



Implementing Inquiry-based Learning in secondary school in science lessons: Exploring engagement and learning outcomes

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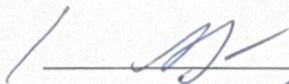
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LIST OF ABBREVIATIONS

ANOVA – Analysis of Variance

BSCS – Biological Sciences Curriculum Study

CPD – Continuing Professional Development

IBL – Inquiry-Based Learning

ICT – Information and Communication Technology

PBL – Project-Based Learning

SPSS – Statistical Package for the Social Sciences

STEM – Science, Technology, Engineering and Mathematics

ZPD – Zone of Proximal Development

ABSTRACT

This study explored the use of Inquiry-Based Learning in secondary science lessons and its impact on students' academic achievement and engagement. The participants were 78 students from Grade 5 and Grade 6. A quasi-experimental pre-test–post-test control group design was used. In each grade, one class received inquiry-based instruction and one class was taught through traditional teacher-centred methods. The Grade 5 unit focused on Ecology and Environmental Impact, while the Grade 6 unit addressed Scientific Investigation and Formulating Hypotheses. Data were collected through pre-tests, post-tests, classroom observations, and student questionnaires. Academic achievement was analysed using a 2×2 mixed ANOVA. Differences in engagement were examined using independent-samples t-tests, and Pearson's correlation coefficient was used to examine the relationship between engagement and achievement gains. Students in the inquiry-based groups demonstrated greater improvement than students in the control groups. They also reported higher levels of engagement during the intervention. The strongest outcomes were observed in Grade 6. The correlation analysis showed that students with higher engagement scores generally achieved larger learning gains.

Keywords: *Inquiry-based learning, learning outcomes, science lessons, student engagement, quasi-experimental design, secondary education.*

АҢДАТПА

Бұл зерттеудің мақсаты жаратылыстану сабақтарында зерттеуге негізделген оқытудың (Inquiry-Based Learning) оқушылардың оқу жетістігі мен сабаққа қатысуына әсерін қарастыру болды. Зерттеуге 5 және 6-сыныптардан барлығы 78 оқушы қатысты. Зерттеу квази-эксперименттік pre-test–post-test бақылау топтарымен жүргізілді. Әр сыныпта бір топ зерттеуге негізделген оқыту арқылы білім алса, екінші топ дәстүрлі оқыту әдісімен оқытылды. 5-сыныпта «Экология және қоршаған ортаға әсері», ал 6-сыныпта «Ғылыми зерттеу кезеңдері және гипотеза құру» тақырыптары оқытылды. Зерттеу барысында алдын ала және қорытынды тесттер, сыныптағы бақылаулар және оқушылар сауалнамалары пайдаланылды. Нәтижелер зерттеуге негізделген оқыту қолданылған топтардағы оқушылардың оқу көрсеткіштері жоғары болғанын көрсетті. Сонымен қатар, бұл оқушылар сабаққа белсендірек қатысып, пәнге көбірек қызығушылық танытты. Зерттеу барысында сабаққа қатысу деңгейі мен оқу жетістігі арасында байланыс бар екені байқалды. Сабаққа белсенді қатысқан оқушылардың нәтижелері де жоғары болды. Жалпы алғанда, зерттеу нәтижелері зерттеуге негізделген оқытудың жаратылыстану пәндерін оқытуда пайдалы әдіс бола алатынын көрсетті. Оқушыларға сұрақ қоюға, өз ойларын талқылауға және дәлелдермен жұмыс істеуге мүмкіндік беру олардың сабаққа қызығушылығын арттырып, оқу нәтижелерін жақсартуға көмектеседі.

Түйін сөздер: *зерттеуге негізделген оқыту, жаратылыстану білімі, оқу жетістігі, оқушылардың қатысуы, квази-эксперименттік зерттеу, орта білім.*

АННОТАЦИЯ

Исследовательское обучение (Inquiry-Based Learning) рассматривается как один из подходов, способствующих повышению учебных достижений и вовлечённости учащихся. Целью работы стало изучение влияния данного подхода на результаты обучения и вовлечённость учащихся на уроках естествознания. В исследовании приняли участие 78 учащихся 5-х и 6-х классов. Работа проводилась с использованием квазиэкспериментального дизайна с предварительным и итоговым тестированием. В каждой параллели один класс обучался с применением исследовательского подхода, а другой — традиционными методами обучения. В 5-м классе изучалась тема «Экология и воздействие на окружающую среду», а в 6-м классе — «Этапы научного исследования и формулирование гипотез». Для сбора данных использовались тесты, наблюдения на уроках и анкетирование учащихся. Результаты показали, что учащиеся экспериментальных групп продемонстрировали больший прирост учебных достижений и более высокий уровень вовлечённости по сравнению с учащимися контрольных групп. Также была обнаружена положительная связь между вовлечённостью учащихся и их учебными результатами. Включение заданий, связанных с постановкой вопросов, обсуждением идей и анализом доказательств, способствует более активному участию учащихся в учебном процессе и улучшению результатов обучения.

Ключевые слова: *исследовательское обучение, естественнонаучное образование, учебные достижения, вовлечённость учащихся, квазиэкспериментальный дизайн, среднее образование.*

INTRODUCTION

Wenning (2004) believed that developing comprehension can be achieved through the use of scientific reasoning and the application of critical thinking skills; all of which can lead to creating more meaningful concepts in relation to the environment (Water, 2012). The practical work conducted through inquiry-based methods provides a deeper level of conceptual understanding and an interest in doing research. However, there is still a predominance of traditional teacher-led instructions within many educational contexts. The study aims to explore the impact of providing students with structured interventions based on the active discovery of biological concepts to the level of content mastery of complex curricular material associated with the biological sciences.

Inquiry in science education entails the processes by which learners can build knowledge and comprehension of concepts of science and the procedures scientists use to explore the natural world (Wenning, 2004). IBL is generally characterized in the literature as an approach that emphasizes active student engagement, scientific reasoning, and the construction of knowledge through investigation (Minner et al., 2010). Inquiry-based science education is based on the idea that the learners are supposed to be challenged to build their own meaningful knowledge, and this idea is expressed in the statement that by the time a learner arrives to a science classroom, they should see an exciting learning environment where learners are wondering why and finding out; learners should be asking questions, resolving discrepancies, figuring out patterns, representing ideas, discussing information, and solving problems (Collette & Chiappetta, 1984).

Wood (2003) suggests that departments of life sciences lead a transition to a more inquiry-based approach in teaching subjects over a wide range of research experiences such as student centred introductory courses and project laboratories and faculty mentored independent research. This suggestion is an indication of a radical change in educator training of life-science teachers, which has to make them an authority in applying it in their field - a requirement that John Dewey echoed in the

maxim of learning that states learning to be founded on discovery and mentoring instead of transmitting information (Wood, 2003). Waters (2012) compares the success of inquiry-based laboratory experiments to the ones that are reminiscent of the cook-book procedures. Waters (2012) argued that inquiry-based laboratory experiences promote student ownership of learning by involving learners in authentic scientific inquiry, fostering research skills, and enhancing their understanding of scientific processes.

Hughes and Ellefson (2013) examined a study conducted in the United States in which graduate teaching assistants in the life sciences received five hours of training in inquiry-based instruction. There were two cohorts of the study, and the control group was undergoing the traditional training that was not based on the principles of inquiry. The finding showed that there was a difference in the effectiveness of the two instructional methods of teaching life-science with the experimental group recording better results. According to these findings, it is possible to achieve the fruits of offering inquiry-based pedagogy graduate teaching assistant instruction in terms of academic performance gains in undergraduate science laboratories and gains in the teaching of life sciences by graduate teaching assistants (Hughes & Ellefson, 2013). Timmerman et al. (2008) evaluated inquiry-based curriculum changes in an introductory life science course and found significant improvements in students' academic performance compared to traditional laboratory instruction, consistent with previous research in inquiry-based science education (Hughes & Ellefson, 2013).

Aim of the Study

The primary aim of this study was to examine the impact of Inquiry-Based Learning on students' academic achievement and engagement in secondary school science lessons. Specifically, the study sought to explore whether the implementation of inquiry-based instructional strategies could enhance students' learning outcomes and promote higher levels of participation, interest, and engagement during science learning activities.

Research Objectives

- To compare the academic achievement of students taught through Inquiry-Based Learning and traditional instruction.
- To compare the levels of student engagement between students taught through Inquiry-Based Learning and traditional instruction.
- To examine the relationship between student engagement and academic achievement.
- To explore whether the effects of Inquiry-Based Learning differ across Grade 5 and Grade 6 science lessons.

Research Questions and Hypotheses

1. To what extent does Inquiry-Based Learning influence students' academic achievement in secondary science education?
2. To what extent does Inquiry-Based Learning influence student engagement in secondary science education?
3. What is the relationship between student engagement and academic achievement in inquiry-based science classrooms?

Hypothesis 1: Students exposed to IBL will achieve significantly higher academic scores than students receiving traditional instruction.

Hypothesis 2: Students exposed to Inquiry-Based Learning will demonstrate significantly higher levels of engagement than students receiving traditional instruction.

Hypothesis 3: there is a positive correlation between student engagement and academic success.

Significance of the study

In this case, the goal of the research was to gain insight into how teachers implement IBL (inquiry-based learning) within the framework of life-science education. This study was particularly interested in understanding the everyday realities associated with the implementation of IBL in classrooms. Previous research (Ramnarain & Hlatshwayo, 2018) has shown that although many teachers support inquiry-based science education, they often experience difficulties in applying this approach due to limited training and insufficient professional development

opportunities. Building on this evidence, the present study explores ways in which teacher engagement with IBL can be strengthened, particularly through identifying the types of support that may enhance effective classroom implementation.

Theoretical framework

As the literature confirms, the constructivist views support appropriateness of IBL in teaching science. For instance, Applefield (2000, p. 41) argues that despite the varying opinions held by the constructivist proponents, there is a salient convergence of four cardinal features of constructivism which include: (1) learners construct their own understanding; (2) new learning relies on pre-existing knowledge by the learners; (3) social interaction is critical; and (4) authentic learning tasks are crucial in factual learning. Jones and Brader-Araje (2002) go on to state that social constructivism is based on the premise that acquisition of knowledge then follows through the communicative process whereby the child then absorbs and internalizes the information thus contributing personal value. These scholars explain that learning is an inherent process of both the teacher and the learner who have significant parts to play in the learning process (Jones & Brader-Araje, 2002). They single out three pedagogical modalities that are consistent with social constructivism namely; reciprocal teaching; interactive dialogues and reciprocal turn-taking between the teacher and learners; peer collaboration; learners work cooperatively on tasks; and apprenticeship programmes; opportunities in institutions like schools to work with experts in all disciplines is afforded to the learner (Jones & Brader-Araje, 2002).

As part of introducing social constructivism, Amineh and Asl (2015, p. 11) note that individuals contribute equally to knowledge and understanding of the world. Vygotsky (1978), quoted by Amineh and Asl (2015) opines that cognitive growth and development takes place at both a social and an individual level, hence requiring constant interaction and cooperation among people. Similar perspectives were presented by Prawat and Floden (1994), who highlighted the role of social and cultural interaction in the construction of knowledge and effective learning. However, the development of learners in the process of social interaction greatly depends on the social and cultural contexts of learners (Amineh and Asl, 2015).

Based on the succinct description above, it can be seen that there is congruency between constructivist learning theory and the inquiry-based learning. The two frameworks hold that learning is best accomplished when learners experience real life situations where they can generate knowledge by way of being exposed to real life situations. Since of these similarities, social constructivism is the most relevant theoretical paradigm to be applied in this work as it supports the principles of IBL.

LITERATURE REVIEW

2.1 Inquiry-Based Learning in Science Education

Inquiry Based Learning (IBL) is an approach to teaching based on the idea of constructivism, where a person learns through making their own meaning out of an experience by exploring, questioning and investigating real world scientific phenomena. IBL requires active involvement in the learning process; students will be required to learn in ways similar to scientists, including observing phenomena, making predictions or hypotheses, experimenting to test their predictions, and concluding based on the results of their experiments. This approach supports the idea that learning is meaningful when a learner interacts with the content rather than simply memorising disconnected pieces of information.

There has been considerable research on inquiry based learning as an instructional method to improve students' achievement and understanding of scientific concepts. Unlike traditional teacher-focused teaching methods, inquiry based learning uses the same processes that scientists use to make meaning of the world, such as questioning, observation, gathering evidence, and developing explanations, which increases student engagement in the process of knowledge construction. Many studies have demonstrated the positive impact of inquiry based learning on students' conceptual understanding and their academic performance. For example, Minner, et al (2010) synthesised research on the relationship between inquiry based learning and student learning outcomes and found that inquiry based learning environments that foster active thinking and student ownership of learning have a positive effect on students' understanding of concepts and academic performance.

In a meta-analysis of experimental and quasi-experimental research studies by Furtak et al. (2012), inquiry-based science instruction was found to positively impact student achievement. The authors determined that the presence of instructional guidance or the degree of active teacher involvement helped tell us if student learning occurred as a result of inquiry-based instruction. The results were consistent with

those of Lazonder and Harmsen (2016), who conducted a meta-analysis of studies comparing guided and unguided inquiry learning and found that students produced statistically greater learning outcomes with guided versus unguided inquiry experiences. The authors stated that the purpose of instructional scaffolding is to support students' efforts to navigate through difficult learning tasks, to assist them with interpreting evidence obtained during inquiry, and to develop valid scientific conclusions.

2.2 The Role of Guidance and Scaffolding in Inquiry Learning

There are strong levels of support among researchers that inquiry-based learning is effective; however, evidence also indicates that factors such as the amount of teacher guidance provided during this type of instruction plays an equally important role in determining how successful a student will be when learning using inquiry-based strategies. To support this, Lazonder and Harmsen's (2016) meta-analysis found that students who received guided support with their inquiry activities (e.g., directed questions) achieved significantly higher levels of academic performance than did students engaging in unguided methods of inquiry (e.g., free-form investigations). The authors of this meta-analysis provide evidence for their argument that many primary school learners have difficulty completing inquiry investigations; they struggle with developing a plan to conduct their investigation, interpreting their findings, and drawing appropriate conclusions from their findings without some type of guidance.

The support for guided, or scaffolded, learning through the teachings of Vygotsky's ZPD theory indicates that learners can develop higher orders of understanding when they receive assistance from "a more knowledgeable person." A teacher's role in creating an inquiry-based classroom involves providing the student with prompts, guiding questions and other, structure support as the student progresses from simple understanding to more sophisticated reasoning through the use of inquiry methods.

Scaffolding has been described as crucial for inquiry and problem-based learning environments by Hmelo-Silver et al. (2007). If scaffolding is not provided to students, the students could feel overwhelmed with too much cognitive load, causing them to develop only a superficial understanding of the information, as opposed to in-depth knowledge. Therefore, inquiry-based instruction needs to provide an appropriate balance between student autonomy and scaffolding in the form of guidance.

Because of the emphasis placed on active knowledge construction and students' involvement in practicing scientific behavior, inquiry-based learning (IBL) has become a dominant approach in science education. Not only do students take on the role of a learner, through IBL, they take on the role of an inquirer who investigates a phenomenon, asks questions, gathers and analyses data, and constructs explanations. Numerous large-scale research synthesis studies have confirmed the positive effects of inquiry-based instruction on enhancing students' learning experiences in science. One example of this can be seen in Furtak et al.'s (2012) meta-analysis of both experimental and quasi-experimental studies that show a positive effect of inquiry-based science instruction on students' learning outcomes and that the extent to which inquiry was effective varied based on the amount of structure provided by the instructor. Likewise, in a synthesis of research spanning almost 20 years, Minner et al. (2010) found significant correlations between instructional techniques that promote active thinking, student responsibility for their learning and their ability to investigate phenomenon with their conceptual understanding of science concepts, suggesting that IBL is an effective model in promoting deeper understanding of scientific principles. These findings suggest that inquiry-oriented environments can support deeper learning when students are actively engaged in scientific reasoning and evidence-based thinking.

According to Lazonder and Harmsen's (2016) meta-analysis of 72 research studies, inquiry-based learning works best when instructional guidance is given. The analysis showed that providing learners with guidance helped them with their learning tasks, achieving their goals, and ultimately, when they learned from using

inquiry. In addition to this, Hmelo-Silver et al. (2007) showed that both inquiry-based and problem-based learning environments are not purely guided, but rather require substantial teacher guidance through questioning, prompting, modelling and structured activities whereby learners can interact with complex scientific concepts. As a result of all these studies, there is strong empirical evidence for the effectiveness of guided inquiry as an instructional approach to be included in science education for use in primary school classrooms.

2.3 Student Engagement in Science Learning

The multiple dimensions of student engagement are typically defined as behavioral, emotional, and cognitive dimensions in relation to learning experiences. Behavioral engagement occurs through participation in classroom-based tasks and activities; emotional engagement occurs with the interest and enjoyment derived from completing a task; and cognitive engagement refers to how students invest time in order to understand complex ideas.

Research has shown that inquiry-based learning leads to increasing levels of student engagement in each dimension of engagement (Hmelo-Silver et al., 2007). When students are placed in environments where they can be active participants in solving real-world problems as opposed to being passive recipients of information, there is a greater level of student motivation and engagement (Hmelo-Silver et al., 2007).

Within science education, one way in which students' engagement levels are positively impacted is through providing appropriate authentic environmental topics for students to explore (i.e. pollution; ecosystem disruption; environmental-related health crises). These types of real-world examples provide students with the ability to link abstract scientific concepts to their own experiences, and as a result, are more interested in and retain the information.

2.4 Learning Outcomes in Inquiry-Based Science Instruction

The student's ability to understand, apply, and transfer a scientific concept represents a learning outcome in science education. There has been a strong correlation between inquiry-based instruction and improved conceptual understanding and long-term retention of knowledge using inquiry-based (as opposed to more traditional) instructions.

According to Minner et al, (2010), students that have been provided with inquiry-based instruction will show more significant gains conceptually than if they had been exposed to traditional methods of classroom instruction. This is particularly visible when students are asked to provide an explanation for a phenomenon, an interpretation of the data, or to construct an opinion based on evidence.

Furtak et al, (2012) also support these claims and provide evidence that the structured inquiry environment produces greater academic performance than other forms of instruction. In addition, the authors note that the improved performance was especially significant for tasks that require higher-order thinking skills, an outcome attributed to the active cognitive processing that occurs when students integrate their knowledge from the past with current evidence.

2.5 Environmental Science - Real-World Case Studies

Environmental science topics lend themselves to being taught via inquiry-based learning strategies due to the multidimensional nature of environmental problems/social issues and their connection to everyday situations. Many examples of this type of learning are related to the environmental problems of industrial pollution and ecological disturbances, where students can see firsthand how scientific processes affect their surroundings.

By investigating "real-world" problems such as contamination of water and disruption of food chains, students will likely learn how to think in system terms and develop a better grasp of cause-and-effect relationships in ecosystems. This is particularly true for examples of mercury contamination of aquatic ecosystems or cadmium contamination in agricultural ecosystems, both of which involve the

transfer of toxic chemicals from one level of food chain to another as organisms move through a food chain and accumulate different amounts of these chemicals over time. These two examples provide students with specific, real-world situations they can relate to and will facilitate their understanding of abstract scientific concepts such as bioaccumulation and biomagnification.

2.6 Conceptual Framework of the Study

This study is grounded in constructivist learning theory, which posits that learners construct knowledge through active engagement with their environment. Inquiry-based learning serves as the instructional approach, influencing both student engagement and learning outcomes.

The conceptual framework assumes that inquiry-based instruction enhances engagement by increasing participation, interest, and cognitive involvement.

Increased engagement, in turn, contributes to improved learning outcomes as students actively process and apply scientific concepts.

IBL has received much research due to its effectiveness as a student-centred method of instruction in mathematics and science education. Although the definition and application are different, the empirical studies on inquiry-based instruction are always conducted in comparison to traditional teacher-centred models of teaching, specifically the rule and example model. The synthesis of the empirical research by Bruder and Prescott (2013) offers a complete overview of the results and comes to the conclusion that the efficiency of IBL can be largely determined by the degree of guidance and the desired learning objectives.

Traditionally, the comparative studies of inquiry-based and rule-based instruction have shown that they produce differentiated impacts. The initial experimental research findings have indicated that conventional teaching can yield slightly better short-term memorization results, whilst the inquiry-based instruction is more successful at facilitating transfer of learning and more profound conceptual knowledge acquisition (Bruder and Prescott, 2013) . Namely, inquiry techniques

proved to have much stronger transfer effects and memorization results favoured rule-based instruction or were not significantly different.

These results are in tandem with what other meta-analytic studies show. According to Bruder and Prescott (2013) synthesized more than 200 studies (large scale) on inquiry-based teaching and found that the methods have a positive effect on critical thinking, domain-specific achievement and learning attitudes. It is worth mentioning that, process-based outcome effects were stronger compared to factual knowledge acquisition. This difference implies that the IBL can be implemented especially well in the situations, in which the educational objectives are not focused on memorization and recall but rather on reasoning, analysis, and transferable knowledge.

Longitudinal research also gives more weight to this stand. To take an example, a three-year comparative study conducted by Boaler (1998) of the project-based teaching of mathematics and traditional classes indicated that students in inquiry-based classrooms achieved the same and occasionally better performance in standardized tests and had more favorable attitudes to mathematics (as explained in Bruder and Prescott, 2013) . In the same vein, Amaral, Garrison, and Klentschy (2002) observed that the participating English Language Learners, who enrolled in long-term inquiry-based science programs realized not only science but also language and mathematics performance improvements. These results suggest that Inquiry-Based Learning could lead to cross-disciplinary academic growth in case applied in long-term periods.

In addition to cognitive outcomes, research has consistently emphasised the motivational benefits of IBL. Studies indicate that students in inquiry-based classrooms are more likely to report higher levels of interest, enjoyment, and engagement compared to those in traditional instructional settings (Bruder & Prescott, 2013). Guided inquiry, in particular, has been associated with increased self-efficacy, persistence in problem solving, and classroom participation among diverse student groups, including gifted students, students with special educational needs, and Indigenous students.

Notably, inquiry classrooms seem to create a perception of mathematics and science as engaging and thought-provoking areas of interests. This change in epistemological beliefs, that is, the shift toward understanding knowledge as something constructed and flexible, as opposed to procedural and fixed, is deemed to be one of the major benefits of this approach (Bruder & Prescott, 2013).

One of the main themes of the literature is the level of teacher instructions. Bruder and Prescott (2013) make a difference between Structured Inquiry, Guided Inquiry, and Open Inquiry. There is some evidence that Guided Inquiry, in which teachers give problems and materials and students decide how to make use of them, yields the most consistent positive results both in the cognitive and affective domains.

By comparison, minimally guided or completely open discovery models are said to run risks of loading the working memory of students, especially when little prior knowledge exists. Studies based on the cognitive load theory (e.g., Kirschner et al., 2006, as cited in Bruder and Prescott, 2013) state that direct instruction can lead to more powerful immediate content acquisition in some circumstances. As a result, it is becoming evident in the literature that strongly guided inquiry as opposed to unguided discovery is more supportive.

The level of task difficulty is also a key factor that determines the learning outcomes. The review of the studies performed by Bruder and Prescott (2013) has shown that too complex or under-scaffolded tasks may minimize the achievement and motivation levels. Positive inquiry based teaching should be thus well calibrated in terms of cognitive challenge, complexity of problems, and strategic teacher intervention.

Instead of trying to bring the debate to the level of inquiry versus direct instruction, modern studies focus on the need of balanced use of both. According to Bruder and Prescott (2013), future studies must not focus on comparing methods; instead, researchers need to focus more on the circumstances when Inquiry-Based Learning is most effective. These requirements are teacher professional development, using proper scaffolding, using an assessment practice, and taking into consideration the previous knowledge of the students.

Generally, according to the literature, IBL especially in its form of Guided Inquiry appears to be highly effective in facilitating higher-order thinking, motivation, and transferable understanding. Although the improvement in the performance on standardized tests is not consistently discussed, the overall advantages of education, such as more effective engagement and deeper conceptual understanding, warrant its inclusion in science and mathematics education nowadays.

According to the research by Romero-Ariza et al. (2020), the cross-national evidence on the perceptions and the classroom practice of Inquiry-Based Learning by science teachers in England and Spain is presented. Based on the survey data (n = 129), supplemented by the interviews and focus groups, the authors reveal that an existing gap exists between positive attitudes of teachers to IBL and its scarce application to practice. This contradiction is summed up in the description of this approach as recommended, but underuse (Romero-Ariza et al., 2020). The paper is especially timely since it focuses on how inquiry is understood and implemented in the classroom setting, instead of being merely advanced in the policy discourse. In both national contexts, educators expressed very favorable views regarding IBL.

Over 90 percent of the respondents responded that inquiry-based methods improve student motivation, engagement, as well as the overall science instructional quality (Romero-Ariza et al., 2020). Teachers conceptually supported the notion of inquiry and were willing to embrace inquiry even more. These results suggest that negative teacher beliefs are not the major reason why implementation is limited, but instead, it is because of contextual and systemic constraints.

The qualitative results indicate that educators relate it to student curiosity, teamwork, classroom engagement and open-ended problem solving. It was characterized as an inspiring and thought-provoking activity, and teachers have recorded cases where students performed better than anticipation during investigations (Romero-Ariza et al., 2020). The inquiry-based lessons were described as more interactive and dialogic in contrast to the traditional teacher-centred teaching. This is in line with studies that identified IBL allied with affective gains especially improved participation and intrinsic interest in science learning.

In the light of the current thesis, these results substantiate the position that it can be used to promote the student engagement to a great extent. The experience of teachers is that inquiry tasks encourage autonomy, creativity, and active participation. Nevertheless, interaction does not ensure better cognitive results. Engagement and interest among students do not always lead to profound conceptual knowledge, which is why there is the necessity to investigate the conceptualization and performance of the inquiry.

An important discovery involves conceptualization of inquiry amongst teachers. In spite of the fact that the participants highly identified Inquiry-Based Learning with practical inquiry and student motivation, they seldom described its epistemic facets, including development of evidence-based explanations, scientific argument, and assessment of conflicting assertions (Romero-Ariza et al., 2020). The question was often placed procedurally and affectively as opposed to a systematic process of developing knowledge. Practical experimentation has been commonly regarded as identical to inquiry and reasoning processes tacit.

This is a pedagogical anomaly. The current literature focuses on the idea that the effective inquiry incorporates epistemic practices, such as modelling, explaining, and arguing (Furtak et al., 2012). Inquiry demands clear chances of the students to relate evidence to explanation and clarify conceptual information. According to the results of Romero-Ariza et al. (2020), even the teachers, who appreciate inquiry, do not always predict these cognitive purposes. Consequently, investigation runs the danger of being action-based instead of being conceptually motivated.

To some degree, this problem can be the reason why IBL fails to generate consistent learning outcomes changes. Inquiry, when lowered to practical action, and cognitively unscaffolded, can leave the students involved busy, but without the ability to build profound insights. The success of Inquiry-Based Learning thus seems to be dependent on the intentional integration of the epistemic participation in investigative activities. It strengthens in the context of this thesis the need to look at these questions, not only on whether IBL is being applied, but how it is being pedagogically framed.

The other significant observation is associated with teacher guidance. Members admitted that open-ended inquiry has to be well scaffolded to keep the conceptual focus and avoid the surface aspects of exploration (Romero-Ariza et al., 2020). The educators stressed that student autonomy and instructional guidance have to be balanced to make sure that the learning goals are achieved. These findings are aligned with meta-analytical findings proving that guided inquiry yields better learning results compared to minimally guided discovery methods (Furtak et al., 2012; Lazonder and Harmsen, 2016). With the assistance of structured support provided by questioning, modeling, and feedback, students can be productively engaged in the process of working on complex tasks and keep the conceptual integrity intact.

Although they had positive attitudes, the teachers cited significant obstacles to long-term implementation. These were time pressure, curriculum overload, high-stakes assessment systems, accountability pressures, lack of sufficient teaching materials, and a lack of collaboration opportunities (Romero-Ariza et al., 2020). The practice of assessment was viewed to be especially problematic, with the examination systems focusing on the factual recall and structured answers. In turn, the educators tended to use more conventional methods to guarantee the coverage of the curriculum and performance in examinations (Romero-Ariza et al., 2020).

One of the cross-national differences with a significant difference was found in reported enactment: 94.4% of teachers in England reported using IBL – Inquiry-Based Learning, whereas only 24% of the teachers in Spain did so (Romero-Ariza et al., 2020). This gap indicates that there is a serious mediation of the translation of belief into practice by systemic and policy contexts. Although the idea of inquiry is typically supported, structural conditions shape the degree of its adherence.

All in all, the outcomes of the research of Romero-Ariza et al. (2020) show that the teachers find IBL to be very engaging and motivating. Engagement, however, is not enough as there should be better learning outcomes. Epistemic practices, systematic guidance, and systemic alignment between assessment and pedagogy seem to be the elements of Inquiry-Based Learning educational impact. To the extent of this thesis, the research reinforces the idea that this approach does indeed hold a lot

of potential in boosting student engagement and student learning as long as it is administered as a guided, cognitively challenging inquiry as opposed to an unstructured, hands-on undertaking.

The extensive mixed-methods study by Laursen et al. (2011) at University of Colorado Boulder offers one of the most empirical studies of Inquiry-Based Learning undergraduate mathematics. The study was based on the data of the four research universities with IBL Mathematics Centers that were used to investigate the student learning outcomes, the changes in attitudes, the instructions and the development of instructors. The results obtained through several independent data sources such as surveys ($n \geq 1,100$), classroom observations (≈ 300 hours), test, academic records ($\approx 3,200$ transcripts) and interviews all point to the same direction and indicate that IBL practices offer significant cognitive, affective and social returns over traditional lecture-based teaching.

Students have reported that using this technique produced substantial increases in their knowledge base. In all forms of knowledge gained from IBL experiences, students who were taught via IBL experienced greater improvements (measured in accordance with cognitive, affective, and social factors) than their peers who were not taught via this method. Findings from both the survey responses and responses from open-ended questions showed that these results were significantly valid. The more common descriptions of deep conceptual understanding that Inquiry-Based Learning students gave concerned the development of such understanding by active problem-solving and discussion with peers, with the emphasis that figuring things out yourself improved retention and transfer. Conversely, traditional section students more frequently related learning with test preparation and passively learning.

Notably, similarities in the results of the data sources enhance the validity of their results. The interview data supported the patterns of the survey: students talked about the enhancement of independence, persistence, and awareness of their mind. Most of them said how Inquiry-Based instruction transformed their learning processes, not necessarily in mathematics but in other subjects. Participation in the interview of the instructors also verified perceived improvements, with some of the

most notable being in the reasoning, communications, and interest of students in mathematical argumentation.

There were objective measures that served as an extra support. The pre-service educators indicated statistically significant improvement in the Learning Maths to teaching (LMT) test, upon taking IBL courses. It is worth noting that the greatest improvements were made by students who performed poorly on their first attempts, which indicates that this approach could potentially be effective with students who had poor prior preparation. Among mathematics majors, there were modest benefits of IBL students on a proof-evaluation test of performers in identifying sound and unsound arguments as well as in making expert-like reasoning. Although the differences were not necessarily statistically significant, there was no evidence as to the IBL students being disadvantaged compared to the lecture-based students. Further, analysis of academic records showed that IBL students were as adept or more so competent in further mathematics courses implying that this approach does not negatively affect content mastery and may even contribute to long-term performance.

The study has made one of the best contributions in terms of its analysis of the varied effects among student groups. The gender analyses showed that women studying in the IBL courses reported an equivalent or better learning outcome than men, but women studying in the traditional courses reported a much lower outcome in critical aspects like confidence and conceptual understanding than their male counterparts. In this way, Inquiry-Based Learning seemed to bring the playing field closer to the level so that gender differences that are usually prevalent in the conventional mathematics teaching by lectures were minimized. Despite the complicated patterns of persistence in the long-term academic performance, short-term results showed obvious benefits of women in the settings of this approach.

Prior achievement also appeared to play a moderating role in student outcomes. In traditional science courses, students with stronger prior performance tended to demonstrate the greatest gains, thereby reinforcing existing achievement gaps. In contrast, IBL appeared to provide additional support for lower-performing students,

particularly among pre-service teachers. Students who entered these courses with weaker mathematical backgrounds reported greater relative improvements in assessments and subsequent course grades. Importantly, there was no evidence that high-achieving students were disadvantaged by this instructional approach. On the contrary, many high-performing students described the method as intellectually stimulating and continued to enroll in additional mathematics courses, including further Inquiry-Based Learning experiences.

Another factor was reported to be experience level. IBL was reported to have especially high cognitive, affective, and collaborative gains among first year students. Exposure to inquiry-based methods earlier on in life seemed to have an effect on study habits, learning strategies and mathematics conviction. Though it was also beneficial to older students (especially in confidence and interest), the transformational effects were the most significant among less experienced learners. This implies that IBL applied early in life can have a lasting developmental influence.

Attitudinal change was another aspect in the study. Although the changes in beliefs and motivation were not significant overall, the trends differed drastically across the instructional forms. Students in non-IBL classes tended to lose confidence, enjoyment, and motivation to engage in learning activities. In contrast, students exposed to Inquiry-Based Learning (IBL) demonstrated either stable or slightly positive changes in their personal interest in mathematics, appreciation of proof as a creative process, and belief in the value of collaborative learning. In the case of women, specifically, IBL – Inquiry-Based Learning was effective in averting negative motivational drops as noticed in lecture situations. These results highlight the significance of classroom atmosphere and structure of teaching in the development of mathematical identity of the students.

One of the unique advantages of the assessment is that it relates classroom practices and outcomes directly. Through observational data, it was established that IBL classrooms spent more than 60% of the classroom time on activities that were student-centered compared to non-IBL classes where instructor talk was the dominant classroom activity (about 87%). Statistical modeling showed that the ratio of student

based time was the most significant predictor of learning gains. The gains associated with small-group work, student presentations, discussion, and shared responsibility in the pacing of students, and all the gain was negatively correlated with extended lecturing by the instructor. Therefore, the research offers empirical support between the pedagogical structure and the quantifiable student outcomes.

These mechanisms were further explained by qualitative analyses. Two processes that were interrelated, such as deep individual engagement and structured collaboration appeared as the central ones. Students reported on spending prolonged problem solving time after which they discussed as a group as necessary to achieve conceptual clarity and permanence. Teamwork also enhanced responsibility, entertainment, interpersonal abilities, and sharing of different reasoning techniques. These processes are consistent with the learning sciences research which focuses on active knowledge building and social interaction.

Lastly, the research recorded significant benefits on instructors. Faculty reported improvement in knowledge of student thinking, pedagogical proficiency and professional satisfaction. The majority reported permanent shifts in their teaching philosophy and practice, not just limited to the courses of IBL that they took. Despite the high demands of time, the overwhelming consensus among instructors was that IBL – Inquiry-Based Learning was both professionally enriching and career-building.

Overall, the analysis offers solid, multi-perspective data that IBL in undergraduate mathematics facilitates the deeper conceptual knowledge, better problem-solving, greater confidence, fair gender results, and meaningful interactions, without negatively affecting performance in the post-IBL courses. The effects are specially high in those groups of women, lower-achieving students, and those in the first year of study. The study provides strong empirical evidence to the emerging research that has supported inquiry-based and collaborative methods of teaching higher mathematics, because it directly relates student gains to practices of student-centered instruction (Laursen et al., 2011).

Norwegian studies in the area of instructor beliefs about Inquiry-Based Learning in the recent past serve to shed more light on the paradoxical nature of

positive beliefs about inquiry and their low levels of classroom application. Sikko, Lyngved, and Pepin (2012) explored the perceptions of mathematics and science teachers towards IBL and its perceived impediments and motivators of implementation in Norway in a study as part of the European PRIMAS project. The authors conducted two surveys based on which 24 teachers who were about to become instructional leaders in IBL were surveyed, and 75 teachers in general were surveyed as a baseline, they discovered that Norwegian teachers were generally willing to increase their application of inquiry-oriented approaches. Most of the respondents saw inquiry-based instructions to be pedagogically valid and useful in helping to increase student motivation and engagement. Teachers linked this approach with possibilities of purposeful, enquiring and student-based learning, which is consistent with all overarching European policy guidance that promotes inquiry as an approach to respond to the decreasing popularity of mathematics and science. Although the researcher found this favorable attitude, it was also possible to pinpoint a number of structural and professional limitations that hindered the daily adoption of inquiry-based learning in the teaching practice.

Time was found to be the biggest obstacle in both groups of the surveys. A sizeable percentage of teachers noted that they were concerned about the extra amount of time needed to plan inquiry-based lessons, and lack of time to instruct within an already overloaded curriculum. Several of the interviewees saw that IBL required more energy and planning than the more traditional, transmission-based approaches. This feeling of time pressure is reminiscent of previous results in both Norwegian and international studies, which indicate that teachers tend to feel stressed between innovative pedagogies and curriculum coverage demands. Notably, though, even though time was often mentioned as a challenge, it did not seem to reduce the overall perception of teachers regarding the importance of IBL – Inquiry-Based Learning instead, it served as a practical challenge to its continued implementation.

The other notable finding was on the professional confidence and the accessibility of support by teachers. Even though the teachers showed eagerness towards inquiry-based practices, most of them complained of having low confidence

levels regarding their capability of implementing and assessing IBL successfully. A significant percentage meant a form of uncertainty of how the learning outcomes of students could be assessed in an inquiry-oriented task, which means that the issue of assessment is an important area of concern. Furthermore, over fifty percent of the baseline respondents claimed that they had substandard access to Continuing Professional Development (CPD) programs directly on IBL. The given results demonstrate the need to focus on continuous, structured professional learning experiences that combine content knowledge with pedagogical practices. Teachers showed a strong inclination to collaborative arrangements, with many of them being interested in closer work with others and involvement in school-wide coordinated inquiry. The paper, therefore, proposes that collegial teamwork and well-organized professional community can also be important facilitating factors in enhancing the inquiry competence of teachers.

Interestingly, contextual elements like textbooks and curriculum framework was not seen to be a significant challenge, yet respondents indicated that the current textbooks had the potential to enhance inquiry elements. Although Norwegian textbooks are relevant to the content of the lessons, there was no overwhelming claim by teachers that they had little use of IBL due to the limitations of the textbook. While national curricula emphasize problem-solving and exploratory learning, particularly within science education under inquiry-oriented frameworks, teachers indicated that inquiry approaches should be more explicitly articulated to better justify and support classroom practice. The Norwegian teachers' responses aligned with broader international trends, as reflected in the PRIMAS European data. They were generally oriented towards inquiry-based learning (IBL), recognized its motivational potential, and expressed a need for additional support, which is consistent with findings across Europe. However, Norwegian teachers were slightly less likely to perceive gaps in students' content knowledge as a major barrier, suggesting a more inclusive understanding of inquiry that is not limited to high-achieving students.

In general, the research indicates that there is a significant correspondence between the pedagogical beliefs of teachers and the latest reform discourses that endorse an inquiry-based teaching. Norwegian mathematics and science teachers seem to envision IBL as an interesting and inspiring method that can provide more profound conceptual knowledge and engagement of the students. However, the positive belief system is intertwined with feasible issues like time management, literacy in assessment, and access to professional development of the special kind. The results support the claim that the inquiry-based learning implementation needs systemic support at the various levels such as policy alignment, curriculum design, resource development, and long-term teacher learning. The study provides the significant empirical contentment by underscoring the passion and the reservations of the teaching practitioners that tend to define educational reform. To study the impact of inquiry-based instruction on student engagement and achievement, these results support the important role of integrating the professional situations and perceived limitations experienced by the teachers because these variables play a pivotal role in the conversion of inquiry-oriented intentions into classroom reality.

The results provided by Morze, Smyrnova-Trybulska, and Gladun (2018) are mostly obtained in the context of a large-scale survey research examining the perceptions of STEM education trends and the influence of Inquiry-Based Learning on the perceptions of various stakeholder groups. The article used a quantitative survey design conducted in September 2018 in Ukraine and it included three categories of participants including 562 academic staff members, 239 school teachers, and 1,602 students. This tool was aimed at determining the priority educational trends and perceived necessity of introducing certain pedagogical technologies in the STEM-oriented education. The findings indicated that STEM education has been identified as one of the highest educational priorities in the modern world, and in all groups of respondents. Nevertheless, the figures also showed that there was a strong disparity between the expectations of students and the teaching methods that are usually suggested by educators and other academic specialists. Specifically, students were more supportive of integrated and innovative

approaches, and the educators showed a more moderate stance towards the adoption of these approaches.

Concerning pedagogical technologies, the results indicate that the Integrated Learning, Inquiry-Based Learning, and Project-Based Learning (PBL) were found to be the most prominent as tools to modernize the teaching of STEM. The findings of the surveys, as depicted in the figures in the study, prove that the respondents gave IBL one of the highest priorities of interventions that are needed in enhancing the quality of education and aligning instruction with labor market needs. Also, respondents emphasized the need of complementary measures like the formation of media literacy, problem-oriented learning, blended learning, formative assessment, development of the critical thinking, and the implementation of e-learning game environments. These results indicate widespread awareness of the necessity of getting out of the old method of lectures and teaching in favor of models that are student-centered and inquiry-oriented.

The paper also places its findings in the context of the modern-day analysis of the labor market. Referring to the employment forecasts in the world, the authors inform that the scope of demand of the professions related to STEM has grown significantly, referring to the data that the number of jobs in the STEM areas had grown between 1.2 and 2.4 million during the years, and to 80 percent of the fast-growing jobs demanded the knowledge of STEM as the basic level. Even though these numbers are based on secondary statistics, but not primary data collection, they provide the sense of urgency to undertake IBL – Inquiry-Based Learning as one of the aspects of the STEM reform. The authors relate these workforce requirements with competencies reported in international employer surveys such as complex problem-solving, critical thinking, creativity, coordination, negotiation, and cognitive flexibility, which supports the use of inquiry methodologies.

Besides the survey aspect, the study presents a comparative methodological study of educational technologies wherein the similarities and differences of Project-Based Learning and Problem-Based Learning are described. Although this part of the research is abstract, as opposed to empirical, it works methodologically as an

analytical framework that assists in the interpretation of survey findings. The authors find that IBL is unique in the structured inquiry cycle and systematic investigation processes focus.

Another way in which the paper contributes to the field of methodology is the synthesis of inquiry cycle models. The authors base their study on the previous research and compare the 5E model of instruction (Engagement, Exploration, Explanation, Elaboration, Evaluation) with the inquiry cycle suggested by White and Frederiksen (Question, Predict, Experiment, Model, Apply). On the basis of such comparative review, they come up with a generalized five-stage framework including orientation, conceptualization, investigation, conclusion, and discussion. This synthesis is proposed as a theoretical model based on the analysis of literature instead of the original experimentation, but as a result of the systematized review of inquiry definitions and phases by the authors.

Another report on the integration of ICT in inquiry based environment is also reported in the article. In particular, the authors study the Go-Lab ecosystem as a feasible tool of supporting IBL implementation. They refer to the existence of about 1,500 online labs (distant and virtual) in various fields of STEM that one can filter by subject, age group, and language. Even though there was no experimental Go-Lab intervention in the framework of the given study, the authors offer it as an evidence-based intervention in accordance with the priorities posed through the survey as the digital and inquiry-based tools.

The authors in the discussion and conclusion sections generalize their findings of the survey with the available European policy reports. It is found that inquiry-based science teaching has proven to be effective at primary and secondary levels in enhancing student interest and performance and citing the studies by Rocard et al. (2007) as testament to this argument.

In general, the essential findings of Morze et al. (2018) are: (1) the high level of awareness of 2,403 surveyed participants towards STEM and IBL as the priority areas of education; (2) the existence of a perceptual gap between students and educators related to the instructional innovation; (3) the high level of importance of

Integrated Learning, IBL, and PBL as the main technologies of modernization; and (4) the fact that ICT-mediated inquiry environments respond to the needs of stakeholders. Theoretically, the research involves a quantitative survey, as the methodology, and comparative theoretical and literature-based synthesis of inquiry models, which places IBL as a requisite and empirically justified part of STEM education reform.

One of the most recent and high-quality evidence-base articles on inquiry-based learning is a systematic review and meta-analysis study by Arifin et al. (2025), who summarizes the existing empirical data on how IBL affects students in terms of their critical thinking skills in science learning. The authors used 36 independent effect sizes to summarize the findings on the overall size of the relationship between IBL interventions and critical thinking outcomes using 25 peer-reviewed articles published between 2000 and 2024 and indexed in the Scopus and ERIC databases. The research was conducted in a systematic review format with a set of predetermined inclusion and exclusion criteria, search in the databases using specific keywords on the topic of inquiry-based learning and critical thinking, and methodological screening. Only those studies that were quantitative and applied IBL in the context of teaching science were included and reported having enough statistical data to determine effect sizes. The meta-analytic technique utilized by the authors was a random-effects model, which was appropriate given the expected variability in educational settings, participant characteristics, and intervention designs. The findings indicated that the overall impact of IBL on the overall performance of students in the critical thinking area is statistically significant and significant in value (mean effect size of 1.27 [95% CI [0.78, 1.76]. According to traditional standards, the effect is large; therefore, this indicates that the pupils within an inquiry-based instructional environment had a higher level of critical thinking development compared to students who were instructed in more traditional or teacher-centered classrooms. However, the amount of heterogeneity was also very high among studies analyzed ($I^2 = 92\%$), which indicates that the variability of the effect size is dissimilar depending on the context and pedagogical factors. In order to

overcome this variance, the authors performed moderator analyses that involved the differences in effect sizes based on the educational level, the type of instructional strategies, incorporation of information and communication technology (ICT), the length of intervention, and assessment methods through which critical thinking could be measured. The effectiveness of inquiry-based learning (IBL) was not uniform across different contexts; however, IBL was influenced by specific factors of design and implementation. For example, there were differences in primary, secondary and tertiary education, indicating that students' level of development affects their ability to effectively use inquiry-based pedagogy. In addition, the differences observed between the use of structured and more open-ended models of instruction were associated with the differing level of results, further illustrating the importance of scaffolding and pedagogic support in developing higher-order thinking. The use of technology in inquiry-based instruction contexts was also seen as a contributing factor toward increasing the likelihood of analytical, evaluative and evidence-based thought. In addition, there was evidence that the length of time an IBL intervention took place had an effect on its results; specifically, long-term implementations produced a greater effect than short-term implementations, suggesting that critical thinking skills develop cumulatively. Furthermore, the type of assessment tool used to assess development of critical thinking also contributed to the variety of results reported, therefore the decision-making process related to methodology disseminating results influenced the effectiveness of outcomes from it. In the study, therefore, not only is the effectiveness of inquiry-based learning demonstrated, but the subsequent analysis of these factors will explain how and when this approach can help develop critical thinking skills in students studying science and to what extent IBL will help do so. Notably, Arifin et al. (2025) frame their results in the context of more general theoretical debates concerning constructivist learning theory, stating that inquiry-based learning practices are consistent with epistemic practices of scientific thinking, including questioning, hypothesis, interpretation of data, and argument based on evidence. By being actively involved in problem solving and investigation, students do not receive the knowledge passively but rather they are co-producers of

understanding which enhances analytical and evaluative skills of critical thinking. The authors make the conclusion that the high aggregated effect size gives empirical credence to the importance of incorporating inquiry-based learning as a part of the overall pedagogical strategy into science curricula; nevertheless, they raise the concern that high heterogeneity may be a manifestation of the necessity of instructional design and implementation that is sensitive to the context. To address the aim of the current thesis, which is to understand how inquiry-based learning affects student engagement and learning results, the meta-analysis provides a convincing quantitative support of the fact that inquiry-based instructions is closely connected with the increase in higher-order cognitive abilities. The massive aggregate impact size supports statements that inquiry-based teaching can significantly impact cognitive outcomes beyond the content acquisition in areas such as those that involve reasoning and reflection. Simultaneously, the moderator results support the idea of engagement and learning benefits being mediated by the quality of instruction, scaffolding, time, and integration of technology, which ought to be taken into account when designing classroom interventions. Moreover, the fact that the study is based on a systematic search of databases, clear selection criteria, and a synthesis of the results by statistical means, enhances the credibility of the findings and places the study in the top tier of the educational research hierarchy. As a result, not only does Arifin et al. (2025) provide empirical validation of the efficacy of inquiry-based learning, but it also provides practical arguments on the optimal way to implement it to achieve cognitive gains, which can be a powerful basis of empirical study on how inquiry-based methods can be used to motivate the engagement of the broader school science setting as well as academic attainments.

The article by Presnillo and Aliazas (2024) investigated how effective inquiry-based instruction is in enhancing the engagement and critical thinking levels of Grade 10 students in the biology subject in the Philippine learning setting. The research design was pre-experimental, single-group pretest-posttest, which was used to establish the changes in the cognitive outcomes of students following the introduction of IBL. The sample size involved in the study was Grade 10 students attending

biology classes, and the information was obtained by means of two 50-item tests of critical thinking that were carried out at the beginning and at the end of the intervention and a survey questionnaire assessing behavioral, cognitive, and emotional engagement. The statistical analyses involved descriptive statistics, standard deviation and paired t-tests to find out significant changes between pre-test and post-test outcomes. Instructional intervention included the use of inquiry-based activities over two units of biology Heredity: Inheritance and Variation and Living Things and Their Environment which were to include questions, inquiry, discussion, and reflection by students. The findings established that there was a significant rise in the level of engagement among the students after the introduction of IBL. With regard to behavioral engagement, the composite mean rose to 3.51 (Highly Engaged) following the instruction, which was higher than it was before the intervention (2.56 - Engaged). As an example, the highest post-test mean of 3.60 was on the indicator I find lessons interesting, which shows a highly engaged level, whereas the pre-test indicator I pay attention in class has a lower mean of 2.48, which shows only an average level of engagement before the intervention. These findings indicate that the use of inquiry-based teaching methods was helpful in enhancing the attentiveness, curiosity, and motivation of students in the classroom. On the same note, cognitive engagement had also improved significantly. The total mean score increased to 3.43 (Engaged) after the IBL implementation against the 2.47 (Moderately Engaged) prior to its implementation. The overall post-test score was greatest in the indicator "I put effort in tackling hard problems and concepts until I get answers and that the mean of the same was 3.60, indicating that I am fully engaged in problem solving activities. Conversely, the results of the pre-test indicated comparatively lower scores in the engagement of connecting learning and personal experience ($M = 2.20$) and forming examples to grasp the concepts ($M = 2.18$). Such outcomes point to the fact that this approach facilitated in-depth thinking through stimulating students to analyze the issues actively, support argumentation, and connect scientific knowledge with the real world. The level of emotional engagement was also enhanced significantly due to the inquiry-based intervention. The composite mean engagement score increased

from 2.24 (Moderately Engaged) before the intervention to 3.47 (Engaged) after introducing of IBL, indicating an improvement in engagement. More importantly, the indicator "I take initiatives to assess my work and reflect on my scores had a post-test mean of 3.55, which corresponds to the level of high engagement. This positive change shows that an inquiry-based learning provided a positive supportive and participative classroom atmosphere where the students were better motivated to pursue feedback, questions and reflection about their academic progress. Besides engagement, the study also estimated the effect of inquiry-based learning on the critical thinking skills of the students such as analysis, evaluation, application, inference, and self-regulation. Before the intervention, the overall performance in critical thinking was at the Beginning level with the mean of 67.83 (SD = 2.16). Following the inquiry- based learning, the average score rose to 80.15 (SD= 7.73) that is equivalent to the Approaching Proficiency level. There was a significant positive change in all the dimensions of critical thinking. As an example, analysis scores went up to 83.75, and inference scores went up to 83.47, whereas the analysis scores were 67.90, and inference was 66.42. On the same note, self-regulation improved by 66.17 to 81.25 which meant that the students were in a better position to monitor and control their thinking process. The positive change in the application (69.83 to 73.75) and evaluation (68.82 to 78.52) were somewhat smaller: however, they still indicate positive progress in the skills of students to use scientific knowledge and evaluate the evidence. They were statistically proven to be significant improvements in all the critical thinking dimensions. The results of the paired t-test showed that the difference between pre-test and post-test scores were highly significant: analysis ($t = 6.142, p < .001$), evaluation ($t = 5.128, p < .001$), application ($t = 3.394, p = .002$), inference ($t = 11.208, p < .001$), and self-regulation ($t = 8.784, p < .001$). These results indicate that the introduction of the inquiry-based learning was very effective in improving higher-order thinking skills of the students. Moreover, there was also a considerable dissimilarity in all areas of engagement following the intervention. The results of the differences between the mean were 0.945 in behavioral engagement ($t = 12.415, p < .001$), 0.956 in cognitive engagement ($t =$

13.494, $p < .001$), and 1.229 in emotional engagement ($t = 13.834$, $p < .001$), which showed that the inquiry-based approach was effective to enhance active nature and motivational nature in students. Overall, the study provides evidence that inquiry-based learning enhances student interaction and critical thinking in science education. The findings suggest that inquiry-based strategies may improve student engagement and support the development of critical thinking skills in secondary education (Presnillo & Alias, 2024).

METHODOLOGY

3.1 Research Design

This study employed a quasi-experimental pre-test–post-test control group design. The intervention was implemented in two grade levels, with one experimental group and one control group in each grade. Students in the experimental groups received instruction based on Inquiry-Based Learning, whereas students in the control groups were taught using traditional teacher-centered methods. All groups completed the same pre-test and post-test assessments.

The study was conducted in Grade 5 and Grade 6 science classes and involved two different instructional units. Using the same design across both grade levels made it possible to examine the effects of Inquiry-Based Learning in more than one educational context.

Random assignment was not possible because the classes had already been formed by the school before the study began. This is a common situation in educational research, where researchers often work with existing classes rather than assigning students to new groups. Cohen, Manion, and Morrison (2017) note that quasi-experimental designs are frequently used in school settings for this reason.

3.2 Participants

The study involved 78 students from one secondary school.

Grade 5 included 34 students. The experimental group consisted of 17 students, while the control group also consisted of 17 students. Grade 6 included 44 students. In total, the experiment included 22 students in both groups.

All four classes had the same teacher for the duration of the intervention, helping to provide consistent learning environments among all students; however, since he was also the researcher in this study, care must be taken when interpreting results as the researcher may have caused some degree of influence on students.

3.3 Intervention

About three weeks was spent on implementation of student experimentation. Students in the experimental groups received inquiry-based learning instruction; while those in the control groups were taught using 'traditional' teacher-centered teaching methods. Both experimental and control students received exactly the same content area coverage (based on the prescribed curriculum). Below is a summary of what each of the experimental and control groups learned in gross detail in Grades 5 and 6.

In Grade 5, students learned the topic of 'Ecology and Environmental Impact' while students participating in the experimental groups were taught with case studies of pollution and deforestation as their focus issues. The students in the experimental groups completed their inquiry projects using printed sources of information and all students engaged in observing possible causes and effects based on evidence from printed sources to support their conclusions. All projects were completed solely in their classrooms (i.e., no laboratory experiments were involved; therefore, all work was conducted in the classroom).

In Grade 6, students learned about 'Scientific Investigation, Formulating Hypotheses'. Students viewed examples of historical scientific investigations and discussed how scientists formed their hypothesis and confirmed or validated their hypothesis through the collection of evidence. Historical cases were used as examples to help students view how scientific discoveries are constantly evolving (Allchin, 2013).

For control classes, both similar topics were taught via teacher directed instruction/explanation; textbook activities; note taking; and classroom questioning.

3.4 Data Collection

Two types of data collection were used for students' academic success and engagement, through the use of pre-and post-tests for any intervention group. The same tests were used for each grade within each group, using the same rubric and were based on the learning outcomes of those instructional units.

Two types of measurement of students' engagement were used. The first measure was collected through an observational checklist used during instruction for the level of engagement demonstrated by students. This checklist includes ways in which the student participated, such as asking questions, contributing to discussion, and maintaining attention to the lesson.

The other measure of student engagement was through a questionnaire, which used 5-point Likert scale rating of statements concerning the level and type of participation, interest and learning that occurred over the intervention. This questionnaire was modified from the Student Engagement Instrument (Appleton et al., 2006).

3.5 Data Analysis

R is the software used for all statistical analyses performed. A 2×2 mixed ANOVA was employed to assess differences in academic achievement as measured by pre-tests compared to post-tests for participants in both experimental and control groups.

Independent-sample t-tests were performed to compare the engagement levels of students in both groups. Pearson's correlation coefficient was determined to measure relationships between student engagement and achievement gains. Statistical significance was established at the .05 level. For the purposes of reporting and interpreting the results, effect sizes were included alongside p-values to provide additional information regarding the practical significance and magnitude of the observed effects. This approach allows for a more comprehensive evaluation of the findings beyond statistical significance alone. Cohen's d was utilized to report effect sizes for between-group comparisons, while generalized eta squared (η^2g) or partial eta squared (ηp^2) were employed for mixed ANOVA analyses. The interpretation of effect sizes followed commonly accepted guidelines in educational research.

3.6 Ethical Consideration

Taking part in the research was voluntary, and student datasets were de-identified before being analyzed for research purposes. There were no sensitive personal identifiers collected during this study, and all activities took place during normal school instructional hours.

The researcher was a classroom instructor for all students in both control and experimental groups. There were no differences between the assessment procedures or marking criteria used for both groups of students to minimize any possibility of bias. All students in both experimental and control groups received instruction based on the same curricular objectives and performed the same assessments throughout the study.

There was no deception involved in the study, and no student's academic record or grades were impacted by the student's participation in this research project.

3.7 Validity and Reliability

To enhance quality, several actions were enacted. Assessment tasks were created in accordance with curriculum objectives/learning outcomes for units of instruction with all students being given the same assessment/assessment conditions both experimental and control groups.

The same learning environment was used across all four classrooms while being taught by one teacher only and provided under the same curriculum specifications to reduce possible sources of variability due to teaching methods or lesson for which students received instruction.

Assessment procedures were performed uniformly through the use of identical criteria for each student being assessed. Student engagement was examined using two sources of information: classroom observations and student questionnaires. Using more than one method made it possible to compare findings from different sources rather than relying on a single measure.

The questionnaire was based on the Student Engagement Instrument developed by Appleton et al. (2006). This instrument has been used in previous educational studies and was adapted for the purposes of the present research.

3.8 Justification of Statistical Analysis

The statistical analyses were selected according to the research questions and the type of data collected.

Academic achievement was analyzed using a 2×2 mixed ANOVA. This method was chosen because achievement was measured twice (pre-test and post-test) and involved two groups (experimental and control). The analysis allowed changes over time to be examined and made it possible to determine whether the two groups improved differently during the intervention.

Student engagement scores were compared using independent-samples t-tests. Since engagement was measured at the end of the intervention and the comparison involved two independent groups, this test was considered appropriate.

Pearson's correlation coefficient was used to examine the relationship between student engagement and academic achievement gains. Both variables were continuous, making Pearson's correlation suitable for this analysis.

Effect sizes were calculated alongside significance tests to provide a more comprehensive interpretation of the results. While p-values indicate whether the observed differences are statistically significant, effect size measures provide information about the magnitude of these differences. Cohen's d was used for group comparisons, while generalized eta squared (η^2g) and partial eta squared (ηp^2) were reported for the mixed ANOVA results. Reporting effect sizes helped determine whether the observed differences were meaningful from an educational perspective rather than merely statistically significant and supported a more thorough interpretation of the findings.

RESULTS

4.1 Student Engagement

Table 4.1 Mixed ANOVA Results for Academic Achievement in Grade 5

Effect	Df	MSE	F	P	η^2g
Group	1, 32	71.64	0.89	.351	.020
Time	1, 32	24.14	115.79	< .001	.477
Group $\times$ Time	1, 32	24.14	8.20	.007	.061

A 2×2 mixed ANOVA was performed to analyze the influence of instructional method (inquiry-based learning or regular teaching) and time (pre-test and post-test) on the level of academic performance of Grade 5 students.

No significant difference between the mean scores of the participants belonging to the two groups (experimental and control) could be detected due to the lack of statistical significance of the main effect of group, $F(1, 32) = 0.89$, $p = .351$, $\eta^2g = .020$.

However, the results of the ANOVA revealed a statistically significant main effect of time, $F(1, 32) = 115.79$, $p < .001$, $\eta^2g = .477$. This finding indicates that academic performance improved significantly from pre-test to post-test across all participants, regardless of the instructional condition to which they were assigned. The large effect size further suggests that the observed improvement was substantial in magnitude. These results imply that students demonstrated measurable learning gains over the course of the study, reflecting overall progress in academic achievement during the intervention period.

Moreover, the presence of a statistically significant interaction between Group and Time factors, $F(1, 32) = 8.20$, $p = .007$, $\eta^2g = .061$, indicates that changes in academic performance over time differed between the experimental and control groups. Specifically, students who participated in the inquiry-based learning intervention demonstrated a greater improvement in academic achievement from pre-test to post-test compared to students who received traditional instruction. This

finding suggests that the intervention had a positive effect on learning outcomes and contributed to higher levels of academic progress among students in the experimental group. These results provide additional support for the effectiveness of inquiry-based learning in enhancing academic achievement.

Table 4.2 Mixed ANOVA Results for Academic Achievement in Grade 6

Effect	F(df)	p	Partial η^2
Group	F(1, 42) = 2.25	.141	.05
Time	F(1, 42) = 154.05	< .001	.79
Group $\times$ Time	F(1, 42) = 38.94	< .001	.48

The partial eta squared was used to assess the practical significance of the interaction effect. The achieved value ($\eta^2 = .20$, 95% CI [.04, 1.00]) was above the conventional threshold for a large effect, showing that the difference in achievement growth between the experimental and control group was not only statistically significant but also educationally meaningful.

Table 4.3 Effect Sizes for the Mixed ANOVA (Grade 6 Academic Achievement)

Effect	Partial η^2	95% CI
Group	.05	[.00, 1.00]
Time	.79	[.69, 1.00]
Group $\times$ Time	.48	[.30, 1.00]

Table 4.4 Pairwise Comparisons of Pre-Test and Post-Test Scores in Grade 5

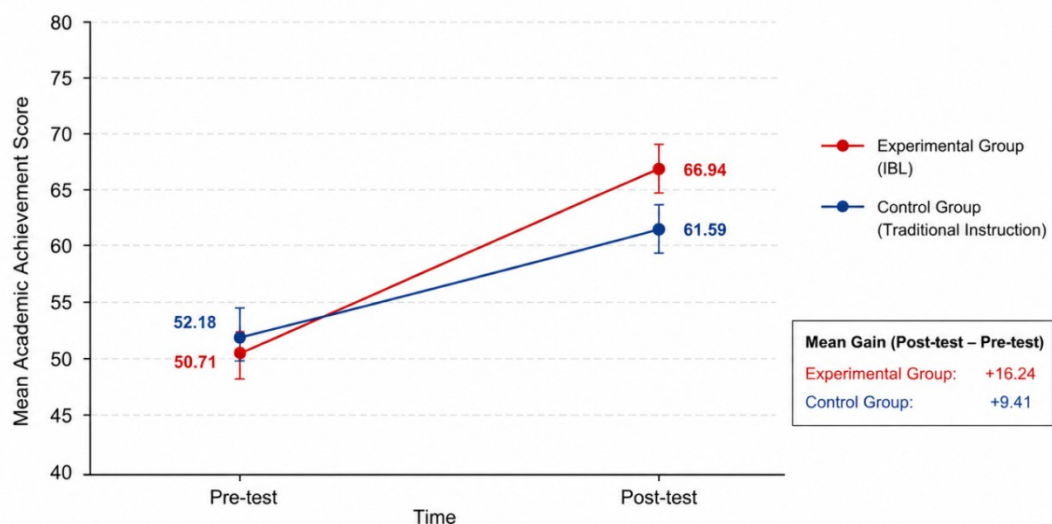
Group	Comparison	Mean Difference	SE	Df	T	P
Control	Pre-test vs. Post-test	-9.41	1.69	32	-5.58	< .001
Experimental	Pre-test vs. Post-test	-16.24	1.69	32	-9.63	< .001

Note. Negative mean differences indicate higher post-test scores than pre-test scores.

Table 4.4 presents the pairwise comparisons between pre-test and post-test scores for Grade 5 students. The results indicate statistically significant improvements in academic performance for both the control group, $t(32) = -5.58$, $p < .001$, and the experimental group, $t(32) = -9.63$, $p < .001$. The mean difference was larger in the experimental group (MD = -16.24) than in the control group (MD = -

9.41), indicating greater improvement in post-test scores. As shown in the table, both groups demonstrated learning gains over time, with a more pronounced increase observed in the experimental group.

Figure 4.1 Mean Academic Achievement Scores Before and After the Intervention in Grade 5



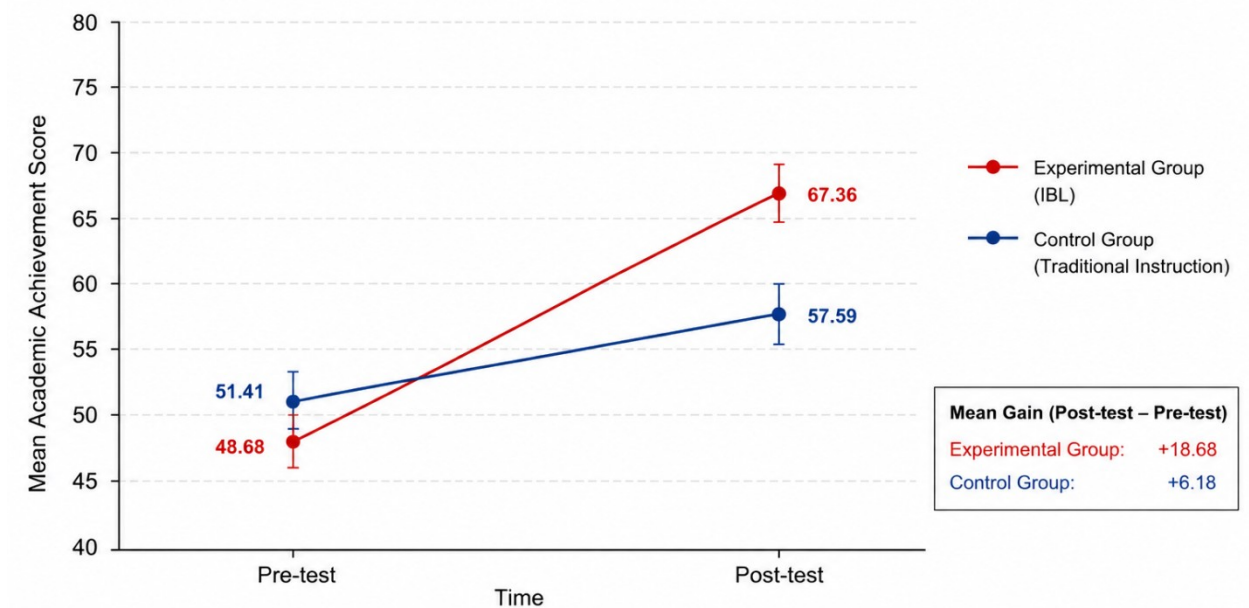
Note. Points represent mean academic achievement scores at pre-test and post-test. Both groups demonstrated improvements over time; however, students in the experimental group exhibited greater gains in academic achievement following the inquiry-based learning intervention.

The interaction effect was large in Grade 5 ($\eta p^2 = .20$) and very large in Grade 6 ($\eta p^2 = .48$), indicating that the observed differences were not only statistically significant but also educationally meaningful.

Table 4.5 Pairwise Comparisons of Pre-Test and Post-Test Scores in Grade 6

Group	Comparison	Mean Difference	SE	Df	t	P
Control	Pre-test vs. Post-test	-6.18	1.42	42	-4.36	< .001
Experimental	Pre-test vs. Post-test	-18.68	1.42	42	-13.19	< .001

Figure 4.2 Mean Academic Achievement Scores Before and After the Intervention in Grade 6



Note. Points represent mean academic achievement scores at pre-test and post-test. Both groups demonstrated improvements in academic achievement over time; however, the experimental group showed substantially greater gains (M gain = 18.68) than the control group (M gain = 6.18) following the inquiry-based learning intervention. The findings indicate that inquiry-based learning was associated with greater improvements in academic achievement among Grade 6 students.

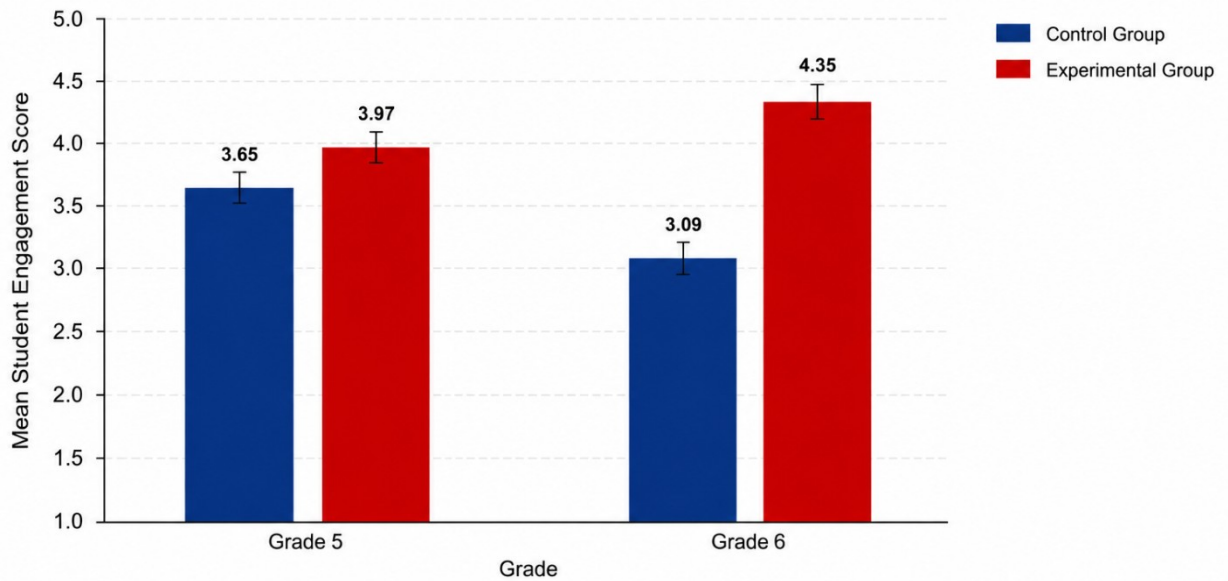
Both groups improved significantly from pre-test to post-test. However, the magnitude of improvement was consistently greater in the experimental groups.

Table 4.6 Descriptive Statistics for Student Engagement Scores

Grade	Group	N	Mean	SD	Min	Max
Grade 5	Control	17	3.65	0.33	2.75	4.08
Grade 5	Experimental	17	3.97	0.35	3.17	4.50
Grade 6	Control	22	3.09	0.36	2.50	3.75
Grade 6	Experimental	22	4.35	0.42	3.42	4.92

Note. Engagement was measured on a five-point Likert scale, with higher scores indicating higher engagement.

Figure 4.3 Mean Student Engagement Scores by Group and Grade



Note. Bars represent mean student engagement scores for the control and experimental groups in Grades 5 and 6. Error bars indicate ± 1 standard deviation (SD). Students in the experimental groups reported higher levels of engagement than students in the control groups in both grade levels. The difference was particularly pronounced in Grade 6, where the experimental group achieved the highest mean engagement score ($M = 4.35$, $SD = 0.42$), whereas the control group demonstrated the lowest engagement level ($M = 3.09$, $SD = 0.36$).

An independent t-test was used to analyze student engagement scores in a fifth-grade experimental versus control group. Results showed significant differences between the two groups with students in the experimental group exhibiting statistical significance as evidenced by $t(32) = -2.75$ and $p = .010$ indicating a student engagement score of ($M = 3.97$ and $SD = 0.35$) as compared to the Control Group Registrants ($M = 3.65$ and $SD = 0.33$). This suggests that being involved in Inquiry-Based Learning is related to higher levels of student engagement; furthermore, analysis of the effect size produced large practical effect (Cohen's $d = 0.94$, 95% CI [0.23, 1.65]) which shows not only are there significant differences between the groups; however these differences are also meaningful for educational purposes.

Similar analyses were performed on the engagement of Grade 6 students. The results showed that students who were participants in the experimental group had significantly more engagement than the students who were in the control group. The

effects size analysis also showed an extremely large practical effect (Cohen's $d = 3.25$, 95% CI [2.33, 4.15]), so there was a very practical meaning of the difference between the participants of both groups regarding their level of engagement in an educational sense. Grade 6 also had a very high level of effect which suggests that Inquiry-Based Learning was particularly effective in increasing the level of engagement for students who were working on more complicated scientific concepts or inquiring about more difficult activities.

The observation checklist results show similar pattern and do not contradict with student engagement questionnaire. The experimental groups got higher means in student engagement based on observations than the control group in both 5th ($M=3.94$ vs $M=3.52$) and 6th grade ($M=4.47$ vs $M=2.95$). The observation data also provides more observational support to the questionnaire results and have shown that students who are involved in inquiry-based learning have greater levels of behaviorally engaged during their science class.

4.2 Summary of Findings

The results generally indicated an increase in students' engagement following the implementation of Inquiry-Based Learning across both grade levels, providing support for the second hypothesis of the study. Although the magnitude of improvement varied between grades, the overall pattern of findings suggests that students who participated in inquiry-based activities tended to demonstrate higher levels of engagement. These results may indicate that Inquiry-Based Learning has the potential to foster greater involvement and participation in science lessons, thereby contributing positively to students' learning experiences.

4.3 Correlational Analysis

In order to assess the strength and direction of the correlational relationship between student engagement levels and academic achievement gains, Pearson's correlation coefficient was calculated using continuous variables. Therefore, Pearson's correlation is an adequate method for determining associations, since both

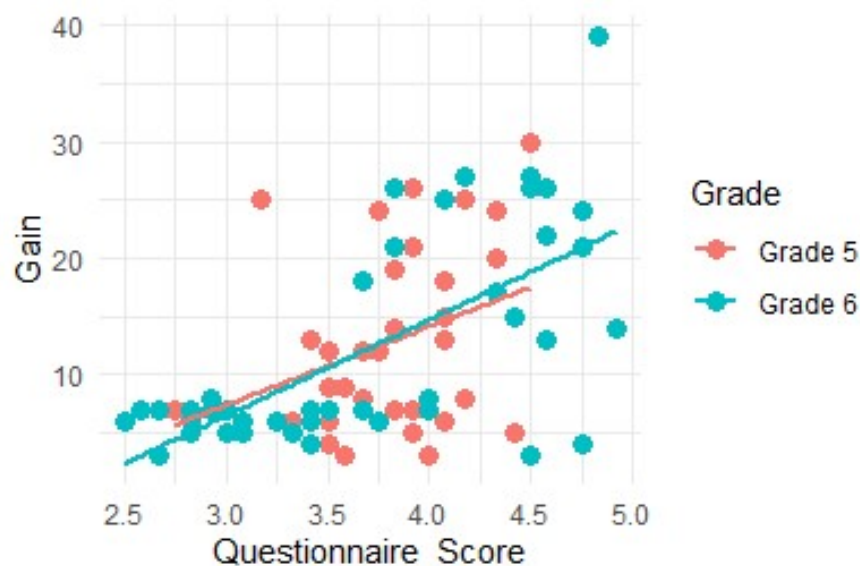
variables are continuous, whereas the use of Pearson's correlation is not appropriate to determine differences between groups.

Table 4.7 Correlations Between Student Engagement and Academic Achievement Gains by Grade Level

Sample	R	95% CI	p
Grade 5	.33	[-.01, .60]	.061
Grade 6	.67	[.47, .81]	< .001
Overall	.57	[.40, .71]	< .001

Table 4.7 shows positive correlations between student engagement and academic achievement gains. The relationship was moderate but not statistically significant in Grade 5 ($r = .33$, $p = .061$), whereas a strong significant correlation was found in Grade 6 ($r = .67$, $p < .001$). Overall, engagement was positively associated with achievement gains across the sample ($r = .57$, $p < .001$).

Figure 4.4 Relationship Between Student Engagement and Academic Achievement Gains



The relationship between student engagement and academic achievement gains was evaluated using Pearson's product-moment correlation coefficient. Both

engagement and academic achievement were measured as continuous variables, making Pearson's correlation an appropriate statistical technique for examining the strength and direction of the association between them. This analysis was conducted to determine whether higher levels of engagement were associated with greater improvements in academic performance. The use of Pearson's correlation also allowed for the identification of the extent to which variations in one variable corresponded to variations in the other. Consequently, the analysis provided additional insight into the relationship between students' involvement in the learning process and their academic outcomes.

Pearson product-moment correlation analyses indicated an overall statistically significant moderate positive relationship between the two variables ($r(76) = .57$, $p < .001$), with a 95% confidence interval of $[.40, .71]$. The results imply that as student engagement levels go up, the level of achievement will tend to increase as well.

In terms of grade levels, the correlation coefficient between the level of engagement with student academic success from Grade 5 was moderately positive ($r(32) = .33$, $p = .061$). However, this relationship merely approached statistical significance. Alternatively, for Grade 6 students, there was a statistically significant and strong relationship between level of engagement and achievement ($r(42) = .67$, $p < .001$), with an 95% confidence interval of $[.47, .81]$. Thus, the relationship between engagement with academic success was greater for Grade 6 than for Grade 5.

The above results provide some support for Hypothesis 3, as evidence was found for a positive association between student engagement and overall academic achievement across the entire sample. This suggests that higher levels of engagement were generally associated with better academic outcomes. However, no statistically significant relationship was observed among Grade 5 students, whereas a statistically significant positive relationship was found among Grade 6 students.

DISCUSSION

5.1 Discussion of Academic Achievement Findings

Both grade levels experienced statistically significant differences in learning gain or the extent to which the students improved from pretest to posttest, and the experimental group had larger learning gains than the control group. It is also important to mention that, although all groups improved, there was a clear overall trend; the experimental students improved more than the controls from pretest to posttest.

A potential reason for the greater improvement by the inquiry-based learners, both in Grade 6 and Grade 5, may be that inquiry-based learning requires greater student engagement. Inquiry-based learning means that instead of being told what to believe by their teachers about scientific concepts and how to conduct science activities, students analyze empirical evidence to find out for themselves what the evidence means based on sound logic, discuss with peers what alternative solutions exist for the same problem based upon the evidence they analyzed, and defend their solution based upon valid reasoning. Participation in inquiry-based activities may promote deeper cognitive processing of information, which can contribute to improved knowledge retention and a more thorough understanding of scientific concepts.

Recent research supports the constructivist belief that students learn by actively creating knowledge for themselves through the process of learning. A major theme within this philosophical perspective is that students will develop a deeper understanding of content if they are allowed to explore and interpret information instead of just memorizing it. Thus, the inquiry activities in this current study were developed based on these principles; therefore, it is plausible that the higher achievement gains seen within the experimental groups are due to the use of inquiry-based activities.

The results of the present study are also consistent with previous research. Bruder & Prescott (2013) indicated that inquiry-based instruction promotes a deeper

conceptual understanding of content material. The results of the present study provide evidence that inquiry-based learning may contribute positively to learning outcomes in lower secondary science education.

The results from Grade 6 were particularly successful in terms of subject matter and there may be an effect due to the way science is taught - scientific investigation and creating hypotheses are generally difficult for children and require abstract reasoning. By using inquiry-based activities, students were able to see concrete samples of investigations, talk about previous examples of how to present evidence, and use scientific methods to develop new ideas. This explanation is consistent with Timmerman et al. (2008), who suggested that inquiry-based approaches may be especially beneficial when teaching complex scientific concepts.

5.2 Discussion of Student Engagement Findings

The results showed that students in the Inquiry-Based Learning groups reported higher levels of engagement than students in the control groups. This pattern was observed in both Grade 5 and Grade 6 and was supported by the questionnaire data as well as classroom observations. In other words, students exposed to inquiry-based activities not only reported being more engaged but were also observed participating more actively during lessons.

One possible reason for this difference is the role that students played during the lessons. In the inquiry-based classes, students were expected to ask questions, discuss ideas, analyze information, and work together to solve problems. In contrast, students in the control groups mainly received information from the teacher and completed more structured tasks. Having a more active role in the lesson may have increased students' interest and willingness to participate.

The difference between the experimental and control groups was especially noticeable in Grade 6. A possible explanation is the topic itself. Scientific investigation and hypothesis formation are often difficult concepts for students to understand when they are taught only through definitions and textbook explanations. The inquiry activities allowed students to explore how scientific ideas are developed

and tested, making the content more meaningful and easier to connect to real examples.

Presnillo and Aliazas (2024) found that inquiry-based learning increased behavioral, cognitive, and emotional engagement in science classrooms. Romero-Ariza et al. (2020) also argued that inquiry activities encourage student participation and ownership of learning. In general, students participating in Inquiry-Based Group Learning had a higher level of engagement than those participating in Control Group Learning (based on data collected). The information obtained showed that students participating in the experimental groups asked more questions than students participating in the control groups did; the experimental group students had a higher level of participation in class discussions (from an observational standpoint); and overall, students in the experimental groups were more active in classroom activities than students in the control groups were.

Based on these results from the overall questionnaire and observational data, it appears that Inquiry-Based Learning may provide a viable means of increasing student engagement in science education.

5.3 Relationship Between Student Engagement and Academic Achievement

According to correlation analysis, there appears to be a positive correlation between engagement and achievement gains. In general, students who report higher levels of engagement have demonstrated greater gain on their post-test scores as compared to pre-test scores. The correlation between students' levels of engagement and growth in academic performance was especially apparent for Grade 6 students with strong positive correlations documented between engagement and actual performance.

The findings of the correlation analysis indicate that students who actively participated in their classrooms tended to be more successful learners. Generally, students who expressed interest in lesson content, actively participated in class

discussions, and engaged in inquiry-based learning demonstrated more progress on their performance measures than those who did not.

While the correlational design of the study does not allow researchers to infer cause and effect, the results suggest that there is a strong relationship between students' engagement and academic success.

The correlation between student engagement and performance measures was significantly more pronounced in Grade 6 than in Grade 5. Although Grade 5 students exhibited moderate positive correlations, the results were not statistically significant. In contrast, the correlation for Grade 6 students was both meaningfully and statistically significant. One possible reason for the disparity may be the degree to which non-traditional learners use inquiry-based learning strategies as a means to support and enhance their learning. As students continue to develop independence as learners, their ability to participate actively in the classroom may facilitate their understanding of rigorous content areas like science.

As the results suggest that there is also support for the social constructivist theoretical perspective. Learning, as proposed by Vygotsky (1978), develops when learners interact and discuss issues and participate actively in activities that are meaningful to them. In this way, the inquiry activities incorporated in this study provided an opportunity for students to exchange ideas, provide reasoning and evaluate together. Therefore, those students who were more actively participating in those activities would have had more opportunities to increase their understanding of the content.

Similar patterns regarding the relationship between engagement and achievement have been reported in previous research. Numerous studies have shown that students who are more engaged in classroom learning tend to demonstrate higher levels of academic performance. The findings of the present study are generally consistent with this body of literature and suggest that engagement may be one of the factors associated with the higher achievement gains observed among students in the inquiry-based learning groups.

Overall, the results suggest that engagement and achievement are closely connected. Students who were more engaged in the learning process generally achieved greater academic gains, particularly in Grade 6, where the relationship was strongest.

Engagement and achievement can be viewed through the lens of social constructivism, as explained by Vygotsky (1978). Through inquiry-based activities, students had opportunities to discuss ideas, develop questions, evaluate evidence, and articulate their reasoning through significant amounts of interaction with each other. The level of student participation by engaging in group discussions and group work allowed students to have an increased opportunity to consolidate their understanding of science concepts through their ongoing social interactions. The current study finds that there is a positive association between the degree of student engagement and student achievement and, therefore, that both individual effort and peer and teacher interaction were factors that contributed to student learning.

5.4 Comparison of Grade 5 and Grade 6 Findings

Positive effects of Inquiry-Based Learning were observed in both grade levels; however, the results were generally stronger in Grade 6. The Grade 6 experimental group showed larger achievement gains, higher engagement scores, and a stronger relationship between engagement and academic achievement than the Grade 5 experimental group.

One possible reason for this difference is the content of the two units. The Grade 5 lessons focused on ecology and environmental issues. Although these topics are important, many students are already familiar with concepts such as pollution, recycling, and environmental protection from everyday life and previous school learning. Unlike the previous grades' units, which relied heavily on the memorization of facts, the Grade 6 unit on science focused on scientific inquiry and hypothesis development. This way of looking at science requires students to examine how scientists gather evidence to develop theories about the universe rather than simply learning the names of the tools they use to measure things.

A strong indicator of success with this type of learning environment for grade six students is that they display significantly higher levels of engagement throughout the unit than students in the other grades. In addition, the Grade 6 students had significantly greater success in terms of learning than students in the other grades by the conclusion of the unit.

As with other research studies, the correlation analysis revealed noticeable differences between the two grade levels. There was a positive correlation between engagement and learning in each grade level, however, there was a much stronger correlation in grade six. This indicates that the degree of engagement that grade six students had with their learning was likely a greater contributor to achieving higher levels of learning than it was for any of the other grades.

These results are supported by previous research findings that support the effectiveness of inquiry-based learning approaches to teaching students difficult-to-understand scientific concepts that require students to explain, reason through, and interpret what they observe (Timmerman et al., 2008). The results of the present study support this view and indicate that the benefits of inquiry-based learning may be especially noticeable when students are working with more abstract scientific ideas.

5.5 Implications for Science Education

The results of this study suggest that inquiry-based learning can be successfully integrated into secondary science classrooms. Across both grade levels, students who participated in inquiry-based activities achieved higher learning gains and reported higher engagement levels than students who were taught through direct instruction. This indicates that inquiry approaches can be used not only to increase student participation but also to support academic achievement.

The strongest effects were observed in Grade 6. This may be because inquiry-based activities were used to teach scientific investigation and hypothesis formation, topics that students often find difficult to understand through textbook explanations alone. By analyzing evidence, discussing ideas, and evaluating explanations, students

had opportunities to engage with these concepts in a more meaningful way. The findings of this research indicate that the use of inquiry-based approaches may be especially beneficial for teaching students about abstract scientific concepts and the nature of science. The results of the engagement aspect were also relevant to teachers in the classroom. In inquiry groups, students were more actively involved with discussions, they asked more questions, and they were interested in the lessons. Therefore, providing students with opportunities to take an active role in their learning may help to promote engagement throughout science lessons and increase student engagement in your classroom.

The correlation analysis shows that students who had higher levels of engagement achieved greater learning gains than those with lower levels of engagement. While this does not prove that engagement directly leads to achievement, it does suggest that it is important to create learning environments in which students are actively engaged. Therefore, encouraging students to engage through discussions, asking questions, and collaboratively solving problems may aid in increasing learning outcomes.

The results also suggest that teachers must be well prepared for inquiry-based learning. Teaching inquiry-based learning requires teachers to provide students with structured activities, guide students in discussions, and assist students as they explore concepts. Thus, professional development programs should focus on providing practical experiences to teachers in terms of designing and implementing inquiry-based lessons.

5.6 Limitations of the Study

There are several limitations to consider when interpreting the results outlined in this study. The research sample consisted of only 78 students from one secondary school, which limits the degree of difference between the control group and the experimental group in a randomised-controlled research design. Thus, while the results show considerable variation between the two groups, the size of the sample limits generalisability beyond this one study, and findings of other research that

includes larger sizes and multiple school environments should be consulted for additional support of generalisability.

Schools typically employ a quasi-experimental design; the students were all mapped to their current classes and not randomly assigned to an experimental or control group. While using this method of instructional grouping better reflects the daily instructional practises taught in a school, it is likely that there were differences between the two groups prior to the research study.

The timing of data collection was limited to just a few weeks, and while the findings indicated improvements in achievement and engagement during that time period, it is impossible to determine if the impacts of inquiry-based learning will last after the instructional unit has been completed. Future research could investigate the long-term impacts of inquiry-based learning.

Engagement data was collected via student surveys and observations. Using more than one source of data helped provide a broader picture of student engagement; however, both methods involve a degree of subjectivity.

Questionnaire responses may be influenced by students' personal perceptions, while classroom observations depend on the judgement of the observer.

An additional limitation is related to the role of the researcher. The researcher taught the lessons and collected the data. Although the same materials, assessment procedures, and lesson schedules were used across all groups, it is difficult to completely exclude the possibility of unintentional bias during the implementation of the intervention or the observation process.

Student engagement was measured only after the intervention. As a result, changes in engagement over time could not be examined directly. Future studies may benefit from including both pre-intervention and post-intervention engagement measures in order to provide a clearer picture of how engagement develops throughout the learning process.

5.7 Recommendations for Future Research

The intervention examined in this study was implemented over a relatively short period of time. While positive effects on both achievement and engagement were observed, it remains unclear whether these improvements would be maintained over several months or an entire academic year. Research conducted over longer periods would provide a better understanding of the long-term impact of inquiry-based learning.

The study involved students from only one secondary school. Conducting similar research in different schools and regions would help determine whether the results can be observed across a wider range of educational contexts. Larger samples would also strengthen the evidence base and allow more detailed comparisons between student groups.

Only two science units were included in the intervention: ecology and environmental issues in Grade 5 and scientific investigation in Grade 6. Examining whether similar results occur in other fields, such as genetics, human biology, chemistry, and physics, will also be worth examining. This research may assist in determining if specific subjects have benefited more from inquiry-based teaching methods than other subjects.

Engagement was determined through surveys and classroom observation at the end of the intervention. If collected before and after the intervention, the engagement data could provide a more accurate portrayal of how engagement has changed through inquiry-based instruction and if any change in engagement correlates with academic achievement.

The current study indicated that there was a positive correlation between engagement and student academic achievement, especially for sixth graders. Additional research may help to clarify this relationship.

Identifying the contributions of participation, interest, and involvement within a classroom to student achievement may provide valuable information both to researchers and to teachers.

While the inquiry activities used in the current research were predominantly guided inquiry, other forms of inquiry-based instructional strategies may yield different outcomes. By comparing inquiry models, it may be determined which models are appropriate for various developmental stages of students and for various subject areas and objective outcomes.

5.8 Relationship Between Findings and Previous Research

There was a similarity between the majority of the findings of this study and the findings of previous inquiry-based learning studies. Students who participated in inquiry-based lessons scored higher than students taught through direct instruction, which supports the findings of Bruder and Prescott (2013) who found that inquiry-based approaches enhanced student understanding of scientific concepts and resulted in improved academic performance.

Student engagement was also similar. The experimental group students were more active during the lessons and reported higher engagement levels than students in the control groups. This is consistent with the findings of Presnillo and Aliazas (2024) who discovered that inquiry-based instruction had a positive effect on the student engagement of their sample. Romero-Ariza et al. (2020) found that inquiry activities promoted discussion, participation, and involvement in learning.

Grade 6 students in the experimental group demonstrated significantly higher achievement and engagement scores than their Grade 5 counterparts. One possible explanation is that the Grade 6 intervention provided more opportunities for discussion, interpretation, and evidence-based reasoning. This interpretation is consistent with Timmerman et al. (2008), who suggested that inquiry-based approaches may be particularly effective for exploring complex scientific concepts.

Consistent with Allchin's (2013) discussion of teaching the nature of science, the Grade 6 findings appear to support his assertions. Beyond learning definitions, students were provided with opportunities to examine examples of scientific investigations, evaluate evidence, and discuss how scientific knowledge is generated. These experiences may have contributed to a deeper understanding of the nature of

science and may help explain the particularly strong outcomes observed among Grade 6 students.

The relationship between engagement and achievement observed in the present study is consistent with previous educational research, which has demonstrated that more engaged students tend to achieve better academic outcomes. The findings of this study, particularly for Grade 6 students, further support this association.

Although no causal relationship can be inferred, the results suggest that engagement and achievement are closely related within inquiry-based learning environments.

Overall, the findings from this study support prior research results. Instead, they add further evidence from a secondary school science context and suggest that inquiry-based learning can support both engagement and academic achievement across different science topics.

CONCLUSION

This research explored the effects of Inquiry-Based Learning on improving academic performance and engagement of students in science. The types of Grade 5 and 6 students were involved with evaluating inquiry-based lessons against the direct instructional method.

The difference between the experimental group (inquiry-based lessons) and control group (traditional direct instruction) was significant, with students in the experimental group demonstrating significantly higher academic gains and reporting greater levels of engagement. All students participating in this study experienced some level of improvement due to the intervention, but those receiving inquiry-based instruction experienced more significant improvements relative to those receiving more directive forms of instruction.

Additionally, a significant correlation existed between student engagement (in-class activity) and student achievement (academic performance). That is, those students who demonstrated more engaged characteristics during their classroom's activities demonstrated higher levels of performance during the academic assessment. The strongest levels of correlation between engagement and achievement were exhibited within the Grade 6 students.

An interesting difference developed between the two groups of students. Both groups benefitted from Inquiry-Based Learning; however, the influence of Inquiry-Based Learning was greater for the Grade 6 students. This could have occurred as a result of the challenges that many students experience as they try to conceptualize the way scientific knowledge develops. Students who are provided opportunities to engage in inquiry will benefit by developing a deeper and more substantial understanding of these principles rather than through a teacher's presentation alone.

Overall, the findings suggest that inquiry-based learning lessons provide students with numerous opportunities to interact with peers, engage actively in the learning process, and apply their knowledge to new contexts. Participation in inquiry-oriented activities may foster greater interest and involvement in learning, which in turn may contribute to more effective knowledge acquisition and understanding.

This in-school study had a small population of students and the intervention occurred over a limited time period. Both constraints would create limitations in generalizing these results. However, the research provides helpful evidence that inquiry-based learning can be utilized in high school science classrooms.

Future research should focus on using inquiry-based learning in many different school settings and for extended periods of time. Additional information is needed to determine if the benefits of this inquiry-based learning program durably affect student performance in ways beyond the timeline of this study.

In summary, the conclusion suggests that Inquiry-Based Learning can enhance academic success and promote student interest in science. Although further research is needed, the results suggest that giving students a more active role in learning may contribute to better educational outcomes.

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APPENDICES

Appendix 1. Student Engagement Observation Checklist

INDICATOR	1 (Never)	2 (Rarely)	3 (Sometimes)	4 (Often)	5 (Very Often)
 Students ask questions related to lesson content	☐	☐	☐	☐	☐
 Students voluntarily participate in discussions	☐	☐	☐	☐	☐
 Students contribute ideas during group work	☐	☐	☐	☐	☐
 Students remain on-task during activities	☐	☐	☐	☐	☐
 Students respond to peers' ideas constructively	☐	☐	☐	☐	☐
 Students demonstrate curiosity about the topic	☐	☐	☐	☐	☐
 Students seek clarification when confused	☐	☐	☐	☐	☐
 Students complete assigned tasks actively	☐	☐	☐	☐	☐

Appendix 2. Student Engagement Questionnaire

Students were asked to indicate their level of agreement with each statement using a 5-point Likert scale.

Student Engagement Questionnaire

Please indicate how strongly you agree or disagree with each statement.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Behavioural Engagement

Statement	1	2	3	4	5
I participate actively during science lessons.	☐	☐	☐	☐	☐
I pay attention during classroom activities.	☐	☐	☐	☐	☐
I complete classroom tasks on time.	☐	☐	☐	☐	☐
I contribute to class discussions.	☐	☐	☐	☐	☐

Cognitive Engagement

Statement	1	2	3	4	5
I try to understand difficult scientific concepts.	☐	☐	☐	☐	☐
I look for explanations when I do not understand something.	☐	☐	☐	☐	☐
I connect lesson content to real-life situations.	☐	☐	☐	☐	☐
I enjoy solving scientific problems.	☐	☐	☐	☐	☐

Emotional Engagement

Statement	1	2	3	4	5
-----------	---	---	---	---	---

I enjoy science lessons.	☐	☐	☐	☐	☐
I am interested in the topics discussed in class.	☐	☐	☐	☐	☐
I feel motivated to learn science.	☐	☐	☐	☐	☐
I look forward to science lessons.	☐	☐	☐	☐	☐

Note. The overall engagement score was calculated as the mean of all questionnaire items. Higher scores indicated higher levels of student engagement.

Appendix 3. Academic Achievement Test Blueprint

The post-test was designed to assess students' understanding of the curriculum content taught during the intervention period. The test consisted of 20 items worth 100 marks in total.

Grade 5: Ecology and Environmental Impact

Learning Objective	Question Type	Number of Items	Marks
Identify ecological relationships	Multiple Choice	5	25
Explain causes of environmental problems	Short Answer	4	20
Analyse environmental case studies	Extended Response	2	30
Propose solutions to environmental issues	Extended Response	1	25
Total		12	100

Grade 6: Scientific Investigation and Hypothesis Formation

Learning Objective	Question Type	Number of Items	Marks
Identify stages of scientific investigation	Multiple Choice	5	25
Distinguish observations from hypotheses	Short Answer	4	20
Analyse historical scientific cases	Extended Response	2	30
Construct and justify hypotheses	Extended Response	1	25
Total		12	100

Appendix 4. Academic Achievement Scoring Rubric

Performance Level	Score Range	Description
Excellent	85–100	Demonstrates comprehensive understanding of concepts, accurate scientific reasoning, and well-supported explanations.
Good	70–84	Demonstrates solid understanding with minor inaccuracies and generally appropriate reasoning.
Satisfactory	50–69	Demonstrates basic understanding but includes gaps in explanation and limited analysis.
Needs Improvement	Below 50	Demonstrates limited understanding of key concepts and weak scientific reasoning.

Extended response items were scored according to the following criteria:

Criterion	Marks
Scientific accuracy	10
Use of evidence	5
Quality of explanation	5
Logical reasoning	5
Total	25

Appendix 5. Sample Academic Achievement Test Items

Grade 5 Ecology

Which of the following best describes an ecosystem?

- A. A group of plants only
- B. Living organisms interacting with each other and their environment
- C. A single species living in an area
- D. A food chain only

Explain two possible consequences of water pollution for aquatic ecosystems.

Case Study Question:

A river near a town has become polluted due to industrial waste. Analyse the possible environmental impacts and propose two evidence-based solutions.

Grade 6 Scientific Investigation

Which stage comes first in the scientific investigation process?

- A. Conclusion
- B. Data Analysis
- C. Observation and Questioning
- D. Evaluation

Differentiate between an observation and a hypothesis.

Historical Inquiry Task:

Read the case of Alexander Fleming's discovery of penicillin. Identify the original observation, formulate a possible hypothesis, and explain how evidence supported the final conclusion.

Appendix 6: Student Worksheet (Bioaccumulation & Food Chains)

Part 1: Food Chain Understanding

Look at the food chain:

Algae → Small Fish → Big Fish → Human

Answer the questions:

What do small fish eat? _____

What do big fish eat? _____

Who is at the top of the food chain? _____

Part 2: Bioaccumulation

Fill in the blanks:

Bioaccumulation is when _____

builds up inside _____ over time.

Choose the correct answer:

The most polluted organism is:

- a) Algae
- b) small fish
- c) big fish
- d) human

Part 3: Case Study Questions

Minamata Disease

What caused the disease? _____

How did humans get poisoned? _____

Itai-Itai Disease

What was the harmful substance? _____

What part of the body was affected? _____

Food Chain Disruption (China case)

What animal was removed? _____

What happened to insects? _____

What happened to crops? _____

Part 4: Reflection

One thing I learned today is:

One way to protect nature is:

Teacher Answer Key

Food Chain:

Algae → Small fish eat algae

Big fish eat small fish

Humans are at the top

Bioaccumulation:

Toxic substances build up inside organisms

Correct answer:

Human (highest concentration of toxins)

Minamata:

Mercury pollution from factory

Eating contaminated fish

Itai-Itai:

Cadmium

Bones / skeletal system

China case:

Sparrows removed

Insects increased

Crops destroyed

Poster Activity Instructions (Group Work Sheet)

TASK: Create a Science Poster

Your poster must include:

- ✓ Title (e.g. “Minamata Disease”)
- ✓ Simple food chain diagram
- ✓ Explanation of what happened
- ✓ How people were affected
- ✓ Link to bioaccumulation OR food chain disruption
- ✓ A warning or safety message

Helpful sentence starters:

“This happened because...”

“The toxin moved from...”

“This affected humans because...”

“This shows bioaccumulation because...”

“We should protect nature by...”

Roles in your group:

Illustrator (draws diagram)

Writer (writes explanation)

Speaker (presents poster)

Checker (checks science accuracy)

Assessment Rubric (Poster Task)

Criteria	Excellent (3)	Good (2)	Needs Improvement (1)
Science understanding	Clear explanation of bioaccumulation/food chain	Mostly correct	Limited understanding

Accuracy	No mistakes in case study	Minor mistakes	Many errors
Diagram	Clear, labelled food chain	Basic diagram	Missing or unclear
Communication	Easy to understand	Some clarity	Hard to understand
Teamwork	All members contribute	Some participation	Unequal participation

Exit Ticket (Quick Assessment)

Define bioaccumulation in your own words:

Name one case study from today:

What happens when pollution enters a food chain?

One new thing I learned today:

Vocabulary List (Grade 5 Support)

Food chain – who eats whom in nature

Ecosystem – living things and their environment

Pollution – harmful substances in nature

Toxin – poison

Bioaccumulation – buildup of toxins in living things

Environment – nature around us

Balance – when everything works properly in nature

Appendix 7. Table of Gain Score Descriptive Statistics by Grade and Instructional Group

Grade	Group	N	Mean Gain	SD	Minimum Gain	Maximum Gain
Grade 5	Control	17	9.41	5.27	3	21
Grade 5	Experimental	17	16.24	8.30	5	30
Grade 6	Control	22	6.18	1.10	3	8
Grade 6	Experimental	22	18.68	9.33	3	39

Note. Gain scores were calculated by subtracting pre-test scores from post-test scores.

Appendix 8. Key R Commands Used for Statistical Analysis

The following R commands were used to prepare the dataset and conduct the statistical analyses reported in this study, including mixed ANOVA, pairwise comparisons, effect size calculations, and independent samples *t*-tests.

```
``r
# Data preparation
data_long <- data %>%
  pivot_longer(
    cols = c(Pre_Test, Post_Test),
    names_to = "Time",
    values_to = "Score"
  )

# Mixed ANOVA for Grade 5
anova_g5 <- aov_ez(
  id = "Student_ID",
  dv = "Score",
  data = grade5,
  between = "Group",
  within = "Time",
  type = 3
)

# Mixed ANOVA for Grade 6
anova_g6 <- aov_ez(
  id = "Student_ID",
  dv = "Score",
  data = grade6,
  between = "Group",
  within = "Time",
  type = 3
)

# Pairwise comparisons
emmeans_g5 <- emmeans(anova_g5, ~ Group * Time)
```

```

pairs(emmeans_g5)

emmeans_g6 <- emmeans(anova_g6, ~ Group * Time)
pairs(emmeans_g6)

# Effect size calculations (Cohen's d)
cohens_d(
  Gain ~ Group,
  data = gain_data %>% filter(Grade == "Grade 5")
)

cohens_d(
  Gain ~ Group,
  data = gain_data %>% filter(Grade == "Grade 6")
)

# Independent samples t-tests
t.test(
  Gain ~ Group,
  data = gain_data %>% filter(Grade == "Grade 5"),
  var.equal = TRUE
)

t.test(
  Gain ~ Group,
  data = gain_data %>% filter(Grade == "Grade 6"),
  var.equal = TRUE
)

```

Appendix 9. Key R Commands Used for Engagement and Correlation Analysis

The following R commands were used to analyse student engagement data, compare engagement levels between groups, calculate effect sizes, examine correlations between engagement and academic achievement gains, and generate the corresponding scatterplot.

```
``r
# Load required packages
library(readxl)
library(tidyverse)
library(effectsize)
library(ggplot2)

# Import engagement dataset
engagement_data <- read_excel("engage.xlsx", sheet = "R_Ready_Data")

# Convert variables
engagement_data <- engagement_data %>%
  mutate(
    Grade = factor(Grade),
    Group = factor(Group)
  )

# Descriptive statistics for student engagement
engagement_summary <- engagement_data %>%
  group_by(Grade, Group) %>%
  summarise(
    N = n(),
    Mean = mean(Questionnaire_Score),
    SD = sd(Questionnaire_Score),
    Min = min(Questionnaire_Score),
    Max = max(Questionnaire_Score),
    .groups = "drop"
  )

# Independent samples t-tests for student engagement
t.test(
```

```

Questionnaire_Score ~ Group,
data = engagement_data %>% filter(Grade == "Grade 5"),
var.equal = TRUE
)

```

```

t.test(
  Questionnaire_Score ~ Group,
  data = engagement_data %>% filter(Grade == "Grade 6"),
  var.equal = TRUE
)

```

Cohen's d for engagement differences

```

cohens_d(
  Questionnaire_Score ~ Group,
  data = engagement_data %>% filter(Grade == "Grade 5"),
  pooled_sd = TRUE
)

```

```

cohens_d(
  Questionnaire_Score ~ Group,
  data = engagement_data %>% filter(Grade == "Grade 6"),
  pooled_sd = TRUE
)

```

Descriptive statistics for observation scores

```

observation_summary <- engagement_data %>%
  group_by(Grade, Group) %>%
  summarise(
    N = n(),
    Mean_Observation = mean(Observation_Score),
    SD_Observation = sd(Observation_Score),
    .groups = "drop"
  )

```

Merge engagement data with achievement gain scores

```

rq3_data <- left_join(
  engagement_data,
  gain_data,
  by = c("Student_ID", "Grade", "Group")
)

# Pearson correlation between engagement and achievement gains
cor.test(
  rq3_data$Questionnaire_Score,
  rq3_data$Gain,
  method = "pearson"
)

# Pearson correlations by grade level
cor.test(
  rq3_data %>% filter(Grade == "Grade 5") %>% pull(Questionnaire_Score),
  rq3_data %>% filter(Grade == "Grade 5") %>% pull(Gain),
  method = "pearson"
)

cor.test(
  rq3_data %>% filter(Grade == "Grade 6") %>% pull(Questionnaire_Score),
  rq3_data %>% filter(Grade == "Grade 6") %>% pull(Gain),
  method = "pearson"
)

# Scatterplot of engagement and academic achievement gains
ggplot(
  rq3_data,
  aes(
    x = Questionnaire_Score,
    y = Gain,
    color = Grade
  )
) +

```

```
geom_point(size = 3) +  
geom_smooth(method = "lm", se = FALSE) +  
labs(  
  x = "Student Engagement Score",  
  y = "Academic Achievement Gain"  
) +  
theme_minimal()  
...
```

Scientific Supervisor Report

Student Name: Toktar Aiymgul

The Theme: Implementing Inquiry-Based Learning in secondary school science lessons:
Exploring student engagement and learning outcomes

The Content of Conclusion:

The thesis examines the use of Inquiry-Based Learning in secondary science education and its influence on students' academic achievement and engagement. The study was conducted with 78 students from Grade 5 and Grade 6 using a quasi-experimental pre-test-post-test control group design.

Two science units were included in the research. Grade 5 students studied Ecology and Environmental Impact, while Grade 6 students studied Scientific Investigation and Formulating Hypotheses. Data were collected through pre-tests, post-tests, classroom observations, and student questionnaires.

The results showed that students in the inquiry-based groups demonstrated greater improvement in academic achievement than students in the control groups. In Grade 5, the interaction effect between instructional group and time was statistically significant, $F(1, 32) = 8.20$, $p = .007$, with a large effect size ($\eta^2 = .20$). The effect was even stronger in Grade 6 ($\eta^2 = .48$).

Student engagement was also higher in the inquiry-based groups. The effect size was large in Grade 5 ($d = 0.94$) and very large in Grade 6 ($d = 3.25$). Observation data showed a similar pattern and supported the questionnaire findings.

The study also found a positive relationship between engagement and academic achievement gains. For the overall sample, the correlation was moderate and statistically significant ($r = .57$, $p < .001$). The strongest relationship was observed in Grade 6 ($r = .67$, $p < .001$).

The thesis is well organised and reflects careful work throughout all stages of the research process. The student demonstrated the ability to conduct an educational experiment, analyse quantitative data, and discuss the findings in relation to previous research. The conclusions are supported by the results obtained during the study.

Decision:

The diploma work meets all the institutional, academic, and empirical requirements of the School of Education and Humanities at SDU University. The student has demonstrated good skills in data analysis, implementation of a pedagogical intervention, and the application of statistical methods in educational research. Therefore, this work is approved and recommended for public defence for the degree of Master of Educational Sciences in Biology.

Scientific Supervisor:



Assistant Professor, Satayev Malik