and feel at ease, they become less afraid of making mistakes and more open to trying new things. This encourages them to ask questions, stay focused, and take part more actively in the lesson. In this way, positive emotional experiences help students stay engaged and committed to their learning, which can lead to better understanding and improved academic performance.

Behavioral Engagement

Table 4 presents the behavioral engagement of the learners prior to the intervention. Behavioral engagement refers to learners' observable participation in classroom activities, including attentiveness, participation in discussions, and completion of learning tasks.

Table 2.3 Mean and Standard Deviation of the Students' Engagement Pre-test Scores in Earth and Life Science in Terms of Behavioral Engagement

Indicator	Control			Experimental		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
I participate actively in class when we discuss rocks and minerals.	2.85	0.834	Moderately Engaged	2.68	0.616	Moderately Engaged
I complete my assignments related to Earth's geological materials on time.	2.70	0.608	Moderately Engaged	2.83	0.958	Moderately Engaged
I follow procedures carefully during mineral property experiments.	2.48	0.640	Slightly Engaged	2.38	0.628	Moderately Engaged
I contribute to group work during hands-on rock activities.	2.88	0.404	Moderately Engaged	2.73	0.506	Moderately Engaged
I read textbooks or materials related to mineral formation.	2.70	0.883	Moderately Engaged	2.53	0.554	Moderately Engaged
I take the initiative to research unfamiliar rock types.	2.38	0.490	Slightly Engaged	2.40	0.810	Moderately Engaged
I bring necessary materials during science activities on rocks.	2.83	0.675	Moderately Engaged	2.78	0.800	Moderately Engaged
I engage in peer discussion about rock samples or processes.	2.65	0.580	Moderately Engaged	2.68	0.526	Moderately Engaged
I pay attention when the teacher explains rock-related topics.	2.98	0.800	Moderately Engaged	2.85	0.736	Moderately Engaged
I use science vocabulary appropriately when describing minerals.	2.68	0.572	Moderately Engaged	2.30	0.516	Slightly Engaged
I respond to questions confidently during recitations on Earth Science.	2.90	0.632	Moderately Engaged	2.98	0.158	Moderately Engaged
I organize my notes based on rock and mineral subtopics.	2.85	0.533	Moderately Engaged	3.03	0.974	Moderately Engaged
I correct my mistakes based on feedback about Earth materials.	2.43	0.549	Slightly Engaged	2.15	0.362	Slightly Engaged
I complete enrichment tasks related to identifying rocks.	2.58	0.549	Slightly Engaged	2.68	0.526	Moderately Engaged
I try to improve my understanding of geological processes through practice.	2.74	0.785	Moderately Engaged	2.80	0.608	Moderately Engaged
Sub-mean	**2.71**	**0.665**	**Moderately Engaged**	**2.65**	**0.689**	**Moderately Engaged**

The results indicate that both groups were classified as Moderately Engaged, indicating that learners generally participated in classroom activities and complied with learning tasks. This level of engagement implies that learners showed a reasonable degree of participation, attentiveness, and cooperation during the lesson. The three highest indicators reflect learners' attentiveness during teacher explanations, participation in group discussions, and completion of classroom tasks.

Meanwhile, the three lowest indicators were related to self-regulation behaviors, such as correcting mistakes based on feedback and independently improving understanding of lesson concepts. These findings suggest that learners were willing to participate in routine classroom activities but had not yet developed strong independent learning behaviors. This pattern is common in traditional classrooms where participation is often limited to responding to teacher instructions rather than actively exploring scientific problems.

In terms of behavioral engagement, students demonstrated active participation, sustained attention, and consistent involvement in the learning tasks, particularly during the hands-on laboratory activities. They were not merely observing but were actively performing procedures, following instructions, and collaborating with peers, which allowed them to practice concepts repeatedly and meaningfully.

As supported by Jennifer Fredricks et al. (2016), students who are behaviorally engaged are more likely to remain focused, persist in completing tasks, and follow through with learning activities effectively. This sustained effort and on-task behavior contribute to improved understanding and, ultimately, better academic performance. In the context of this study, the hands-on laboratory approach encouraged such active involvement, which played a key role in strengthening students' learning outcomes.

Pretest Overall Engagement of the Control and Experimental Groups

Table 5 consolidates the baseline engagement profile reflected in the earlier dimensions by showing that the two groups began the study with nearly identical overall engagement levels. The closeness of the grand means suggests that, prior to the intervention, learners in the control and experimental groups shared comparable readiness and involvement in Earth and Life Science learning activities.

Table 5 Grand Mean and Standard Deviation of the Students' Overall Engagement Pre-test Scores in Earth and Life Science

Variable	**Control**			**Experimental**		
	Grand Mean	**SD**	**Descriptive Level**	**Grand Mean**	**SD**	**Descriptive Level**
Overall Engagement	2.62	0.644	Moderately Engaged	2.65	0.661	Moderately Engaged

In terms of the summary values, both the control group and experimental group are within the *moderately engaged* level. This result indicates that both groups demonstrated a similar level of engagement prior to the intervention. Such baseline similarity strengthens the basis for subsequent comparisons, as any differences observed after the intervention may be more confidently attributed to the instructional approach rather than to substantial pre-existing differences between the groups.

The moderate engagement result in both groups suggests that learners were already somewhat involved in the learning process, making them responsive to instructional strategies. This level of engagement provided a meaningful starting point for the intervention, allowing the hands-on laboratory approach to further enhance students' involvement and potentially improve their academic performance.

Learning Engagement of the Learners After Intervention

Cognitive Engagement

Table 6 presents the posttest mean scores and standard deviations of Grade 11 learners' cognitive engagement in Earth and Life Science after the implementation of the instructional treatments. The table compares the control group, which was taught using the conventional approach, and the experimental group, which was exposed to the hands-on laboratory approach. Each indicator is interpreted using the study's descriptive levels of engagement, providing a clear picture of how cognitively engaged the learners were after the instruction. This comparison highlights whether the hands-on laboratory approach led to a higher level of cognitive engagement than the conventional method.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

Table 6 Mean and Standard Deviation of the Students' Engagement Posttest Scores in Earth and Life Science in Terms of Cognitive Engagement

Indicator	Control			Experimental		
	Mean	**SD**	**Descriptive Level**	**Mean**	**SD**	**Descriptive Level**
I try to understand the characteristics and types of rocks deeply.	4.00	0.392	Engaged	4.43	0.501	Highly Engaged
I relate mineral properties to real-life applications.	4.00	0.392	Engaged	4.40	0.545	Highly Engaged
I make connections between rock formation and Earth processes.	3.95	0.504	Engaged	4.58	0.549	Highly Engaged
I use strategies like notetaking and diagrams to understand rock cycles.	4.00	0.506	Engaged	4.60	0.496	Highly Engaged
I analyze the differences among igneous, sedimentary, and metamorphic rocks.	4.13	0.570	Engaged	4.63	0.667	Highly Engaged
I ask questions when rock and mineral topics confuse me.	4.05	0.389	Engaged	4.40	0.672	Highly Engaged
I review rock cycle processes to reinforce my learning.	4.15	0.427	Engaged	4.45	0.597	Highly Engaged
I apply scientific terms correctly when discussing rocks and minerals.	4.00	0.392	Engaged	4.48	0.506	Highly Engaged
I use various learning materials to study Earth materials.	4.08	0.417	Engaged	4.43	0.501	Highly Engaged
I can explain how minerals are identified by their properties.	3.80	0.564	Engaged	4.45	0.504	Highly Engaged
I try to recall lessons related to plate tectonics and rock formation.	3.93	0.267	Engaged	4.55	0.504	Highly Engaged
I find it interesting to compare different rock samples.	4.00	0.320	Engaged	4.45	0.597	Highly Engaged
I reflect on how geologic processes impact the environment.	3.90	0.496	Engaged	4.43	0.675	Highly Engaged
I connect past science topics to the current discussion of rocks.	3.95	0.389	Engaged	4.58	0.675	Highly Engaged
I enjoy solving problems related to Earth's geologic materials.	4.08	0.267	Engaged	4.63	0.490	Highly Engaged
Sub-mean	**4.00**	**0.433**	**Engaged**	**4.50**	**0.569**	**Highly Engaged**

The results reveal that learners in the control group were described as *engaged*, with the qualifying statement indicating that they showed consistent effort in understanding lesson concepts and applying learning strategies during instruction. In contrast, learners in the experimental group were described as *highly engaged*, which suggests stronger cognitive involvement, deeper thinking, and greater effort in understanding the scientific concepts presented in the lesson.

Among the experimental group, the three highest indicators of cognitive engagement were focused on analyzing the differences among rock types, solving problems related to geologic materials, and using strategies such as diagrams and note-taking to understand the rock cycle. These indicators show that learners were not merely receiving information but were actively processing, organizing, and applying knowledge during the hands-on laboratory activities. Such responses reflect a higher level of mental effort, as learners were required to observe, compare, interpret, and connect ideas while engaging with actual learning materials.

On the other hand, the three lowest indicators involved explaining mineral identification processes, recalling previous geologic lessons, and reflecting on the environmental implications of geologic processes. Although these were still interpreted as Highly Engaged, they appeared relatively lower because they required more complex conceptual reasoning, prior knowledge retrieval, and reflective thinking. These tasks demand not only understanding of present activities but also the ability to connect laboratory experiences with broader scientific ideas and previous learning.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

The higher cognitive engagement of the experimental group may be attributed to the nature of the hands-on laboratory approach. During the activities, learners examined actual rock samples, identified mineral properties, conducted simple tests, recorded observations, and discussed their findings with group members. These tasks encouraged them to become active participants in the learning process rather than passive recipients of information. By directly interacting with tangible materials, learners were able to connect abstract geological concepts to real examples, making learning more meaningful and easier to process.

This finding suggests that experiential and activity-based instruction strengthens learners' ability to think critically, analyze information, and construct understanding from experience. The hands-on laboratory approach therefore appears to support deeper cognitive processing and improved problem-solving abilities, which are essential in science learning.

Emotional Engagement

Table 7 presents the posttest emotional engagement of the learners after the instructional intervention. Emotional engagement refers to the learners' interest, curiosity, enjoyment, and confidence while participating in learning activities related to Earth and Life Science.

Table 7 Mean and Standard Deviation of the Students' Engagement Posttest Scores in Earth and Life Science in Terms of Emotional Engagement

Indicator	Control			Experimental		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
I feel excited when identifying rock and mineral samples.	4.18	0.385	Engaged	4.58	0.501	Highly Engaged
I enjoy doing hands-on activities like testing mineral hardness.	4.13	0.463	Engaged	4.53	0.506	Highly Engaged
I find the rock cycle visually and conceptually interesting.	4.00	0.453	Engaged	4.48	0.554	Highly Engaged
I feel confident during discussions on Earth materials.	4.08	0.526	Engaged	4.48	0.554	Highly Engaged
I am interested in how rocks are formed and transformed.	4.23	0.620	Highly Engaged	4.68	0.474	Highly Engaged
I look forward to activities about minerals and the Earth's crust.	4.15	0.662	Engaged	4.58	0.549	Highly Engaged
22. I feel accomplished when I understand geologic processes.	4.08	0.694	Engaged	4.40	0.632	Highly Engaged
23. I enjoy watching videos or simulations of volcanic rock formation.	4.20	0.516	Engaged	4.60	0.496	Highly Engaged
24. I like sharing facts about rocks and minerals with my peers.	4.18	0.675	Engaged	4.53	0.506	Highly Engaged
25. I feel curious about how rocks affect human activities and history.	4.23	0.577	Engaged	4.43	0.549	Highly Engaged
26. I find mineral identification tasks engaging.	4.03	0.620	Engaged	4.35	0.622	Highly Engaged
27. I am motivated to learn when the topic involves Earth's layers.	4.00	0.641	Engaged	4.25	0.588	Highly Engaged
28. I appreciate the value of rocks and minerals in daily life.	4.33	0.616	Highly Engaged	4.55	0.552	Highly Engaged
29. I enjoy drawing or interpreting diagrams of the rock cycle.	4.25	0.543	Highly Engaged	4.55	0.504	Highly Engaged
30. I feel more interested in science because of this topic.	4.30	0.608	Highly Engaged	4.60	0.496	Highly Engaged
Sub-mean	4.16	0.582	Engaged	4.50	0.545	Highly Engaged

The results show that the control group was generally classified as *engaged*, indicating that learners demonstrated positive interest and emotional connection toward the lesson. In contrast, the experimental group achieved the *highly engaged*, indicating that learners demonstrated strong enthusiasm, curiosity, and enjoyment in learning about rocks and minerals. The three highest indicators of emotional engagement in the experimental group were associated with strong interest in rock formation processes, increased interest in science because of the lesson topic, and excitement when identifying rock and mineral samples. These indicators suggest that the laboratory activities stimulated learners' curiosity and enjoyment in exploring scientific phenomena.

Conversely, the three lowest emotional indicators were related to drawing diagrams of the rock cycle, identifying mineral properties through structured tasks, and discussing geologic processes. Although these indicators were relatively lower compared with the others, they were still interpreted as *highly engaged*, indicating that learners maintained strong emotional involvement throughout the learning activities.

The higher emotional engagement observed in the experimental group may be attributed to the interactive nature of the hands-on laboratory activities. During the laboratory sessions, learners were given the opportunity to directly observe rock samples, perform mineral identification tests, and participate in collaborative group investigations.

These activities created a stimulating learning environment in which learners experienced curiosity, enjoyment, and excitement while exploring scientific concepts. Through the hands-on laboratory tasks, learners were not only observing information but were actively engaging with real materials and participating in the process of discovery. The opportunity to manipulate actual rock and mineral samples, conduct identification procedures, and collaborate with peers during group activities likely strengthened learners' emotional connection to the lesson. Such experiences allowed learners to develop a sense of interest and enthusiasm toward the subject, as they were able to witness scientific concepts in a concrete and meaningful way. As a result, science learning became more engaging and relevant for the learners, transforming the lesson from a purely theoretical discussion into an interactive and meaningful learning experience.

Behavioral Engagement

Table 8 presents the posttest results for behavioral engagement, which refers to learners' observable participation in classroom activities such as attentiveness, cooperation in group tasks, completion of assignments, and active involvement in discussions. This dimension of engagement reflects how learners translate their interest and understanding of the lesson into concrete actions during the learning process.

Table 8 Mean and Standard Deviation of the Students' Engagement Posttest Scores in Earth and Life Science in Terms of Behavioral Engagement

Indicator	Control			Experimental		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
I participate actively in class when we discuss rocks and minerals.	4.10	0.379	Engaged	4.35	0.533	Highly Engaged
I complete my assignments related to Earth's geological materials on time.	4.08	0.350	Engaged	4.43	0.501	Highly Engaged
I follow procedures carefully during mineral property experiments.	4.15	0.483	Engaged	4.40	0.496	Highly Engaged
I contribute to group work during hands-on rock activities.	4.20	0.464	Engaged	4.53	0.554	Highly Engaged
I read textbooks or materials related to mineral formation.	4.33	0.694	Highly Engaged	4.60	0.496	Highly Engaged
I take the initiative to research unfamiliar rock types.	4.15	0.622	Engaged	4.45	0.504	Highly Engaged
I bring necessary materials during science activities on rocks.	4.30	0.564	Highly Engaged	4.68	0.474	Highly Engaged
I engage in peer discussion about rock samples or processes.	4.30	0.516	Highly Engaged	4.45	0.504	Highly Engaged
I pay attention when the teacher explains rock-related topics.	4.20	0.464	Engaged	4.48	0.506	Highly Engaged
I use science vocabulary appropriately when describing minerals.	4.15	0.483	Engaged	4.25	0.670	Highly Engaged

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue IV April 2026

I respond to questions confidently during recitations on Earth Science.	4.35	0.483	Highly Engaged	4.55	0.504	Highly Engaged
I organize my notes based on rock and mineral subtopics.	4.33	0.572	Highly Engaged	4.55	0.504	Highly Engaged
I correct my mistakes based on feedback about Earth materials.	4.20	0.608	Engaged	4.63	0.586	Highly Engaged
I complete enrichment tasks related to identifying rocks.	4.30	0.648	Highly Engaged	4.58	0.549	Highly Engaged
I try to improve my understanding of geological processes through practice.	4.38	0.490	Highly Engaged	4.68	0.474	Highly Engaged
Sub-mean	**4.23**	**0.532**	**Highly Engaged**	**4.51**	**0.533**	**Highly Engaged**

Both the control group and the experimental group achieved the *highly engaged* level, indicating strong participation and involvement in learning activities. However, the experimental group demonstrated consistently stronger engagement across several indicators, particularly those related to collaboration and self-regulated learning.

The three highest behavioral engagement indicators in the experimental group included bringing necessary materials during science activities, practicing to improve understanding of geological processes, and correcting mistakes based on feedback. These indicators suggest that learners actively participated in laboratory activities and demonstrated strong commitment to improving their understanding of the lesson.

The three lowest indicators involved active participation in classroom discussions, appropriate use of scientific vocabulary, and independent research on unfamiliar rock types. Although these indicators were relatively lower compared with the others, they were still interpreted as *highly engaged*, indicating strong behavioral participation overall.

The high level of behavioral engagement observed in the experimental group indicates that the hands-on laboratory approach encouraged learners to become more actively involved in classroom tasks. During laboratory activities, learners were required to follow procedures, handle scientific materials, collaborate with peers, and report their findings. These responsibilities promoted active participation and encouraged learners to take greater ownership of the learning process. Consequently, learners became more involved in scientific investigations and cooperative learning activities.

Posttest Overall Engagement of the Control and Experimental Groups

Table 9 summarizes the learners' overall engagement during the posttest by combining cognitive, emotional, and behavioral engagement. The results show that the experimental group demonstrated a higher overall engagement level than the control group, indicating a more consistently strong engagement profile after instruction. This aligns with the patterns in Tables 6, 7, and 8, where the experimental group repeatedly posted higher means and more *highly engaged* classifications across the engagement dimensions.

Table 9 Grand Mean and Standard Deviation of the Students' Overall Engagement Posttest Scores in Earth and Life Science

Variable	**Control**			**Experimental**		
	Mean	**SD**	**Descriptive Level**	**Mean**	**SD**	**Descriptive Level**
Overall Engagement	4.13	0.528	Engaged	4.50	0.549	Highly Engaged

In terms of the summary results, the control group was interpreted as *engaged*, whereas the experimental group was interpreted as *highly engaged*. These findings indicate that learners exposed to the hands-on laboratory approach demonstrated stronger overall engagement compared with those who received conventional approach. The results suggest that laboratory-based activities encouraged greater interest and enjoyment in learning, deeper cognitive involvement in scientific concepts, and more active participation during classroom activities.

The higher levels of engagement seen in the experimental group were highly consistent with previous reviews highlighting the multidimensional advantages of hands-on laboratory instruction. Fredricks et al. (2016)

conceptualized the idea of engagement as a multidimensional construct of cognitive investment, emotional connection, and behavioral participation. The findings from the current study indicate that the experimental group demonstrated enhanced outcomes across all three dimensions, highlighting that experiential learning environments engage various facets of involvement at the same time.

Studies by Maglines (2020) found that open-ended laboratory activities promote conceptual understanding as they also increase students' willingness to participate and collaborate. The study also reinforces the findings of behavioral and emotional engagement improvements observed among the experimental group. Similarly, Meilina et al. (2024) pointed out that differentiated laboratory instruction enhances intrinsic motivation; learners are more personally invested when activities engage exploration and hands-on participation.

Lazaro and Paglinawan's (2025) discovery on the positive association between laboratory resource availability and engagement suggested that accessing resources in the lab is instrumental in the development of more active cognitive and behavioral engagement. The strong responses the researcher found in this study are also in line with findings of Brown et al. (2020), that laboratory experiences make science more relatable, interesting, and enjoyable and therefore have been associated with increased curiosity and sustained interest.

In addition, Jones and Stapleton (2017) pointed out that real exposure of learners to laboratory work, in particular if they use real tools and materials, raises their enthusiasm, learning as well as their performance within STEM courses. Wero et al. (2022) similarly reported that lab sessions are more engaging than traditional lectures, leading inevitably to improved classroom participation. All these findings tell us that hands-on laboratories are not just supplementary to learning but rather are essential for the development of a unified student experience in science education.

Difference in the Academic Performance of the Learners After the Intervention Using ANCOVA

Table 10 presents the one-way analysis of covariance examining whether there is a significant difference in posttest academic performance in Earth and Life Science between grade 11 learners exposed to the hands-on laboratory approach (experimental group) and those taught through traditional instruction (control group), after statistically controlling for pretest exam scores. The said statistical treatment was employed to adjust posttest outcomes for baseline performance differences and to provide a more accurate estimate of the instructional effect.

Table 10 One-Way ANCOVA Summary in the Academic Performance of Learners in Grade 11 When Exposed to Hands-on Laboratory and Those Not Exposed

Source	SS (Type III)	df	MS	F	p	Partial Eta Square
Model	2453.43	2	1226.715	63.327	0.000	0.622
Pre-test Exam(Covariate)	4086.866	1	4086.866	210.978	0.000	0.733
Group	2453.43	2	1226.715	63.327	0.000	0.622
Error	1491.57	77	19.371			
Total	87150	80				

*Significant at p<0.05 alpha level. a. R Squared = .622 (Adjusted R Squared = .612)

Prior to the main analysis, the assumptions of ANCOVA were checked and found to be satisfactory. The relationship between the covariate (pretest scores) and the dependent variable (posttest performance) was linear, the homogeneity of regression slopes assumption was met, and the residuals were deemed acceptable in terms of normality and variance patterns. These results indicate that the use of ANCOVA and the interpretation of adjusted group differences are appropriate.

The analysis revealed that the overall model was statistically significant, indicating that the variables included in the model collectively explained a substantial portion of the variance in posttest performance. This result suggests that the model was appropriate in examining the influence of the instructional approach while controlling for differences in learners' initial achievement levels.

The pretest examination score, entered as a covariate, was found to be a significant predictor of posttest performance. This finding indicates that learners' initial level of understanding had a strong influence on their performance after the intervention. In other words, students who demonstrated stronger prior knowledge tended to achieve higher scores in the posttest. This result highlights the importance of controlling for baseline differences when evaluating the effectiveness of instructional strategies.

After adjusting for the influence of pretest scores, the instructional group effect remained statistically significant. This indicates that posttest academic performance differed meaningfully between learners who experienced the hands-on laboratory approach and those who received conventional approach. Consistent with the descriptive results presented earlier, learners in the experimental group demonstrated higher posttest performance compared with those in the control group.

These findings suggest that the hands-on laboratory approach contributed to improved academic achievement in Earth and Life Science beyond what can be explained by learners' initial performance levels. By actively engaging learners in observation, experimentation, and analysis of geological materials, the laboratory activities provided opportunities for deeper conceptual understanding and practical application of scientific concepts. The results therefore indicate that experiential learning strategies, such as hands-on laboratory activities, can serve as an effective instructional approach for improving learners' academic performance in science.

Interpretation of this statistically significant effect should remain measured in terms of educational meaning. Although the experimental group performed better, the average posttest score is still around the mid-30s out of a perfect score of 50, indicating that learners had not yet reached a high mastery level and that substantial learning gaps may remain. Moreover, the dispersion in scores (as reflected in the relatively wide standard deviations reported in the descriptive table) suggests that gains were not uniform across students, some learners likely benefited more than others. This pattern implies that while hands-on laboratory instruction can produce meaningful improvements, its impact may be strengthened further through added supports such as clearer scaffolding during laboratory tasks, structured reflection prompts, targeted remediation for struggling learners, and consistent feedback mechanisms to help all students translate laboratory experiences into stronger test and performance outcomes.

The statistically significance of analysis controlling for covariates results provide inferential confirmation of what has been descriptively described in previous literature. Koessler (2014) presented experimental findings which have shown that highly organized pre-laboratory preparation is associated with greater post-lab performance, indicating that a well-designed laboratory scaffolding positively enhances academic performance. This is consistent with the present results, in which adjusted posttest scores of the experimental group remained considerably above those of control participants after adjustment for baseline differences.

In the work of Sabasales (2019), posttest scores of learners exposed to virtual laboratory tools were statistically significantly higher than those in traditional settings – a pointer that active experimentation, whether physical or simulated, increases measurable accomplishment. Simanullang (2020) also noted better practical usage of skill through lab-based exercise, which further emphasizes the ability of experiential learning environments to enhance instruction.

Collectively, the statistically significant adjusted differences support a compelling theoretical argument: students' academic performance increases in a quantifiable and educationally important way when they actively participate in experimentation, prediction, and analysis.

Difference in Overall Learners' Engagement After the Intervention Using ANCOVA

Table 11 presents the one-way ANCOVA results examining whether grade 11 learners' posttest engagement in Earth and Life Science differs between those exposed to the hands-on laboratory approach and those taught through conventional approach, while controlling for their corresponding pretest engagement scores. Separate ANCOVA models were computed for cognitive, emotional, behavioral, and overall engagement to determine whether posttest differences are attributable to the instructional approach beyond baseline engagement. Prior to analysis, the key assumptions of Covariate-adjusted analysis were checked and were satisfactorily met, supporting the appropriateness of interpreting the adjusted group comparisons.

Table 11 One-Way ANCOVA Summary in the Engagement of Learners in the Grade 11 When Exposed to Hands-on Laboratory and Those Not Exposed

Source	SS (Type III)	df	MS	F	p	Partial Eta Square
Cognitive						
Model	5.136	2	2.568	33.98	0.000	0.469
Pre-Cognitive (Covariate)	12.377	1	12.377	163.781	0.000	0.68
Group	5.136	2	2.568	33.98	0.000	0.469
Error	5.819	77	0.076			
Total	1454.701	80				
Emotional						
Model	2.525	2	1.263	17.922	0.000	0.318
Pre-Emotional (Covariate)	18.008	1	18.008	255.61	0.000	0.768
Group	2.525	2	1.263	17.922	0.000	0.318
Error	5.425	77	0.07			
Total	1507.284	80				
Behavioral						
Model	1.519	2	0.76	10.048	0.000	0.207
Pre-Behavioral (Covariate)	22.52	1	22.52	297.828	0.000	0.795
Group	1.519	2	0.76	10.048	0.000	0.207
Error	5.822	77	0.076			
Total	1534.511	80				
Overall						
Model	2.799	2	1.4	31.827	0.000	0.453
Pre-Overall (Covariate)	9.793	1	9.793	222.678	0.000	0.743
Group	2.799	2	1.4	31.827	0.000	0.453
Error	3.386	77	0.044			
Total	1495.982	80				

*Significant at $p<0.05$ alpha level; a. R Squared = .469 (Adjusted R Squared = .455); b. R Squared = .318 (Adjusted R Squared = .300); c. R Squared = .207 (Adjusted R Squared = .186); d. R Squared = .453 (Adjusted R Squared = .438)

For cognitive engagement, the ANCOVA model was statistically significant, indicating that the model accounted for a substantial portion of the variance in posttest cognitive engagement. The covariate, pre-cognitive engagement, significantly predicted posttest cognitive engagement with a large effect size, indicating that learners' baseline cognitive engagement strongly influenced their engagement after the intervention.

After controlling for pretest cognitive engagement scores, the instructional group effect remained statistically significant, with a large effect size. This finding indicates that learners exposed to the hands-on laboratory approach demonstrated significantly higher cognitive engagement at posttest compared with those taught using traditional instruction. The result suggests that the laboratory-based instructional strategy promoted deeper thinking, analysis, and active processing of scientific concepts beyond what could be explained by learners' initial cognitive engagement levels.

For emotional engagement, the ANCOVA model was also statistically significant and explained a meaningful portion of the variance in posttest emotional engagement. The covariate, pre-emotional engagement, significantly predicted posttest emotional engagement with a very large effect size, indicating that learners' initial levels of interest, enjoyment, confidence, and motivation strongly influenced their emotional responses after instruction.

Even after controlling for baseline emotional engagement, the group effect remained statistically significant, with a moderate-to-large effect size. This finding suggests that the hands-on laboratory approach enhanced learners' positive emotional responses toward Earth and Life Science, including increased interest, enjoyment, and enthusiasm for the lesson, beyond what could be attributed to their initial emotional disposition toward the subject.

For behavioral engagement, the ANCOVA model was likewise statistically significant, although it accounted for a relatively smaller proportion of the variance compared with the other engagement dimensions. The covariate, pre-behavioral engagement, strongly predicted posttest behavioral engagement with a very large effect size, indicating that learners' baseline participation patterns and classroom behaviors strongly influenced their behavior during the posttest period.

After adjusting for pretest behavioral engagement, the group effect remained statistically significant, with a small-to-moderate effect size. This result indicates that learners exposed to the hands-on laboratory approach demonstrated higher levels of behavioral engagement, including participation in tasks, involvement in learning activities, and cooperation during laboratory work. However, the magnitude of the effect suggests that behavioral engagement may also be influenced by additional classroom factors, such as learning routines, peer interaction, and classroom management practices.

For overall engagement, the ANCOVA model was statistically significant and explained a substantial portion of the variance in learners' posttest engagement levels. The covariate, pre-overall engagement, significantly predicted posttest overall engagement with a large effect size, confirming that learners' baseline engagement levels strongly influenced their engagement outcomes.

After controlling for pretest engagement, the instructional group effect remained statistically significant, with a large effect size. This finding indicates that learners exposed to the hands-on laboratory approach demonstrated significantly higher overall engagement at posttest compared with learners taught through conventional approach, even when initial engagement levels were statistically controlled. The result suggests that the hands-on laboratory approach was effective in enhancing multiple dimensions of student engagement, including cognitive involvement, emotional interest, and behavioral participation in the learning process.

Taken together, the findings in Table 11 show a consistent pattern across the four models. Even after the pretest engagement scores were statistically accounted for, the hands-on laboratory approach remained associated with significantly higher posttest engagement in the cognitive, emotional, behavioral, and overall dimensions compared with conventional approach. The magnitude of the adjusted group differences was strongest for cognitive engagement and overall engagement, indicating that laboratory-based learning was most evident in strengthening learners' mental involvement, such as understanding concepts deeply, making connections, and using learning strategies, and in elevating engagement as a whole.

The adjusted difference for behavioral engagement, while still statistically significant, was comparatively smaller, suggesting that observable participation behaviors (e.g., consistent task completion, active involvement, and use of feedback) may be more sensitive to other classroom conditions and may require sustained reinforcement through clear routines, structured roles during activities, and consistent feedback practices to ensure that all learners benefit equally from hands-on instruction.

The differences in group adjusted for engagement dimensions are significant and consistent with research that suggests the psychosocial and inquiry-based benefits of laboratory environments. Laboratory environments are significantly predictive of both self-engagement and academic achievement (Dulinayan & Antonio, 2021), leading to a favorable situation for learners to devote effort to learning tasks.

Idris et al. (2022) have argued that inquiry-based science teaching breeds analytical reasoning and continuous curiosity which is likely to be the reason for these significant cognitive engagement effects found in the present study. Erickson et al. (2020) also showed that hands-on and problem-based learning strategies lead to higher levels of active participation than lecture-based methods, thus reiterating the behavioural differences observed between groups.

Walker et al. (2016) showed how laboratory exercises contribute to an increasing amount of inclusive and accessible science, resulting in deeper engagement for a wider range of learners. Bhagavathula et al. (2021) pointed out that pre-laboratory preparation boosts motivation and readiness to engage during laboratory sessions resulting in improved engagement outcomes. Moreover, De Gruyter (2024) reported that laboratory experiences enhance learners' scientific identity and sense of belonging, both of which are strong predictors of sustained emotional engagement.

The findings of the study reveal a significant relationship between students' academic performance and their level of learning engagement, particularly in terms of cognitive, emotional, and behavioral dimensions. Students who exhibited strong cognitive engagement demonstrated deeper understanding by actively analyzing concepts, applying knowledge, and solving problems, which contributed to higher academic performance. In terms of emotional engagement, learners who showed interest, enthusiasm, and positive attitudes toward the learning activities were more likely to remain focused and receptive to instruction. Meanwhile, behavioral engagement, reflected through active participation, on-task behavior, and involvement in laboratory activities, further supported the learning process by encouraging consistent practice and interaction.

Moreover, all these findings are supported by Louis Deslauriers et al. (2019), who found that students engaged

in active learning environments achieved better actual learning outcomes compared to those in passive, lecture-based settings, even if learners initially perceived lectures as easier. Similarly, Nir Orion and Avi Hofstein (2022) emphasized that hands-on laboratory activities and field-based learning enhance students' cognitive involvement, foster positive learning experiences, and encourage active participation, all of which are essential components of effective engagement. In the context of this study, the hands-on laboratory approach likely strengthened these three aspects of engagement, which in turn contributed to the improvement of students' academic performance. These results highlight that when learners are cognitively invested, emotionally connected, and behaviorally involved, they are more likely to achieve meaningful and lasting learning outcomes.

As a result, the increased level of engagement contributed to improved academic performance, highlighting the importance of integrating instructional strategies that support holistic student involvement in the learning process.

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