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Effects of High-Intensity Interval Training at Low and Moderate Altitudes on the Physiological, Functional Performance and Perceptual Responses of Trained Long-Distance Athletes

Sisay, Fentaw

BAHIR DAR UNIVERSITY

COLLEGE OF EDUCATION

SCHOOL OF TEACHER EDUCATION

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

The Effect of Indigenous Knowledge-Based Biology Instruction on Students' Achievement, Attitude, and Engagement: A Gender based Analysis in Middle Schools of Injibara, Ethiopia

By

Shitaye Kassahun Yerukie

May 2026

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Shitaye Kassahun Yerukie

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Education in Biology

Principal Advisor: Melaku Wale (PhD, Professor in Biology)

Co-advisors: Tadesse Melese (PhD, Professor in Curriculum and Instruction)

May 2026

Bahir Dar, Ethiopia

DECLARATION

I, the undersigned, declare that this dissertation work, entitled **"The Effect of Indigenous Knowledge-Based Biology Instruction on Students' Achievement, Attitude, and Engagement: A Gender based Analysis in Middle Schools of Injibara, Ethiopia"** submitted in partial fulfillment of the requirements for a Doctor of Education in Biology, is a record of original work completed by me and has never been submitted to this or any other institution to receive any other degree or certificate.

Candidate Name: Shitaye Kassahun Yerukie; Signature: ______________Date: May 2026
Place: Bahir Dar University, Ethiopia

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APPROVAL OF DISSERTATION FOR DEFENSE

We hereby certify that we have supervised, read, and evaluated this dissertation entitled **"The Effect of Indigenous Knowledge-Based Biology Instruction on Students' Achievement, Attitude, and Engagement: A Gender based Analysis in Middle Schools of Injibara, Ethiopia"** prepared under our guidance. We recommend that the dissertation be submitted for oral defense**.**

Melaku Wale (Prof.)	____________________	**May, 2026**
Principal Advisor's name	**Signature**	**Date**
Tadesse Melese (Prof.)	____________________	**May, 2026**
Co- advisor's name	**Signature**	**Date**
Adem Mohammed (PhD, Assi. Prof.)	____________________	**May, 2026**
Department head's name	**Signature**	**Date**

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APPROVAL OF DISSERTATION FOR DEFENSE RESULT

As members of the head of examination, we examined the dissertation entitled **"The Effect of Indigenous Knowledge-Based Biology Instruction on Students' Achievement, Attitude, and Engagement: A Gender based Analysis in Middle Schools of Injibara, Ethiopia"** by Shitaye Kassahun Yerukie. We hereby certify that the dissertation is accepted for fulfilling the requirements for the award of the Doctor of Education in Biology

Board of Examiners

External Examiner	**Melese Negash** **(PhD, Assoc., Prof.)**	**Signature**	**May, 2026** **Date**
Internal Examiner	**Sissay Menkir** **(PhD, Assoc., Prof.)**	**Signature**	**May, 2026** **Date**
Chair Person‘s Name	**Adem Mohammed** **(PhD, Assis. Prof.)**	**Signature**	**May, 2026** **Date**

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ABSTRACT

Biology education, as a part of science education in Ethiopia, continues to face persistent challenges characterized by low student achievement, limited classroom engagement, and unfavorable attitudes toward the subject. These challenges are often associated with the disconnection between formal science instruction and learners' sociocultural experiences. Guided by culturally responsive pedagogy and social constructivism, this study examined the effect of integrating Indigenous Knowledge (IK) into Grade 8 Biology instruction in Injibara City, Ethiopia. Specifically, the study investigated the effects of IK-based instruction on students' academic achievement, engagement, and attitudes toward ecology, while also examining whether gender moderated these effects. The study employed a mixed-methods approach using a quasi-experimental non-equivalent pretest–posttest control group design. Participants were assigned to either an experimental group receiving IK-integrated instruction or a control group taught using conventional methods over a six-week instructional period. Quantitative data were collected using the ecology achievement Test (EAT), ecology attitude questionnaire (EAQ), and ecology engagement questionnaire (EEQ), while qualitative data were generated through focus group discussions (FGDs) and classroom observations. Quantitative data were analyzed using independent samples *t*-tests and Analysis of Covariance (ANCOVA), whereas qualitative data were analyzed thematically. The findings revealed statistically significant differences in favor of the experimental group across all measured outcomes. After controlling for pretest scores, students exposed to IK-based instruction achieved significantly higher posttest scores in ecology achievement, engagement, and attitude compared to those taught through conventional instruction ($p < .05$). The magnitude of these differences ranged from moderate to large effect sizes, indicating substantial practical significance of the intervention in improving students' learning outcomes. The ANCOVA results further demonstrated that the instructional intervention accounted for a meaningful proportion of variance in posttest performance, suggesting that the observed improvements were educationally important rather than only statistically significant. No statistically significant interaction effects were found between instructional approach and gender, indicating that the effectiveness of IK-based instruction was comparable for both male and female students and therefore pedagogically gender-inclusive. Qualitative findings supported the quantitative results. Students consistently perceived the instructional approach as making ecological concepts more understandable, meaningful, and connected to their daily lives. The study concludes that integrating IK into ecology instruction appears to be an effective and culturally responsive pedagogical approach capable of improving both academic and affective learning outcomes in Biology education. The findings underscore the practical value of contextualized Biology instruction in enhancing conceptual understanding, engagement, and learner motivation within culturally diverse educational settings. The study therefore recommends the integration of IK into curriculum materials, teacher education, and classroom practice. It further suggests the need for longitudinal and large-scale studies to examine the sustainability and broader applicability of IK-based Biology instruction across different educational contexts in Ethiopia and beyond.

Keywords: Achievement; Attitude; Biology Education; Ecology; Engagement; Gender; Indigenous Knowledge; Interaction Effect; Perception

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ANCOVA – Analysis of Covariance

CESA- Continental Education Strategy for Africa

CRP-Culturally Responsive Pedagogy

CG-Control Group

EG-Experimental Group

EAQ- Ecology Attitude questioner

EAT- Ecology achievement test

EEQ-Ecology engagement questioner

FGD – Focus Group Discussion

IK- Indigenous Knowledge

IKBI-Indigenous Knowledge based instruction

IKMPGCA- Itse-Komole Cultural Medicinal Plant Growth and Conservation Association

KR-20 - Kuder Richardson-20

MOE – Ministry of Education

MKO- More Knowledgeable Others

NEAEA- National Educational Assessment and Examination Agency

NLA – National Learning Assessment

qual-qualitative

QUAN-Quantitative

SK-Scientific knowledge

TM- Teaching Method

CHAPTER ONE: INTRODUCTION

Introduction

This research seeks to assess the effect of incorporating IK into Biology teaching and how it influences the learning outcomes of grade eighth students. This chapter includes the study's background, the problem statement, general and specific objectives, research questions, the significance of the study, its scope and limitations, as well as definitions of key terms and concepts.

1.1 Background of the study

Education serves as a central mechanism for social, cultural, economic, and environmental transformation by facilitating the transmission of knowledge, skills, and values across generations (UNESCO, 2022). In the twenty-first century, education is increasingly conceptualized not only as a driver of economic growth but also as a means of promoting cultural sustainability and environmental stewardship (World Bank, 2021). Within this broader educational mission, science education—and particularly Biology—plays a pivotal role in developing ecological literacy, scientific reasoning, and problem-solving capacities necessary to address global challenges such as biodiversity loss, ecosystem degradation, and climate change (Tilbury & Mulà, 2020).

Despite this significance, science education in many developing countries continues to face persistent pedagogical and epistemological challenges. One of the most widely documented concerns is the dominance of western-oriented scientific frameworks that marginalize local and IK systems (Jegede, 1995; Aikenhead & Ogawa, 2007; Battiste, 2013). Scholars argue that such decontextualized approaches create what Aikenhead (2001) describes as cultural border crossing, whereby learners must navigate between the culture of their home communities and the culture of school science. For many students, particularly in non-western societies, this transition becomes cognitively and emotionally difficult because science instruction fails to recognize learners' existing cultural experiences and ecological understandings.

In Ethiopia, this challenge is particularly evident within Biology education. Although national educational reforms emphasize contextual relevance and learner-centered pedagogy (MoE, 2023), classroom instruction remains largely textbook-driven, examination-oriented, and teacher-centered (Onwu, 2011; Oyovwi, 2015). Consequently, Biology is often perceived by learners as abstract, foreign, and disconnected from their lived experiences (Dagne & Alemu, 2021). This pedagogical disconnection has contributed to persistently low learning outcomes. National assessment reports indicate that only 22.9% of Grade 10 students and 48.5% of Grade 12 students achieved passing scores in Biology (NEAEA, 2017). These findings suggest that conventional instructional practices have not adequately supported meaningful understanding of scientific concepts.

Scholars increasingly attribute this underperformance to the mismatch between formal science instruction and students' sociocultural realities (Worku & Abate, 2022). Ethiopian learners, particularly those from rural and semi-rural communities, possess extensive ecological experiences related to agriculture, biodiversity management, soil conservation, and environmental sustainability (Alemayehu, 2012). However, these experiences are not integrated into classroom instruction; resulting in what Chalchisa (2010) termed a pedagogical misalignment between school science and learners' cultural contexts.

IK refers to locally developed systems of knowledge, beliefs, practices, and skills accumulated through long-term interaction between communities and their environments (Barnhardt & Kawagley, 2005). IK encompasses ecological management practices, traditional medicine, weather forecasting, agricultural systems, biodiversity conservation, and resource management strategies that have enabled communities to sustain livelihoods across generations (Altieri & Nicholls, 2017; Berkes, 2018). Within educational contexts, IK integration seeks to connect learners' cultural experiences with formal scientific concepts through culturally responsive pedagogy.

Globally, increasing attention has been given to integrating IK into Biology education as a means of improving learning relevance and inclusivity. In Canada and New Zealand, frameworks such as two-eyed seeing encourage learners to approach scientific understanding through both Indigenous and Western perspectives simultaneously (Reid et al., 2021). Similarly, studies in

Australia report that integrating Aboriginal ecological knowledge into Biology instruction improved Indigenous students' participation, engagement, and conceptual understanding (Carter et al., 2019). These international experiences demonstrate that contextualizing Biology instruction within learners' cultural realities can enhance both academic learning and cultural affirmation.

At the continental level, African scholars and policymakers increasingly recognize IK as a strategic resource for improving educational relevance and sustainability (Owuor, 2007). The continental education strategy for Africa (CESA 2016–2025) emphasizes the importance of embedding African knowledge systems and local innovation within educational frameworks (African Union, 2016). Empirical studies from various African countries further support the educational value of IK integration. In South Africa, Ogunniyi and Hewson (2008) found that students exposed to instruction integrating Indigenous and western scientific explanations demonstrated significantly better conceptual understanding and academic performance than those taught using conventional methods. Likewise, Nigerian studies reported that integrating Indigenous agricultural analogies into science instruction improved retention, problem-solving skills, and ecological understanding (Eze, 2014; Abonyi et al., 2014). In Ghana, Amponsah et al. (2021) found that integrating local environmental knowledge enhanced students' attitudes toward biodiversity conservation. Collectively, these findings suggest that IK-based instruction can strengthen cognitive, affective, and participatory dimensions of learning.

In Ethiopia, policy frameworks increasingly advocate for culturally responsive education. The 2023 Ethiopian education and training policy explicitly emphasize the integration of IK and local realities into teaching and learning processes (MoE, 2023). Similarly, the Ethiopian education development roadmap (2018–2030) identifies contextual relevance and curriculum localization as strategic priorities (MoE, 2018). However, despite these policy commitments, implementation remains limited in practice. Biology instruction continues to rely predominantly on standardized textbooks and conventional lecture methods that marginalize local knowledge systems (Nyoni, 2022).

At the national level, Ethiopia possesses rich Indigenous ecological knowledge systems across diverse cultural groups. Historical and contemporary studies document cultured practices related to soil conservation, agroforestry, water management, biodiversity preservation, and agricultural sustainability. For example, the Harla civilization in eastern Ethiopia developed advanced soil and water conservation practices (Norbert et al., 2002), while the Borana pastoral community established Indigenous water management systems for drought resilience (Chemeda et al., 2005). Similarly, farmers in northern Ethiopia classify soils and ecological conditions using Indigenous environmental indicators (Bekele, 1998).

Research in Konso documented advanced terrace farming and moisture conservation techniques (Tesfaye, 2003), while studies in the Awi Zone identified Indigenous agroforestry systems, composting practices, and biodiversity conservation strategies consistent with ecological sustainability principles (Alemayehu, 2018). In particular, the Agew and Amhara people of the Amhara region possess extensive ecological knowledge related to terrace farming, watershed management, traditional weather prediction, and soil fertility preservation (Asmare et al., 2021). These practices correspond directly with ecological concepts taught in Biology.

Despite this richness, IK remains largely excluded from formal classroom instruction. Studies examining Ethiopian curricula and textbooks report limited integration of Indigenous perspectives into science education (Yeseraw et al., 2023). Consequently, learners are often unable to connect scientific concepts with the environmental knowledge embedded within their communities.

The integration of IK into Biology education is theoretically grounded in social constructivism and culturally responsive pedagogy (CRP). Social Constructivist theory argues that learning occurs most effectively when new knowledge is linked to learners' prior experiences, cultural understandings, and social interactions (Vygotsky, 1978). Similarly, culturally responsive pedagogy emphasizes that students learn more meaningfully when classroom instruction recognizes and values their cultural identities, local experiences, and community knowledge systems (Gay, 2018). Within Biology education, Indigenous ecological practices provide culturally familiar contexts through which abstract scientific concepts can be interpreted, negotiated, and internalized. Consequently, IK-based instruction is increasingly viewed as an important pedagogical strategy for improving multiple dimensions of student learning outcomes, including achievement, attitude, engagement, and perception.

Academic achievement is one of the most widely used indicators of educational effectiveness and refers to the extent to which learners attain intended instructional objectives (Shehzad & Aziz, 2019). In Biology education, achievement involves learners' ability to understand, apply, analyze, and interpret scientific concepts related to ecological systems and environmental sustainability. However, conventional science instruction in many African contexts often emphasizes rote memorization and abstract content delivery, limiting students' conceptual understanding and long-term retention (Hodson, 2009). Scholars argue that students frequently fail to connect classroom Biology with their lived environmental experiences because instruction ignores the ecological knowledge embedded within their communities (Aikenhead & Michell, 2011).

Integrating IK into Biology instruction addresses this challenge by contextualizing scientific concepts within familiar cultural and environmental practices. Indigenous ecological activities such as crop rotation, terracing, agroforestry, composting, and traditional biodiversity conservation provide concrete examples through which abstract concepts like nutrient cycling, ecosystem interaction, soil fertility, and conservation can be understood. Research conducted in different educational settings indicates that contextualized science instruction significantly improves students' conceptual comprehension and retention (Zidny & Eilks, 2020). Similarly, Ogunniyi and Hewson (2008) reported that learners exposed to instruction integrating IK demonstrated superior academic performance compared to those taught through conventional approaches. In Ethiopia, where many students possess substantial experiential ecological knowledge acquired through agricultural participation and community interaction, IK-based instruction may provide cognitive bridges that facilitate meaningful understanding of ecological concepts.

Beyond achievement, attitude toward science constitutes another critical dimension of educational outcomes. Attitude refers to learners' feelings, beliefs, values, interests, and predispositions toward a subject (Osborne et al., 2003). Positive attitudes toward Biology influence students' motivation, persistence, classroom participation, and future interest in science-related careers (Adesoji, 2018). Conversely, negative attitudes often contribute to disengagement, poor performance, and avoidance of science subjects (Hodson, 2009). In many developing countries, students perceive Biology as difficult, abstract, and culturally disconnected because instructional examples are frequently derived from unfamiliar contexts and foreign scientific traditions (Duit & Treagust, 2008).

IK-based instruction has the potential to transform these perceptions by making Biology more relevant and culturally meaningful. When learners recognize their community practices, local ecological experiences, and Indigenous environmental knowledge within classroom instruction, they are more likely to develop a sense of ownership and emotional connection to the subject matter Eze, 2014. Studies from Africa indicate that integrating Indigenous examples into science teaching strengthens learners' interest, confidence, and positive attitudes toward science learning (Amponsah et al., 2021). Furthermore, culturally inclusive instruction validates students' identities and reduces the psychological alienation often associated with western-oriented science education (Jegede & Aikenhead, 1999). Therefore, IK integration may contribute not only to improved academic outcomes but also to more favorable learner attitudes toward ecology and environmental conservation.

Student engagement represents another crucial dimension through which the effectiveness of IK-based instruction can be understood. Engagement refers to the degree of students' behavioral participation, emotional involvement, and cognitive investment in learning activities (Fredricks et al., 2004; Roorda et al., 2017). Behavioral engagement includes participation in classroom discussions, attendance, task completion, and collaborative activities. Emotional engagement reflects learners' interest, enjoyment, sense of belonging, and emotional attachment to learning experiences. Cognitive engagement involves deep mental effort, critical thinking, problem-solving, and willingness to invest in understanding complex concepts. Research consistently identifies engagement as a strong predictor of academic success and meaningful learning outcomes (Mädamürk et al., 2020).

Traditional teacher-centered approaches often limit student engagement because learners remain passive recipients of information rather than active participants in knowledge construction. In contrast, IK-based instruction promotes active learning through storytelling, collaborative discussion, local environmental observation, problem-solving, and community-based examples (Tsay et al., 2020). Such approaches encourage learners to interact with scientific concepts using familiar cultural frameworks and experiential knowledge. Jegede and Aikenhead (1999) argue that culturally contextualized science instruction enhances cognitive engagement because learners can interpret scientific ideas through their own sociocultural realities. Similarly, Demmert (2001) found that Indigenous-centered instructional approaches improved learners' classroom participation, motivation, and emotional involvement. Anor et al. (2022) further reported that culturally responsive science instruction increased students' collaborative learning behaviors and sustained classroom attention. Consequently, integrating IK into Biology instruction may transform science classrooms into more participatory, interactive, and learner-centered environments.

In addition to achievement, attitude, and engagement, students' perceptions of instructional approaches significantly influence the success of educational interventions. Perception refers to learners' interpretations, beliefs, and subjective evaluations regarding the nature, relevance, and effectiveness of a teaching approach (Jegede & Aikenhead, 1999). In Biology education, students' perceptions are closely associated with their willingness to participate actively, their confidence in understanding Biological concepts, and their acceptance of classroom practices. Aikenhead's (1996) concept of cultural border crossing explains that many non-western learners experience school science as a movement between two distinct knowledge systems: their home culture and the culture of western science. When classroom instruction dismisses Indigenous experiences and cultural realities, students may perceive science as alien, inaccessible, or disconnected from their identities.

IK-based instruction potentially alters this perception by repositioning IK as a legitimate and valuable component of scientific learning. According to Jegede and Aikenhead (1999), students exposed to culturally responsive science instruction often perceive Biology as more inclusive, understandable, and relevant to their lives. Through the integration of local ecological practices, Indigenous narratives, and culturally familiar examples, learners begin to see connections between school science and community knowledge systems. This shift in perception may strengthen students' confidence, participation, and overall acceptance of Biology as a meaningful subject rather than a foreign discipline.

Overall, the literature suggests that IK integration influences learning outcomes multidimensionally. Rather than affecting academic achievement alone, culturally responsive instruction shapes students' attitudes, engagement, and perceptions simultaneously. These dimensions are interrelated: positive perceptions enhance emotional engagement; stronger engagement improves conceptual understanding; and meaningful understanding contributes to improved achievement and favorable attitudes. Therefore, examining achievement, attitude, engagement, and perception together provides a more comprehensive understanding of how IK-based instruction affects Biology learning within culturally diverse educational contexts such as Ethiopia.

Gender remains an important issue in science education globally and within Ethiopia. International evidence shows persistent gender disparities in Science, Technology, Engineering, and Mathematics (STEM) participation and achievement (UNESCO, 2021). In Ethiopia, female students continue to score lower than males in science subjects at primary and middle school levels (MoE, 2023). Although structural and socioeconomic factors contribute to this disparity, pedagogical approaches also influence learners' participation and achievement.

IK integration may provide opportunities for more gender-inclusive science instruction because many Indigenous ecological practices involve women's expertise in areas such as seed preservation, herbal medicine, and water management (Workineh, 2010; Asmare et al., 2021). By recognizing women's contributions within classroom instruction, IK-based pedagogy may challenge traditional gender stereotypes associated with Biology learning.

However, empirical findings regarding gender effects in IK-based instruction remain inconsistent. Some studies report no significant interaction between gender and achievement under IK-oriented pedagogy (Ugwu, 2016; Agboghoroma & Oyovwi, 2015). Others suggest that girls perform better within collaborative and culturally responsive learning environments (Nbina & Wagbara, 2012). Conversely, studies by Uduaka et al. (2020) and Chibuye and Singh (2024) reported higher achievement among male students under similar instructional conditions. These conflicting findings indicate the need for localized investigation into whether gender moderates the effectiveness of IK-integrated Biology instruction within Ethiopian contexts.

Although Ethiopia possesses extensive Indigenous ecological knowledge and supportive educational policy frameworks, empirical research examining the pedagogical impact of IK integration remains limited. Existing Ethiopian studies primarily document Indigenous practices related to agriculture, medicine, biodiversity conservation, and environmental management (Negash et al., 2000). However, there is no studies experimentally examined how integrating IK into classroom instruction influences students' achievement, attitudes, engagement, and perceptions in Biology education.

Moreover, most Ethiopian studies remain descriptive rather than intervention-based, leaving a significant methodological gap regarding the actual educational effectiveness of IK integration (Tadesse & Mehari, 2020). Quantitative evidence demonstrating whether IK-based instruction improves measurable learning outcomes within the Biology is scarce. Furthermore, the moderating role of gender within IK-based learning environments remains largely unexplored in Ethiopian science education research.

Injibara City provides an appropriate context for investigating these issues because the area possesses rich Indigenous ecological traditions that closely align with ecological concepts taught in Grade 8 Biology (Asmare et al., 2021). The Agew community's Indigenous practices related to terrace farming, soil fertility management, biodiversity conservation, and watershed protection provide culturally relevant examples for contextualized Biology instruction (Alemayehu, 2018). At the same time, local schools continue to rely predominantly on conventional teacher-centered instructional approaches with minimal integration of Indigenous perspectives (Dagne & Alemu, 2021).

This mismatch between students' lived ecological experiences and formal science instruction creates a pedagogical opportunity to investigate whether IK-integrated instruction can improve academic achievement, engagement, and attitudes toward Biology. Therefore, the present study seeks to address these empirical, contextual, and methodological gaps by examining the effects of integrating IK into Grade 8 Biology instruction within the General Science curriculum in Injibara City, Ethiopia.

1.2 Statement of the problem

Despite growing recognition of IK as a valuable resource for science education, Biology instruction in Ethiopia continues to rely predominantly on decontextualized and teacher-centered approaches that marginalize learners' cultural and ecological experiences (Tadesse & Mehari, 2020; Nyoni, 2022). As a result, many students perceive Biology as abstract, foreign, and disconnected from their everyday lives, which contributes to low academic performance, weak classroom engagement, and negative attitudes toward science learning (Duit & Treagust, 2008).

This problem remains evident despite national educational reforms that advocate learner-centered, contextually relevant, and culturally responsive education (MoE, 2023). The contradiction between policy expectations and classroom practice has created a persistent instructional gap in which science teaching rarely connects formal biological concepts with local environmental knowledge and community experiences (MoE, 2018). Consequently, students often struggle to relate ecological concepts to real-life environmental practices within their communities.

The seriousness of the problem is reflected in recent national learning outcomes. The 2022 National Learning Assessment (NLA) reported that only 37% of Grade 8 students achieved proficiency in life science, which is below the national benchmark (MoE, 2022). Studies conducted in Ethiopia further indicate that many learners experience difficulty understanding ecological concepts because instruction emphasizes memorization of textbook content rather than contextualized conceptual learning (Worku & Abate, 2022). This suggests that conventional instructional methods have not adequately supported meaningful science learning.

One major factor contributing to this challenge is the limited integration of IK within Biology curriculum and instructional materials. Yeseraw et al. (2023) reported that most activities in the revised Grade 7 General Science curriculum fail to meaningfully incorporate Indigenous perspectives or local environmental practices. As a result, science instruction continues to privilege external scientific examples while overlooking the ecological knowledge embedded in Ethiopian communities. This weakens the relevance of Biology education and reduces students' opportunities to connect classroom learning with their lived realities.

The problem addressed in this study has three major dimensions. First, there is a significant methodological gap exists in the existing literature on IK integration in science education. Most previous studies conducted in Ethiopia and related contexts have employed descriptive, survey-based, or ethnographic approaches that primarily document Indigenous practices and community knowledge systems (Alemayehu, 2018). Although such studies provide important cultural and contextual insights, they offer limited evidence regarding the actual instructional effectiveness of IK integration in classroom settings.

In particular, there is a scarcity of experimental and intervention-based studies that systematically examine the impact of IK-integrated instruction on students' learning outcomes in Biology education. Existing studies regarding IK in Ethiopia, does not utilize rigorous quasi-experimental designs capable of establishing causal relationships between instructional approaches and outcomes such as achievement, attitude, and engagement.

Another methodological limitation is the limited use of mixed-methods approaches in examining IK-based instruction (Asmare et al., 2021). As to my knowledge no studies triangulate quantitative findings with qualitative evidence such as classroom observations and student perceptions to provide a deeper understanding of how and why IK integration influences learning processes. As a result, the mechanisms through which IK-based pedagogy affects students' participation, motivation, and conceptual understanding remain insufficiently explored.

Therefore, this study addresses these methodological gaps by employing a quasi-experimental mixed-methods design involving pretest–posttest control groups, quantitative measurement of multiple learning outcomes, and qualitative exploration through classroom observation and focus group discussions. This approach provides more comprehensive and empirically grounded evidence regarding the pedagogical effectiveness of IK-based Biology instruction within the Ethiopian context.

The second important research gap in the literature is the narrow focus of previous studies. Most existing researches regarding IK, has concentrated primarily on academic achievement while giving limited attention to other important dimensions of learning such as student engagement, attitude, and perception (Shishigu, 2021). However, effective science learning involves not only cognitive achievement but also learners' emotional involvement, classroom participation, and perceptions of relevance (Osborne et al., 2003; Roorda et al., 2017). There is therefore a need for a more comprehensive investigation into how IK-based instruction influences multiple dimensions of learning simultaneously.

The third research gap relates to the inconsistent findings regarding the role of gender in culturally responsive science instruction. Although gender disparities in science achievement remain a continuing concern in Ethiopia, existing studies provide inconclusive evidence on whether IK-based instruction benefits male and female students equally (MoE, 2023). Some studies suggest that culturally responsive and collaborative learning environments favor female students by increasing participation and confidence (Nbina & Wagbara, 2012), while others report higher performance among male students under similar instructional conditions (Uduaka et al., 2020; Chibuye & Singh, 2024).

Moreover, very few studies have examined gender as a moderating variable within IK-integrated science classrooms, particularly in the Ethiopian context where cultural roles and learning experiences are strongly shaped by gender norms. Although Indigenous practices often involve women's expertise in areas such as seed preservation, medicinal plants, and environmental management (Workineh, 2010; Asmare et al., 2021), there is limited empirical evidence showing whether integrating such knowledge into Biology instruction promotes equitable learning opportunities for both male and female students.

Therefore, the present study addresses this gap by examining whether gender moderates the effects of IK-based instruction on students' achievement, attitude, and engagement in ecology learning. Through this, the study seeks to determine whether culturally responsive pedagogy can support inclusive and equitable science learning within the Ethiopian middle school context.

By situating the investigation within Injibara City, a region characterized by a high wealth of ecological IK but low formal science proficiency, this research moves beyond the descriptive limitations of prior studies. It applies a quasi-experimental framework to test a culturally grounded instructional model, thereby providing the empirical weight needed to inform curriculum developers and policymakers. Ultimately, this study aims to validate a pedagogical pathway that treats students' indigenous heritage not as a barrier to science, but as its most potent foundation.

1.3 Research questions

The following research questions are raised to achieve the research objectives.

1. What is the effect of IK-based instruction on Grade 8 students' academic achievement in ecology compared to conventional teaching methods?
2. What is the effect of IK-based instruction on students' attitudes toward ecology?
3. What is the effect of IK-based instruction on students' classroom engagement?
4. Are there significant differences in achievement, attitude, and engagement between male and female students?
5. Is there a significant interaction effect between instructional approach and gender on students' achievement, attitude, and engagement?
6. How do students perceive the use of IK-based instruction in learning ecology?

1.4 Objectives of the study

1.4.1 General objectives

The objective of this study is to examine the effect of Indigenous Knowledge-based instruction on Grade 8 students' academic achievement, attitude, and engagement in ecology, and to determine the moderating role of gender.

1.4.2 Specific objectives

To achieve the general objective, the study specifically aims:

1. To determine the effect of IK-based instruction on students' academic achievement in ecology.
2. To examine the effect of IK-based instruction on students' attitudes toward ecology.
3. To assess the effect of IK-based instruction on students' classroom engagement during ecology lessons.
4. To evaluate whether there is significant gender differences in students' academic achievement, attitudes, and engagement in ecology.

5. To examine the interaction effect between instructional approach and gender on students' academic achievement, attitudes, and engagement in ecology.
6. To explore students' perceptions regarding the use of IK-based instruction in learning ecology.

1.5 Significance of the study

This study holds both theoretical and practical significance for science education, particularly within the Ethiopian context and comparable developing settings. Theoretically, it contributes to the growing discourse on culturally responsive pedagogy by empirically investigating how IK integration influences students' learning in Biology. While numerous global and African studies have underscored the value of IK in enhancing conceptual understanding and learner engagement, limited empirical evidence exists from Ethiopian middle schools. This research thus bridges an important gap by providing experimental data that link IK-based pedagogy with specific learning outcomes, academic achievement, engagement, attitude, and perception—among Grade 8 students.

Practically, the findings will benefit science teachers and educators by demonstrating context-based instructional approaches that align with students' cultural and environmental experiences. By incorporating locally relevant ecological practices, teachers can make abstract biology concepts, such as ecosystem balance, nutrient cycling, and biodiversity, more tangible and meaningful, thereby improving student motivation and comprehension.

The study will also inform curriculum developers and policymakers at the Ethiopian ministry of education and regional education bureaus. Evidence from this research can guide curriculum reform and textbook revision to include locally grounded examples that reflect Indigenous ecological practices and enhance contextual learning.

At the community level, the research will reinforce the cultural preservation and validation of Indigenous ecological wisdom, promoting community engagement in environmental sustainability and biodiversity conservation. The integration of IK into formal education not only supports academic learning but also fosters environmental stewardship and intergenerational knowledge transmission.

This research will aid both instructors and students in appreciating local practices and cultures, along with their associated knowledge and ethics. Additionally, it will enhance their understanding of indigenous science and technology, as well as the utilization of local resources, ultimately promoting sustainability. Finally, given the limited research on the impact of integrating IK into Biology instruction, the findings from this study will contribute to the existing body of knowledge in science education.

1.6 Scope and delimitations of the study

This study focuses on investigating the effect of IK- based Biology instruction on students' achievement, attitude, and engagement in middle schools of Injibara, Ethiopia. The instructional content centers on ecology topics like ecosystems, biodiversity, environmental conservation, and nutrient cycles, embedded within the Grade 8 General Science curriculum.

The study employs a quasi-experimental mixed-methods design involving one experimental group, taught using IK-based instruction and one control group, taught using conventional methods. The primary variables under investigation include students’ academic achievement, engagement (behavioral, emotional, and cognitive), attitude toward Biology, and perception of IK-based teaching. Gender is examined as a moderating variable to determine whether learning outcomes vary between male and female students.

The geographical scope of the study was delimited to Injibara City, located in the Awi Zone of the Amhara Regional State, Ethiopia. The selection of this area was informed by its rich Indigenous ecological practices and the researcher familiarity with these sociocultural contexts, which facilitated access to local knowledge systems and supported contextual interpretation of the findings. The study participants comprised Grade 8 students drawn from selected middle schools within the city administration. In terms of content scope, the study focused specifically on ecology and biodiversity conservation topics embedded within the Grade 8 General Science curriculum. The temporal scope of the investigation was limited to a six-week intervention period, corresponding to the instructional duration allocated for the ecology unit in the syllabus.

In terms of delimitations, the research does not extend to other science subjects such as chemistry or physics, nor does it include students beyond the middle school level. It also does not assess long-term retention or longitudinal effects beyond the intervention period. These boundaries are intentionally set to ensure depth of analysis and methodological manageability within the specified timeframe and resources.

The study focused on the ecology section of the middle school General science curriculum, addressing topics such as ecosystem interactions and the conservation of natural resources, including soil, water, air, and biodiversity. Research by Oyovwi (2015) highlighted that ecology was deemed one of the more challenging subjects for both primary and middle school students and Biology teachers.

1.7 Limitations of the study

Like any empirical inquiry, this study is subject to certain limitations that may influence the interpretation and generalization of its findings. First, the sample size is limited to middle schools in Injibara City, which may constrain the generalizability of results to other regions of Ethiopia with differing sociocultural or ecological contexts. Awi are different culturally somehow and findings in terms of IK may not be transferable and be generalized to other communities. Communities naturally vary at least to some degree.

Second, the duration of the instructional intervention is limited to one academic term. This relatively short timeframe may capture immediate learning effects but not long-term retention or behavioral change. Similarly, while the mixed-methods approach includes qualitative insights, FGD may be influenced by social desirability bias, where students provide favorable responses about the instructional innovation.

Third, teacher variability:-differences in pedagogical skill, motivation, and familiarity with IK may also affect the consistency of instructional delivery. To minimize this, teachers received orientation and support throughout the study; however, differences in teaching style may still influence outcomes.

Finally, logistical constraints such as limited instructional resources, time pressure, and dependency on school schedules posed operational challenges. Despite these limitations, the study employed methodological triangulation, rigorous data collection, and validated instruments to enhance the reliability, validity, and credibility of the findings.

1.8 Operational definitions of key terms

IK: The cumulative body of Awi knowledge, skills, and values developed through generations of interaction with the natural environment. It encompasses ecological, agricultural, and cultural wisdom transmitted orally and practiced communally to sustain environmental balance and social harmony.

IK-Based Instruction: A culturally responsive teaching approach that integrates Indigenous ecological practices, such as terraced farming, composting, intercropping, and water conservation—into ecology lessons to make ecological concepts more relevant, meaningful, and experiential to learners.

Learning Outcomes: The comprehensive result of students' learning, encompassing their academic achievement, engagement, and attitudes toward ecology and environmental conservation after exposure to the instructional intervention

Academic Achievement: The cognitive dimension of learning measured through students' scores on standardized ecology achievement tests assessing understanding of key ecology concepts such as ecosystems, nutrient cycles, and biodiversity.

Student Engagement: The degree of students' behavioral, emotional, and cognitive involvement in learning processes. In this study, it includes classroom participation, curiosity, enjoyment, and sustained effort toward understanding ecological concepts

Behavioral Engagement: Observable participation in classroom tasks, including attentiveness, question-asking, and involvement in practical activities related to Indigenous ecological practices.

Emotional Engagement: Students' affective connection to learning like interest, enjoyment, and sense of cultural relevance, elicited through recognition of IK within science instruction

Cognitive Engagement: The level of mental investment and strategy use students apply to understand, integrate, and apply scientific and Indigenous ecological concepts critically

Attitude Toward ecology: The affective orientation of students toward ecology topics, including their interest, motivation, and perceived value of learning science through locally meaningful contexts.

Conventional Instruction: The traditional, teacher-centered and textbook-driven instructional method focusing on factual recall and rote learning with minimal contextual or cultural connection to students' lived experiences.

Interaction Effect: The extent to which the effect of instructional strategy (IK-based instruction versus conventional teaching) on students' posttest achievement, attitude, or engagement differs across gender groups, as determined through two-way ANCOVA analysis.

Experimental Group: The group of students who received instruction using IK–based instructional approach, incorporating local ecological examples and practices.

Control Group: The group of students taught the same ecology topics through conventional, lecture-based, and textbook-oriented instructional strategies.

Perception: Students' awareness, interpretation, and evaluation of the effectiveness, relevance, and cultural value of IK-based teaching compared with conventional methods.

Ecological concepts: In this study, ecological concepts refer to the scientific ideas, principles, and relationships related to interactions among living organisms and their environment as included in the Grade 8 General Science curriculum.

CHAPTER TWO: REVIEW OF THE LITERATURE

Introduction

This chapter begins with a conceptual clarification of IK, providing a detailed examination of its definitions and foundational principles. It then presents diverse scholarly perspectives on the relationship between IK and Western scientific knowledge, highlighting areas of convergence, divergence, and potential integration. Subsequently, the chapter explores the pedagogical value of incorporating IK into Biology education, emphasizing its demonstrated influence on students' academic achievement, cognitive engagement, and attitudinal development. The discussion underscores how culturally responsive instruction grounded in IK enhances meaningful learning and contextual understanding in science classrooms. The chapter concludes with a critical review of relevant empirical studies, drawing on recent research to support the theoretical arguments and practical implications of integrating IK into science education.

2.1 Definitions and concepts of IK

The concept of IK is multifaceted and context-dependent, making it difficult to define precisely. Several scholars have highlighted the challenges associated with defining IK, beginning with the inherent ambiguity of the term "indigenous." Posey (2002) notes that the term raises fundamental questions of identity, such as who qualifies as indigenous and within which contexts. As a result of these complexities, various alternative terms are often used interchangeably with IK, including "local knowledge," "traditional ecological knowledge," and "indigenous science."

Sillitoe (2002) describes IK as contextually grounded in local culture and developed through shared understanding, serving as a framework through which communities interpret the world. Similarly, Kumar (2020) emphasizes that IK is acquired through sustained interaction with the natural environment over generations, reflecting the lived experiences of communities. This perspective positions IK as an adaptive and experiential knowledge system that evolves in close relationship with local ecosystems.

From a scientific standpoint, IK has often been mischaracterized as rudimentary or unstructured. Semali and Kincheloe (1999) argue that formal educational systems of developing nations have historically undervalued IK, frequently perceiving it as primitive or inferior to Western scientific paradigms. However, in many regions of the world—particularly in Africa, Asia, Latin America, and Oceania—IK forms the epistemological foundation for understanding human–environment relationships. As noted by Oyovwi (2015), IK is holistic, localized, and primarily transmitted orally through storytelling, songs, rituals, and other culturally embedded practices.

Warren and Rajasekaran (1993) define IK as a unique body of local knowledge embedded within specific cultures or societies, developed through direct engagement with the environment. It encompasses practical applications for daily survival and reflects a community understands of natural systems. Mkabela (2006) reinforces this definition by asserting that IK is deeply practical and rooted in everyday life experiences, often existing outside formal academic settings. Onwu and Mosimege (2004) further explain that IK includes values, customs, traditions, and belief systems integral to cultural identity and social cohesion.

Kincheloe and teinberg (2008) describe IK as a multidimensional body of knowledge that supports local communities through culturally relevant epistemologies, ontologies, and cosmologies. It provides insights into ecological systems, sociocultural dynamics, and historical continuity, enabling communities to address both traditional and contemporary challenges. Similarly, Battiste (2005) views IK as an interconnected system rooted in ecological relationships, transmitted through language, and embedded with moral and epistemic responsibilities.

Hart (2010) conceptualizes IK as a cognitive and practical legacy developed through sustained environmental interaction, involving problem-solving strategies and experiential knowledge passed down through generations. Chandra (2014) extends this view by suggesting that IK serves as a repository of culturally informed techniques and classifications applied in agriculture, medicine, and environmental management. According to Alessa et al. (2016), these practices are informed by systematic local observations of natural phenomena, contributing to resilience and sustainability. Regmi and Fleming (2012) emphasize that factual knowledge and practical experience are interwoven within IK systems, supporting human adaptation across environmental and sociocultural contexts.

Drawing on these scholarly perspectives, IK can be conceptualized as a community-generated system of knowledge developed through continuous interaction with natural and cultural environments. It is primarily informal, experiential, and transmitted orally through culturally embedded means such as stories, songs, rituals, and proverbs. IK is collectively owned and maintained, reflecting shared histories, values, beliefs, and traditions. Importantly, IK is not limited to Africa or non-Western societies; rather, it exists globally and contributes significantly to ecological sustainability, cultural continuity, and educational development.

Thus, IK represents a dynamic, evolving, and contextually grounded epistemology that merits serious consideration within formal education and scientific inquiry, particularly in efforts to promote inclusive, culturally responsive, and sustainable solutions to contemporary global challenges.

2.2 Concept of IK in relation to science

The concept of IK in science is closely aligned with the principles of ethno-biology, a field that examines how different cultures understand, interact with, and utilize living organisms within their environments. Ethno-biology explores the complex relationships between human societies, biological entities, and ecological systems across historical and cultural contexts (Harrington, 2007). It provides a culturally embedded framework through which biological knowledge can be interpreted, communicated, and applied.

Ethno-biology serves as a critical interface between cultural traditions and biological science. Alemu and Tarekegn(2020) notes that it enables learners to meaningfully engage with their immediate environment by linking local cultural practices to formal biological concepts. This connection enhances relevance and deepens understanding. Abonyi (1999) explains that ethno-biology encompasses not only material practices and technologies but also the beliefs, values, and knowledge systems underpinning human–nature interactions, including environmental stewardship.

Kelly (2009) emphasizes that ethno-biology offers a holistic educational approach that bridges scientific knowledge and learners' sociocultural realities. This approach promotes active participation, critical thinking, and the internalization of biological knowledge through real-life applications. Consequently, Biology education extends beyond content transmission to empower students to address ecological challenges rooted in their lived experiences.

Onuoha (2007); Kelly (2009) advocate transitioning from conventional teacher-centered approaches to learner-centered strategies informed by ethno-biological practices. Such strategies enhance learner agency, engagement, and contextual understanding. This pedagogical shift supports the development of problem-solving skills, collaboration, and environmental responsibility, which are essential for sustainable development.

Moreover, ethno-biology highlights the adaptive capacity of cultures within diverse ecosystems. Practices such as plant domestication, animal husbandry, and sustainable resource management illustrate how biological knowledge is embedded in indigenous survival strategies. Recognizing the scientific value of these practices enriches Biology education by situating it within learners' cultural realities.

In summary, integrating IK through an ethno-biological lens enriches Biology education by making it more inclusive, culturally relevant, and engaging. It enables students to connect biological theories to their daily lives and cultural backgrounds, fostering deeper and more meaningful learning (Harrington, 2007; Kelly, 2009;).

2.3 IK and Scientific knowledge

The relationship between IK and scientific knowledge has been widely debated, particularly regarding whether IK constitutes a form of science or represents a fundamentally distinct epistemological system. Traditionally, IK has been marginalized and described as "dominated knowledge," often perceived as inferior to scientific knowledge (Jegede, 1999). However, contemporary scholarship increasingly recognizes IK as a legitimate and valuable knowledge system that can be regarded as scientific in its own context (Agrawal, 2021).

A major distinction lies in modes of transmission and communal engagement. IK is predominantly oral and communal, transmitted through storytelling, rituals, and shared experiences (Snively & Corsiglia, 2024). In contrast, SK is typically documented, institutionalized, and learned through formal education systems. The communal nature of IK necessitates dialogic and participatory pedagogical approaches, which are conducive to classroom integration (Snively, 1995).

Attempts to differentiate IK and SK often emphasize substantive, methodological, epistemological, and contextual differences. However, Agrawal (2021) critiques such binary classifications, arguing that they oversimplify complex knowledge systems and hinder constructive dialogue. For instance, the assumption that IK is purely practical while SK is abstract ignores the reality that SK also shapes everyday life (Le Grange, 2019). Le Grange (2019) further argues that all knowledge systems are locally situated, shaped by specific contexts, beliefs, and practices. Knowledge production involves negotiation and collaboration, creating opportunities for integrative "knowledge spaces" that draw from both IK and SK.

Despite shared features, epistemological differences remain. Jegede (1999) characterizes SK as mechanistic, reductionist, and empirically driven, whereas IK is holistic, relational, and often embedded with spiritual and ethical dimensions. IK incorporates cultural mechanisms such as taboos that regulate environmental interactions, reflecting moral responsibility toward nature (Semali & Kincheloe, 2020).

Although SK presents itself as universal and objective, scholars argue that it is also culturally situated within Western historical and social contexts (Semali & Kincheloe, 2020). Loubser (2005) demonstrates that Western scientific disciplines evolved from indigenous traditions, highlighting that so-called universal knowledge is localized knowledge institutionalized by dominant epistemologies. Colonial suppression of African IK led to its marginalization in formal education, contributing to learner alienation and cognitive dissonance (Mignolo, 2018).

This disconnect has educational consequences, as students may perceive science as abstract and irrelevant, sometimes dismissing it due to lack of cultural resonance (Tobin, 1993). Moreover, indigenous contributions to science and technology have historically been overlooked (Donoghue, 2004), reinforcing epistemic inequality.

Despite these challenges, IK and SK share empirical foundations rooted in observation and experience (Antweiler, 1996). While SK seeks generalization, IK remains context-specific.

Although IK may include metaphysical elements, dichotomizing the two knowledge systems perpetuates an unnecessary divide (Battiste, 2018).

In conclusion, IK and SK exhibit both differences and substantial commonalities. Contemporary scholarship advocates integrative frameworks that recognize IK as a legitimate epistemology alongside SK. Such recognition promotes culturally responsive science education, inclusive knowledge production, and epistemic justice (Berkes, 2017; Simpson, 2021).

2.4 IK as prior knowledge and its effect on learning

Prior knowledge—often described as learners' experiential and culturally acquired understanding—includes the skills, values, and interpretations students develop through interaction with their families, communities, and local environments. Educational research consistently demonstrates that instruction grounded in learners' existing knowledge structures substantially improves the acquisition and internalization of new concepts (World Bank, 2023). When learning content is perceived as personally meaningful, students demonstrate higher levels of retention and deeper cognitive engagement (Merrill, 2021).

Learning theories position prior knowledge as a critical determinant of effective learning. Galeen (1997) maintains that learners process new information more efficiently when it connects with relevant background knowledge, including language competence, conceptual understanding, and experiential skills such as sensory or motor abilities. These cognitive assets are shaped by learners' socio-cultural, geographical, and environmental contexts (Santos et al., 2022). As a result, students enter classrooms with diverse interpretations of scientific ideas that reflect their cultural experiences rather than standardized scientific explanations. Therefore, teachers must intentionally diagnose and integrate learners' prior knowledge—particularly IK—into instructional planning (Snively & Corsiglia, 2024).

Cobern (1996) argues that traditional science instruction often fails to align with learners' lived realities, resulting in knowledge that lacks contextual meaning. Knowledge construction is inherently interpretive and shaped by existing beliefs and experiences. This is especially relevant for indigenous learners, whose knowledge systems may differ from, rather than contradict, Western scientific frameworks. For instance, Ethiopian learners frequently develop ecological understandings rooted in indigenous conceptions of human–nature relationships, reflecting epistemological diversity rather than scientific invalidity (Wolde-Selassie 2002).

Scott et al. (1994) further explain that children's ideas evolve through socialization and lived experience, giving rise to culturally grounded "commonsense" explanations. Historically, IK has been undervalued or excluded in formal education in favor of Western science, which has been treated as the only legitimate knowledge system (Nygren, 1999). However, IK encompasses critical domains such as environmental management, agriculture, and traditional medicine that hold substantial educational value. Recent scholarship challenges the dominance of Western epistemologies and advocates for pluralistic knowledge systems that recognize multiple ways of knowing (Mazzocchi, 2020).

From a pedagogical perspective, valuing prior knowledge aligns strongly with constructivist learning theories, which emphasize learners' active role in constructing understanding (World Bank, 2023). Teachers are encouraged to contextualize instruction, pose culturally relevant problems, and build incrementally on learners' existing knowledge bases. Such scaffolding reduces the formation of alternative conceptions that emerge when abstract ideas are introduced without adequate grounding (Taber, 2022). Meaningful learning occurs when students consciously connect new information to what they already know (Bransford et al., 2020).

In summary, incorporating IK as prior knowledge in science education is essential for promoting authentic, meaningful learning. Aligning instruction with learners' cultural and experiential backgrounds enhances understanding, relevance, and retention, contributing to more inclusive and equitable science education.

2.5 Integrating IK into formal schooling

The integration of IK with scientific knowledge is increasingly viewed as vital for enriching education, strengthening rational decision-making, and facilitating reciprocal knowledge exchange between indigenous communities and scientific practitioners (Roba, 2008). Such integration entails collaborative partnerships characterized by shared authority, mutual respect, and joint responsibility between scientists and IK holders (Berkes, 2008).

Education is fundamentally a social process involving interaction between teachers and learners in the co-construction of knowledge (Cherif, 2011). For learning to be meaningful and relevant, formal education systems must recognize IK as a complementary component rather than a peripheral addition. This integration bridges indigenous worldviews and Western scientific traditions, enabling holistic understanding (Ogundiran & Adeoye, 2021).

Contemporary educational discourse increasingly critiques Western-centric curricula that marginalize local knowledge systems, positioning IK at the center of curriculum transformation (Semali & Kincheloe, 2020). Scholars emphasize the need for balance, arguing that neither school science nor IK should dominate at the expense of the other (Agbo & Alabi, 2019). Such balance enhances curricular relevance, accessibility, and cultural responsiveness.

The revival of IK in education is closely linked to the African Renaissance movement, which seeks to reclaim African identity, language, and development pathways (Du Toit, 2019). Embedding IK in formal schooling is viewed as a pathway for restoring African intellectual traditions and fostering culturally grounded education (Makgoba, 2020). Recognizing learners' cultural knowledge is central to this intellectual renewal.

The relationship between the African Renaissance and sustainable development highlights the necessity of aligning formal education with learners' lived realities (Grenier, 2021). Sustainability initiatives are unlikely to succeed without the inclusion of indigenous epistemologies at all levels of development (Muller & Okorie, 2022). Integrating IK ensures indigenous communities actively contribute to and benefit from educational and development processes.

Integrating IK into formal education yields multiple pedagogical benefits. First, it enhances relevance and learner ownership by linking abstract scientific concepts—such as those in Biology—to familiar cultural practices (Adesoji & Akpan, 2017). This contextualization helps reconcile potential tensions between scientific ideas and students' existing knowledge systems (Kasanda et al., 2018).

Second, IK integration affirms learners' socio-cultural identities, fostering self-esteem and enabling students to value their cultural heritage alongside Western scientific knowledge

(Emeagwali, 2019). This dual epistemic engagement promotes inclusivity, flexibility, and critical thinking (Chilisa, 2020).

Third, combining indigenous and scientific knowledge enriches curriculum content by offering multiple explanatory lenses (Jegede & Aikenhead, 2000). Biology, chemistry, and physics benefit from indigenous examples that reduce abstraction and increase real-world applicability (Mukuka, 2021). Teachers thus become facilitators of culturally meaningful learning.

Fourth, IK integration strengthens coherence between classroom learning and learners' social and ecological environments, supporting experiential and holistic education (Jegede & Aikenhead, 2000). This approach is also cost-effective, drawing on existing community knowledge and resources (Ogundiran & Adeoye, 2021).

Finally, IK-based instruction enhances learner autonomy, self-efficacy, and critical thinking by encouraging active participation and experiential learning (Onwu & Mosimege, 2015). Students develop transferable decision-making skills relevant to real-life contexts (Onuoha, 2018). Such pedagogy fosters intrinsic motivation and intellectual confidence (Bruner, 1966; Mukuka, 2021).

Therefore, the systematic incorporation of indigenous biological practices—particularly those relevant to Ethiopia and Africa—is essential for improving understanding, achievement, and cultural connectedness in Biology education (Emeagwali, 2019; Mukuka, 2021).

2.6 IK and teaching of ecological concepts

Ecology is the scientific study of the interactions among organisms and between organisms and their environment, explaining patterns of distribution, adaptation, and survival (Townsend et al., 2008). Within the Ethiopian General Science and Biology curriculum for Grades 7–10, ecological concepts include ecosystems, biotic and abiotic factors, food chains and food webs, energy flow, nutrient cycling, population dynamics, biodiversity, and environmental conservation. These concepts are fundamental to promoting scientific literacy and environmental sustainability.

Natural resources such as air, water, soil, forests, wildlife, minerals, and energy sources constitute the ecological foundation upon which human societies and ecosystems depend

(Yuankai, 2010). However, rapid industrialization, population growth, urban expansion, and unsustainable exploitation of resources have intensified environmental degradation, habitat destruction, and biodiversity loss (Ayerst et al., 2005). Consequently, conservation education has become increasingly important in addressing environmental challenges such as climate change, ecological imbalance, and resource depletion (Knight, 2003). Developing ecological literacy—defined as the knowledge, skills, values, and attitudes necessary for responsible environmental decision-making is therefore a major goal of science education (UNESCO, 2012).

Indigenous communities possess extensive ecological knowledge developed through generations of close interaction with local environments (Nel, 2006). This IK encompasses practices related to soil and water conservation, biodiversity protection, medicinal plants, sustainable agriculture, and natural resource management. Such knowledge systems reflect practical ecological understanding and provide culturally relevant contexts through which scientific concepts can be taught meaningfully (Yuankai, 2010). Integrating IK into ecology instruction can therefore support both environmental sustainability and the preservation of valuable local knowledge systems.

The effectiveness of ecology instruction depends not only on curriculum content but also on the instructional strategies employed in classrooms. Teaching is increasingly viewed as a dynamic and interactive process that requires flexible, learner-centered pedagogical approaches rather than rigid transmission-oriented methods (Bergin, 1990). In contemporary educational practice, effective teachers function as facilitators of learning by creating opportunities for inquiry, discussion, collaboration, and contextual application of knowledge (Mangal, 2009). Within science education, connecting classroom instruction to learners' community experiences enhances the relevance and applicability of scientific concepts.

Constructivist learning theory provides a strong theoretical basis for integrating IK into science teaching. Constructivist pedagogy emphasizes that learners actively construct knowledge through interaction, exploration, reflection, and engagement with prior experiences rather than through passive memorization (Sichalwe, 2011). Learner-centered instructional approaches encourage students to participate actively in problem-solving and critical thinking activities, thereby promoting deeper conceptual understanding and long-term retention. Such approaches are particularly relevant in ecology education, where many scientific concepts can be linked to students' everyday environmental experiences.

Research indicates that instructional strategy selection significantly influences students' academic achievement, engagement, and attitudes toward learning (Ganyaupfu, 2013). Effective instruction requires alignment among content, pedagogy, learner characteristics, and sociocultural context (Adunola, 2011). Since learners interpret new information through the lens of prior knowledge and cultural experiences, meaningful learning occurs when instruction builds upon familiar contexts (Henson, 2003). Consequently, student-centered approaches generally produce better learning outcomes than teacher-centered methods because they promote active participation and cognitive engagement (Anderson et al., 2006). Similarly, Ausubel (1963) emphasized that meaningful learning depends on the integration of new knowledge with learners' existing cognitive structures through carefully organized instructional experiences.

Integrating IK into science instruction exemplifies a constructivist and culturally responsive teaching strategy. Approaches such as ethno-biology contextualize scientific concepts within learners' cultural and environmental realities, enabling students to connect abstract ecological principles with familiar local practices (UNESCO, 2012). For example, Indigenous farming systems, traditional conservation practices, and community environmental management strategies can be used to illustrate concepts such as ecosystem balance, nutrient cycling, biodiversity conservation, and sustainability. By situating learning within culturally meaningful contexts, IK-based instructional strategies can enhance students' conceptual understanding, engagement, motivation, and retention of ecological concepts.

2.7 IK, Student engagement, and academic achievement interactions

Academic achievement is commonly defined as the extent to which learners attain intended educational objectives, typically measured through examinations, assessments, and classroom performance indicators (Shehzad & Aziz, 2019). In science education, achievement reflects students' ability to understand, apply, and retain scientific concepts. Within the context of this study, academic achievement specifically refers to students' performance in ecology-related topics taught under the Grade 8 General Science curriculum. Achievement in ecology is particularly important because ecological understanding supports environmental awareness, conservation practices, and sustainable decision-making. However, achievement in Biology and ecology-related subjects remains persistently low in many developing countries, including Ethiopia, where science instruction is frequently criticized for being abstract, examination-oriented, and disconnected from students' lived experiences (Dagne & Alemu, 2021).

Research increasingly suggests that students' academic success is closely linked to their level of engagement in the learning process. Student engagement refers to the degree of behavioral, emotional, and cognitive involvement learners demonstrate during instructional activities (Fredricks et al., 2004; Roorda et al., 2017). Behavioral engagement includes observable actions such as classroom participation, attendance, attentiveness, assignment completion, and adherence to classroom norms. Emotional engagement reflects learners' affective reactions toward learning, including interest, enjoyment, enthusiasm, and sense of belonging. Cognitive engagement involves the psychological investment learners make in understanding complex concepts, solving problems, and applying knowledge critically. Together, these dimensions determine the quality of students' participation in learning and strongly influence academic outcomes.

Engagement is shaped by several instructional and contextual factors, including classroom climate, teacher support, motivation, relevance of instructional content, and opportunities for active participation (Ali et al., 2018; Rodríguez et al., 2020). Studies have consistently shown that students are more likely to engage meaningfully when learning activities connect with their personal experiences and sociocultural realities. Observable indicators of engagement include active participation in discussions, consistent attendance, collaborative learning behaviors, completion of academic tasks, and sustained attention during classroom activities (Winstone et al., 2021). High levels of engagement are positively associated with improved academic performance, deeper conceptual understanding, increased motivation, and greater satisfaction with learning experiences (Tsay et al., 2020).

The relationship between engagement and achievement is strongly supported by constructivist learning theory, which posits that learners actively construct knowledge through interaction, exploration, and reflection rather than through passive reception of information. From a constructivist perspective, meaningful learning occurs when students connect new information with prior experiences and existing cognitive structures (Vygotsky, 1978). Consequently, Biology instruction should emphasize inquiry-based, collaborative, and experiential learning strategies that encourage active student participation (Mädamürk et al., 2020). Such approaches are particularly important in ecology education because ecological concepts can be directly linked to learners' local environmental experiences and community practices.

Within the Ethiopian educational context, Biology instruction is expected to promote scientific reasoning, environmental awareness, and the practical application of scientific knowledge to real-life situations (MoE, 2018). However, conventional teaching approaches often fail to achieve these objectives because they rely heavily on teacher-centered methods and textbook memorization. As a result, students frequently perceive Biology as difficult and unrelated to their everyday lives. Integrating Indigenous Knowledge (IK) into Biology instruction offers a potential solution to this problem by contextualizing scientific concepts within learners' cultural and environmental experiences. Kaino (2013) argues that culturally relevant instruction enhances motivation and participation by making learning more meaningful and relatable to students.

The integration of IK into science instruction aligns closely with culturally responsive and constructivist pedagogies. Indigenous ecological practices, including traditional farming methods, biodiversity conservation systems, medicinal plant use, and local environmental management strategies provide authentic contexts for teaching ecological concepts (Asmare et al., 2021). By incorporating these familiar practices into classroom instruction, teachers can bridge the gap between formal scientific knowledge and students' lived realities. Such contextualized instruction encourages learners to participate actively in discussions, collaborative activities, field observations, and problem-solving tasks, thereby strengthening behavioral engagement. At the same time, validating students' cultural knowledge fosters emotional engagement by increasing learners' sense of identity, belonging, and confidence within the classroom.

IK-based instruction also promotes cognitive engagement by encouraging students to compare Indigenous explanations with scientific principles, analyze ecological relationships critically, and apply knowledge to local environmental issues. Fredricks et al. (2004) emphasize that behavioral, emotional, and cognitive engagement are interrelated dimensions that collectively contribute to academic success. Similarly, Beale (2018) notes that culturally responsive instruction reduces disengagement and enhances learners' commitment to academic activities by affirming their sociocultural identities.

Empirical evidence further supports the positive relationship among IK integration, student engagement, and academic achievement. Rahmawati et al. (2019) found that culturally contextualized science instruction improved students' participation and conceptual understanding. Zidny and Eilks (2020) reported that integrating indigenous environmental practices into science lessons enhanced learners' motivation and achievement by making abstract concepts more concrete and meaningful. Likewise, Anor et al. (2022) demonstrated that culturally embedded instructional activities promoted collaboration, inquiry, and deeper cognitive processing among science learners. These findings suggest that IK-based pedagogy can strengthen both affective and cognitive dimensions of learning, ultimately contributing to improved academic outcomes.

In conclusion, the interaction between IK, student engagement, and academic achievement highlights the importance of culturally responsive pedagogy in science education. Integrating IK into Biology instruction provides learners with meaningful, contextually relevant learning experiences that strengthen behavioral, emotional, and cognitive engagement. Enhanced engagement, in turn, supports improved conceptual understanding and academic achievement in ecology. Therefore, IK-based instructional approaches represent a potentially effective strategy for promoting inclusive, relevant, and sustainable science education within the Ethiopian context and similar educational settings.

2.8 IK, attitude, and achievement interactions

Student attitude has become a central construct in science education research, given its well-established influence on learners' academic achievement and engagement in scientific subjects. Attitude, as articulated in contemporary literature, refers to an individual's predisposed cognitive, emotional, and motivational orientation toward learning situations, shaped by both personal experiences and social influences (Ajzen, 2020). It encompasses affective readiness and motivational tendencies that guide learners' goals, behaviors, and responses to academic content. Within science education particularly ecology students' attitudes are reflected in their interests, values, and emotional reactions to ecological concepts and learning tasks (Osborne et al., 2023).

Scholars suggest that attitude emerges from an interaction between intellectual curiosity and affective experiences, both of which are influenced by learners' sociocultural environments (Eagly & Chaiken, 2024). Instructional approaches that draw on students' lived experiences and indigenous contexts—especially through the integration of IK—have been identified as effective in cultivating positive attitudes toward science learning (Sibanda et al., 2022). Such approaches enhance the perceived relevance and accessibility of scientific knowledge.

One of the persistent challenges in science education is identifying factors that diminish student interest and achievement. Among these factors, attitude has been recognized as a key determinant influencing students' participation, performance, and long-term commitment to science disciplines and careers (Ardies et al., 2019). Empirical studies show that learning environments which meaningfully connect formal curricula with indigenous and real-world knowledge foster more positive attitudes and improved academic performance (Regan et al., 2022). Similarly, instructional practices that relate Biology concepts to learners' everyday experiences have been shown to enhance motivation and engagement (Cherono et al., 2021).

Students' attitudes toward science are shaped by a constellation of contextual influences, including family background, motivational factors, teaching practices, social interactions, and prior academic experiences (Potvin & Hasni, 2014). Pedagogical research consistently indicates that instructional strategies emphasizing dialogue, contextualization, and cultural relevance significantly improve both learner attitudes and academic outcomes. Empirical evidence further supports the effectiveness of incorporating indigenous practices—such as ethno-Biology and ethno-chemistry—in enhancing understanding and achievement in science classrooms (Aikenhead et al., 2021).

Recent studies highlight a reciprocal relationship between attitude and achievement, whereby positive attitudes contribute to improved performance, while effective teaching strategies simultaneously strengthen learner attitudes (Scherer et al., 2023). This underscores the pivotal role of teachers in shaping meaningful learning experiences and suggests that culturally responsive pedagogies, including ethno-Biology, can substantially transform students' attitudes and achievement in ecology.

In summary, fostering positive attitudes toward science through the integration of IK and culturally responsive instructional strategies represents a powerful pathway for improving academic achievement and sustaining students' interest in scientific learning (Snively & Williams, 2022).

2.9 IK, gender, and achievement interactions

Gender—understood as the socially and culturally constructed attributes associated with masculinity and femininity—remains a critical variable in educational research and development discourse. Gender equality, enshrined as a core sustainable development goal, reflects global efforts to address persistent disparities that continue despite progress since the Millennium Development Goals (United Nations, 2023). Nevertheless, deeply rooted societal norms continue to restrict women's equitable participation and benefits in education and development (Fatokun & Odagboyi, 2011). Traditional stereotypes frequently portray science and mathematics as masculine domains, while subjects such as home economics are viewed as feminine and less intellectually demanding (Smith & Lee, 2022). These perceptions reinforce power imbalances and perpetuate unequal access to educational opportunities (Clark & Evans, 2024).

Such gendered social constructions extend into classrooms, shaping learners' academic experiences and outcomes. Chigeza et al., (2020) found that female students were more likely than males to perceive Biology concepts as difficult, indicating differential learning experiences. These differences may stem from gender-based socialization and classroom dynamics, where boys often demonstrate higher competitiveness and self-efficacy, while girls may exhibit lower confidence and more passive learning behaviors (Harrison & Johnson, 2021). These patterns contribute to variations in engagement and academic performance across genders.

However, a growing body of research challenges the assumption of inherent gender differences in science achievement. Ugwu (2016) reported no statistically significant performance differences between male and female students taught using IK-integrated instructional strategies, with both groups outperforming those taught conventionally. Similarly, Mavrikaki & Koumparou (2012) found that gender did not significantly influence students' perceptions of Biology topic difficulty, while Oyovwi (2015) observed no gender- or location-based differences in students' understanding of complex Biology concepts. These findings highlight the mediating role of pedagogy rather than gender alone.

Given these inconsistent findings, the influence of gender on Biology achievement and attitudes remains inconclusive. Consequently, gender warrants careful consideration as a moderating variable in studies evaluating innovative instructional approaches. In this regard, the present study examines gender differences in students' academic achievement in ecology and biodiversity conservation when instruction is delivered through an integrated ethno-Biology framework. The study seeks to determine whether IK-based instruction can promote gender equity and improve learning outcomes for all students.

2.10 Students' perceptions of the IK-based teaching strategy

The success of any pedagogical intervention is inherently tied to the learners' perceptions of its utility, relevance, and legitimacy. In the context of science education, student perception acts as the primary filter for "Cultural Border Crossing" (Aikenhead, 2001). For students in non-Western or indigenous communities, school science is often perceived as a "subculture" that may conflict with their home culture. The literature suggests that integrating Indigenous Knowledge (IK) fundamentally reshapes this perception, moving science from the periphery of the student's identity to the center.

A recurring theme in global literature is the perception of science as an imported or western construct. In Ethiopia, students frequently perceive Biology as a collection of abstract facts disconnected from the African reality (Dagne & Alemu, 2021). When IK is integrated, students' perceptions of science undergo a transformation from viewing it as a foreign imposition to seeing it as a universal human endeavor that is deeply rooted in their own heritage.

Empirical evidence from Kassa et al. (2024) indicates that students perceive IK-based instruction as a validation of their community's wisdom. By seeing the scientific principles of biodiversity conservation reflected in Agew agroforestry, students begin to perceive themselves as legitimate participants in the scientific discourse rather than passive recipients of foreign information (Alemayehu, 2018).

Students' perceptions of the difficulty of a subject often dictate their performance. Traditional, lecture-based strategies are frequently perceived as abstract and "rote-heavy" (Onwu, 2011). In contrast, IK-based strategies are perceived by students as providing cognitive clarity. According to Zidny and Eilks (2020), students report that using indigenous contexts (e.g., traditional fermentation to explain microbiology) makes the subject feel more transparent and "less intimidating." This shift in perception increases academic self-efficacy—the student's belief in their ability to succeed. In a study by Abonyi et al. (2014), students perceived the IK-based method as more "truthful" because it provided physical, local evidence for concepts that were previously only seen in textbook diagrams.

The literature emphasizes that students perceive the inclusion of IK as a socio-emotional catalyst. Gay (2018) argues that culturally responsive pedagogy fosters a perception of inclusion. When Agew proverbs or ecological narratives are utilized in Biology, students perceive their culture as having epistemic value (Semela, 2010). This positive perception directly impacts behavioral engagement. Okebukola (2020) found that students who perceive the curriculum as culturally relevant are more likely to participate in peer discussions, as they feel they have "expert knowledge" from home to contribute. This transforms the student’s perception of the classroom from a space of silence to a space of voice and agency.

Perceptions of IK-based instruction are often filtered through gendered lenses. In many Ethiopian societies, specific ecological tasks are gendered, for example, women often possess superior knowledge of seed selection and herbal medicine (Workineh, 2010; Asmare et al., 2021). Positive Perceptions for Girls: Female students may perceive the IK approach as a pathway to STEM equity, as it highlights roles where women are already recognized experts (Nbina & Wagbara, 2012). Mixed Perceptions: However, if the IK content focuses exclusively on male-dominated domains (like large-scale plowing), female students may perceive the strategy as reinforcing traditional hierarchies (Ugwu, 2016). This underscores the need for a balanced instructional design to ensure both genders perceive the strategy as an empowering and inclusive framework.

2.11 Empirical studies on IK

Recent empirical research reflects growing scholarly interest in integrating IK into science education, driven by its potential to enhance students' achievement, engagement, and attitudes toward science. Studies conducted across Africa and other regions provide valuable insights into the effectiveness, design, and challenges of IK-based pedagogical approaches. In Ethiopia, Shishigu et al. (2021) employed a quasi-experimental pretest–posttest design to examine the integration of traditional medicine into Grade 9 Biology instruction. Their findings revealed that contextualizing Biology topics with locally relevant indigenous practices significantly improved students' attitudes compared to conventional teaching methods.

Similarly, Ugwu (2016) investigated the impact of IK-integrated chemistry instruction in Nigeria using a quasi-experimental design. Results showed higher achievement among students taught using IK-based methods, with no significant gender differences or interaction effects. The study recommended the systematic inclusion of indigenous knowledge in science curricula to enhance understanding and achievement. Abonyi's earlier work further supports these findings, demonstrating that ethno-science instructional models enhance student interest and conceptual understanding in integrated science. By embedding community knowledge and cultural practices into instruction, ethno-science approaches bridge the gap between students' lived experiences and abstract scientific concepts.

In Zambia, Chibuye & Singh (2014) examined the effects of ethno-chemistry on students' attitudes using a non-equivalent control group design. Findings indicated significantly more positive attitudes among students exposed to culturally contextualized instruction. Subsequent studies in Zambia emphasize the broader educational and economic relevance of Ethno-chemistry-based instruction. Evidence from the United States also reinforces these trends. Elaine (2008) reported that incorporating local ethno-Biology into K-12 instruction increased students' environmental awareness and engagement. However, methodological limitations—such as reliance on self-report surveys highlight the need for mixed-method approaches.

Despite these positive outcomes, several studies identify challenges in implementing IK-based instruction, including limited teacher expertise, curriculum constraints, and negative perceptions of IK (Absalom, 2008). These challenges underscore the need for targeted professional development, supportive policies, and curriculum reform. Overall, empirical evidence confirms that IK-based instruction positively influences students' attitudes and achievement, while emphasizing the importance of teacher preparedness, policy support, and rigorous research methodologies.

2.12 Synthesis of literature and identification of research gaps

The comprehensive review of the preceding literature establishes a global consensus: the integration of Indigenous Knowledge (IK) into formal science education is not merely a pedagogical alternative, but a fundamental requirement for achieving epistemic justice and instructional relevance (Aikenhead, 2001; Battiste, 2013). Theoretically, the synergy between Social Constructivism (Vygotsky, 1978) and Meaningful Learning (Ausubel, 1963) provides a robust framework for understanding how cultural anchors facilitate the "border crossing" from home-based worldviews to school-based scientific paradigms (Jegede, 1995). Empirically, the literature demonstrates that when students perceive their own ecological heritage such as the local people's sophisticated soil management as having scientific legitimacy, their academic achievement, interest, and engagement levels rise significantly (Ogunniyi & Hewson, 2008; Eze, 2014; Kassa et al., 2024).

However, a critical analysis of the current state of research reveals profound deficiencies that undermine the practical application of IK in Ethiopian classrooms. These gaps, categorized below, constitute the scholarly mandate for the present study.

Empirical Gap: While several studies in Ethiopia have documented the existence and sociocultural significance of IK systems, limited research has empirically examined how such knowledge can be systematically integrated into science instruction to improve measurable learning outcomes. Existing Ethiopian studies have largely focused on describing indigenous practices, such as medicinal animal use in West Gojjam (Manaye et al., 2020), indigenous soil classification and conservation systems in North Shoa (Negash et al., 2000), and traditional agricultural knowledge in Gondar and Gojjam (Baye & Teshome, 2020). Similarly, Ali et al. (2022) examined the transfer of indigenous medicinal and agricultural knowledge across generations. More recently, Tadege and Tadesse (2025), in their study reported that, IK remains minimally integrated into classroom instruction despite its recognized educational and cultural relevance. Their findings revealed that instructional materials and pedagogical practices inadequately reflect local knowledge systems, thereby limiting opportunities for contextualized and culturally responsive learning.

Despite these contributions, there remains a significant lack of empirical studies investigating the relationship between IK-based teaching methods and measurable educational outcomes such as academic achievement, engagement, and attitudes toward science. In particular, little evidence exists regarding whether the positive outcomes reported in international contexts (Ugwu & Diovu, 2016) can be replicated within the specific cultural, linguistic, and ecological context of the Awi community and the Ethiopian General Science curriculum.

Methodological and Practical Gap: Existing local literature on IK integration is predominantly descriptive, exploratory, or policy-oriented, with limited use of rigorous experimental or quasi-experimental designs capable of establishing instructional effectiveness. Bohensky and Maru (2011) highlighted the scarcity of evaluations examining the practical “lessons learned” from integrating Indigenous and scientific knowledge systems within classroom contexts. Similarly, Kassa et al. (2024) emphasized the need for empirical validation of claims that IK-based pedagogies can transform abstract scientific concepts into concrete and meaningful mental models. However, few Ethiopian studies have employed controlled intervention designs, mixed-method approaches, or inferential statistical procedures to examine the pedagogical effects of IK integration in science classrooms. Consequently, there remains insufficient evidence concerning how IK-integrated instruction influences students’ conceptual understanding, classroom engagement, and attitudes toward Biology-related concepts within the General Science framework.

Gender Interaction Gap: The moderating role of gender in IK-based science instruction also remains inconclusive and underexplored. Some scholars argue that integrating Indigenous ecological practices into science education may enhance female students’ participation and confidence by validating women’s traditional roles in agriculture, herbal medicine, and environmental management (Workineh, 2010). However, empirical findings regarding gender differences remain inconsistent. While some studies report improved outcomes for female learners under culturally responsive approaches, others document higher male achievement or no statistically significant gender differences (Uduaka et al., 2020; Chibuye & Singh, 2024). Within the Ethiopian context, particularly at the middle school level, little empirical evidence exists regarding whether gender moderates the effects of IK-based instruction on students' achievement, engagement, and attitudes toward ecology and biodiversity conservation.

In response to these empirical, methodological, and contextual gaps, the present study investigates the effects of an IK-integrated instructional intervention on Grade 8 students' academic achievement, engagement, and attitudes toward ecology and biodiversity conservation. Focusing on biological concepts embedded within the Ethiopian General Science curriculum (MoE, 2018), the study seeks to determine whether culturally responsive instruction grounded in the ecological knowledge systems of the Awi community can enhance learning outcomes and reduce students' perception of Biology as an abstract or foreign subject.

Accordingly, a systematic quasi-experimental investigation is required to evaluate whether integrating the rich ecological heritage of the Awi community into classroom instruction can transform the prevailing transmissive and lecture-dominated teaching practices into a more meaningful, contextually relevant, gender-responsive, and academically effective science learning environment.

2.13 Theoretical framework

This research is theoretically grounded in a synthesis of Vygotsky's (1978) social constructivism and Ausubel's (1963) theory of meaningful learning. While constructivism provides the philosophical basis for knowledge acquisition through prior experience, these theories are operationalized here to provide a structured mechanism for integrating IK into Biology instruction. By bridging these frameworks, the study establishes a direct link between sociocultural mediation and measurable shifts in students' academic achievement, attitudes, and multi-dimensional engagement.

Vygotsky's (1978) theory serves as the primary reference point for investigating how sociocultural interactions facilitate cognitive growth. In this study, Vygotsky's principles are operationalized to address behavioral, emotional, and cognitive engagement through the following mechanisms: Vygotsky posited that learning is an internal developmental process catalyzed by interactions with more knowledgeable others (MKO) and peers (Onuoha, 2007). This study operationalizes this through an IK-based approach where students collect cultural insights from parents, caregivers, and elders (the MKO). This process transforms the student from a passive recipient into a proactive researcher. When students return to the classroom to exchange these insights during group discussions, they engage in peer learning, which directly correlates with different engagement levels (behavioral, emotional and cognitive) (Okebukola, 2020)

In this research, IK serves as the scaffolding tool. By utilizing the cultural tools of the local community (e.g., folktales and proverbs regarding ecological interdependence), the intervention assists students in navigating complex scientific reasoning that might otherwise be outside their current reach (Woolfolk, 2005). Vygotsky emphasized that community is essential to creating meaning. In this study, students' perception of Biology is measured by their ability to see science as a relatable, non-foreign entity. By validating their culture's intellectual tools, the intervention aims to shift student perceptions from science as western to science as a universal process reflected in local heritage.

David P. Ausubel's (1963) theory provides the cognitive mechanism for the study, specifically focusing on how the advance organizer impacts academic achievement and attitude. Meaningful learning occurs when new information is non-arbitrarily anchored to the learner's existing cognitive framework (Ausubel, 2012). This study operationalizes IK specifically traditional agricultural and ecological practices as advance organizers. These serve as the cognitive bridge that prepares the mind for new, abstract material (Gidena & Gibeyehu, 2017).

Comparative organizers are used to activate existing schemas. In this study, they are operationalized by asking students to contrast conventional scientific principles (e.g., nutrient cycling) with traditional practices (e.g., organic fertilization). This contrast helps students recognize scientific principles within their own heritage, leading to improved conceptual achievement (Dansu & Olateju, 2022). Expository organizers introduce new information by linking it to familiar concepts. During ecology instruction, unfamiliar ecological concepts were linked to familiar indigenous practices (e.g., using terrace farming to explain soil erosion control). This link reduces cognitive load and fosters meaningful learning (Okebukola, 2020).

Ausubel defines subsumption as the process of integrating new information into the existing cognitive hierarchy. This study measures achievement via a quasi-experimental pre-test and post-test design, where the "Subsumer" (IK) is expected to prevent rote learning. When learners encounter unfamiliar material without an anchor, they resort to rote memorization; by providing an IK anchor, this study aims to facilitate enduring cognitive structures that lead to higher achievement scores (Enekwechi, 2018).

Ausubel (2012) noted that meaningful learning is active and constructive. In this study, attitude is operationalized through students' self-reported interest and persistence. When students can connect new scientific ideas to familiar home practices, the perceived difficulty of the subject decreases, fostering a more positive affective response (Mukuka, 2019). The synthesis of these theories allows for a learner-centered shift from transmissive pedagogy to an inquiry-based, culturally grounded model (Emeagwali, 2003). The study operationalizes the theoretical framework through the following variable-measurement alignments (Table 1)

Table 1 : The interaction of theoretical principle and research variables in theoretical framework

Theoretical Principle	Research Variable	Operational Measurement
Scaffolding (Vygotsky)	Engagement	Engagement Scale scores; frequency of participation in IK-based group tasks.
Sociocultural Interaction (Vygotsky)	Perception	Qualitative perception interviews and observation on the "foreignness" vs. "relatability" of Biology.
Advance Organizers (Ausubel)	Achievement	Quantitative scores on the Ecology Achievement Test (EAT) focusing on Ecology and Biodiversity.
Meaningful Subsumption (Ausubel)	Attitude	Science Attitude questioner (EAQ) scores, measuring interest, motivation, and subject relevance.

Finally, this framework accounts for gender as a moderating variable. In Ethiopian culture, labor and knowledge are often gender-segregated (e.g., male-dominated plowing vs. female-dominated seed selection and medicinal plant use). Vygotsky’s theory emphasizes that culture dictates the development of cognitive skills (Westen, 1996). Therefore, this study investigates how IK-based instruction interacts with these gendered knowledge systems. By incorporating cultural practices that reflect both male and female expertise, the instructional model aims to provide an equitable cultural bridge, ensuring that both genders can navigate the complexities between their indigenous culture and the culture of school science.

This dual-theory approach ensures that the integration of IK is not merely a descriptive addition to the curriculum, but a fundamental restructuring of the cognitive and social processes within the classroom, aimed at rectifying the systemic underperformance identified in the problem statement.

2.14 Conceptual framework

The conceptual framework of this study illustrates the analytical nexus between culturally grounded pedagogy and multi-dimensional learning outcomes. Rather than viewing instructional delivery as a linear process, this framework posits that the integration of IK into Biology instruction functions as a catalytic intervention that restructures the cognitive and social architecture of the classroom. The model is built upon the interaction between the independent variable (IK-based instruction), the dependent variables (Academic Achievement, Engagement, Attitude, and perception), and the Moderating Variable (Gender).

The framework is operationalized through three primary analytical pathways: The Cognitive Pathway (Achievement): Rooted in Ausubelian subsumption, the framework suggests that IK-based instruction serves as a cognitive anchor. By utilizing Awi-specific ecological practices such as terrace farming and indigenous soil management as advance organizers, the intervention facilitates the non-arbitrary linkage of abstract biological concepts to existing mental schemas. This analytical link is expected to bypass the limitations of rote memorization inherent in conventional instruction, leading to enhanced conceptual mastery and academic achievement.

The affective pathway (Attitude and perception): drawing on culturally responsive pedagogy (Gay, 2018), the framework analyzes the shift in student attitude and perception as a byproduct of cultural validation. When students perceive their indigenous heritage as scientifically significant, the psychological foreignness of Biology is mitigated. The framework posits that this validation converts subject-matter alienation into intrinsic motivation and subject relevance.

The behavioral-social pathway (Engagement): applying Vygotskian social constructivism, the framework identifies engagement (behavioral, emotional, and cognitive) as an emergent property of sociocultural mediation (Vygotsky, 1978). By encouraging peer exchange of local knowledge, the instruction increases participation and investment.

A critical analytical component of this framework is the moderating variable of gender. Sociocultural and gender theories (Bandura, 1997; UNESCO, 2021) suggest that the cultural bridge provided by IK may be navigated differently by male and female students based on their traditional roles in Agew society. The framework does not assume a uniform impact; instead, it empirically tests whether the strength and direction of the instructional effect are conditioned by gender-segregated knowledge systems (e.g., male expertise in plowing vs. female expertise in seed selection). This analytical layer addresses the inconclusive evidence identified in previous studies (Nbina & Wagbara, 2012; Ugwu, 2016).

As depicted in Figure 1, the framework hypothesizes that IK-based instruction directly drives improvements across the dependent variables. However, this relationship is not direct but is mediated by the perceived relevance and cognitive accessibility of the content, and is moderated by gender-based classroom dynamics.

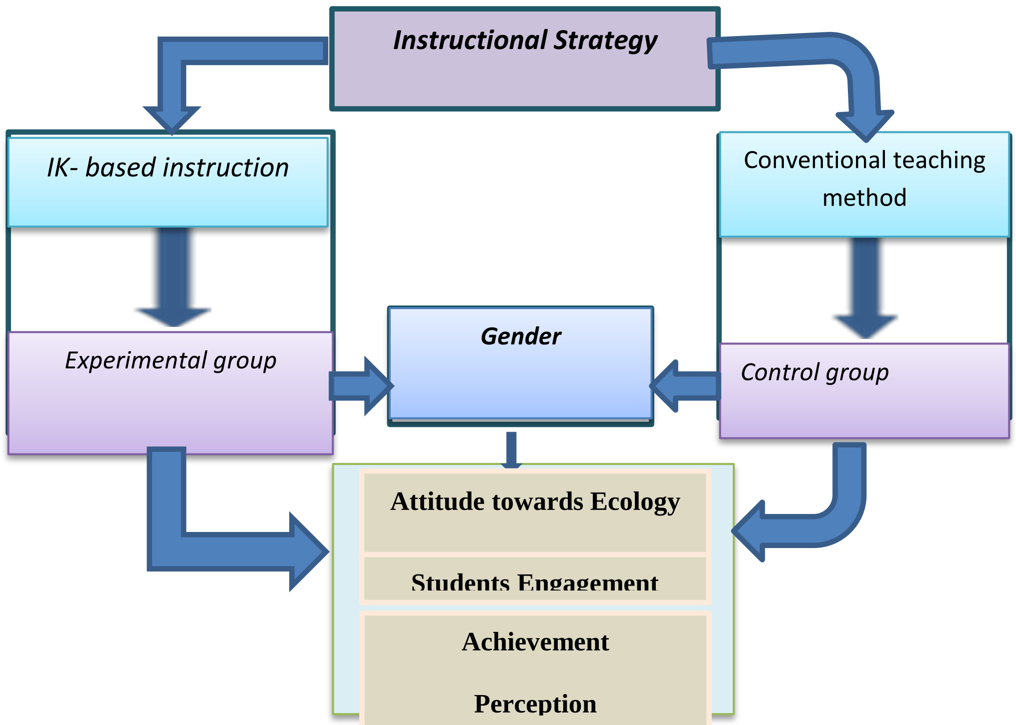

Figure 1 : Conceptual framework of the study

Summary of the review

This review synthesizes theoretical perspectives and empirical evidence on the integration of IK in Biology education. IK is conceptualized as culturally embedded scientific knowledge unique to specific communities, with significant potential to revitalize science education in Ethiopia and comparable contexts (Ngcobo, 2020; Zidny et al., 2020). Integrating IK into instruction supports learners' transition into western science, which is often perceived as foreign or contradictory to indigenous worldviews. This alignment facilitates knowledge reconciliation and reduces cognitive dissonance experienced by students when confronted with unfamiliar scientific paradigms (El Yazidi & Rijal, 2024).

The review highlights strong conceptual links between IK systems and western science, particularly in their shared focus on sustainability and holistic understandings of nature (Zidny et al., 2023). Embedding IK within science curricula therefore bridges epistemological divides and promotes inclusive, contextually relevant education (Ngcobo, 2020). By drawing on local materials, contexts, and cultural practices, IK-based instruction mitigates alienation, enhances engagement, and strengthens learners' scientific identity (Magni, 2017; Mavuru & Ramnarain, 2020).

Collectively, empirical evidence demonstrates that IK integration improves students' achievement, engagement, and attitudes toward Biology. These findings justify further investigation into curriculum design, teacher preparedness, and culturally responsive pedagogy to optimize learning outcomes (Anor et al., 2022; Govender & Mudzamiri, 2022). In conclusion, integrating IK into science education represents a transformative approach that reconciles diverse knowledge systems, enhances educational relevance, and supports sustainable development goals in culturally diverse contexts such as Ethiopia.

CHAPTER THREE: RESEARCH METHODOLOGY

Introduction

This chapter presents the fundamental approach and process the researcher utilized while conducting the research. It discusses the research paradigm, research approach, and study design. Additionally, it covers the area of study, the population, the sample and sampling methods, instrumentation, the validation of the instrument, reliability, the method of data collection, and the method of data analysis.

3.1 Research philosophy

According to Saunders et al. (2019), the research philosophy represents the foundational layer of the Research Onion, the set of beliefs and assumptions that guide how researchers understand reality, acquire knowledge, and interpret findings. It shapes the entire research process, influencing methodological choice, data collection, and analysis. This study adopts the pragmatic research philosophy, which emphasizes the practical application of knowledge and values research outcomes that solve real-world problems. Pragmatism rejects the rigid dichotomy between positivist objectivity and interpretivist subjectivity, instead advocating a flexible approach that integrates both quantitative and qualitative perspectives based on the nature of the research problem (Creswell & Clark, 2018; Saunders et al., 2019).

Pragmatism holds that knowledge is grounded in experience and action; truth is determined by what works in practice (Morgan, 2014). It recognizes that reality is not singular but multiple and dynamic, shaped by the interaction between individuals and their social, cultural, and physical environments (Simpson, 2018). This makes pragmatism particularly suited for educational research involving culturally embedded phenomena such as IK. In this worldview, knowledge is socially constructed and context-dependent, yet it can be empirically examined and tested for its practical consequences. Thus, pragmatism allows researchers to integrate scientific measurement and contextual interpretation within the same study (Andresen & Brink, 2013).

The present study, titled *"*The Effect of IK based Biology instruction on students' achievement, attitude, and engagement: A Gender based Analysis in Middle Schools of Injibara, Ethiopia*"*, seeks to explore how incorporating IK-based practices into Biology instruction affects students' academic performance, engagement, and attitudes toward ecology. These objectives inherently demand a philosophical stance that values both objective measurement (e.g., achievement, engagement, and attitude scores) and subjective measurements (eg. FGD and classroom observation). The pragmatic paradigm accommodates this dual need, making it the most appropriate foundation for the study's concurrent embedded mixed-methods design (QUAN+qual), where quantitative data are prioritized and qualitative insights are used to enrich and explain quantitative findings.

Pragmatism directly supports the study's aim of generating actionable insights into how IK-based instruction influences learning outcomes. It prioritizes practical problem-solving and contextual relevance, key aspects of educational innovation in developing countries like Ethiopia. The integration of IK in Biology instruction is not merely a theoretical exercise; it is a response to real pedagogical and cultural challenges such as students' disengagement, gender disparities, and the detachment of school science official curriculum from local realities. Pragmatism enables the researcher to combine empirical testing of instructional impacts (quantitative) with a nuanced understanding of participants' experiences (qualitative), aligning with the study's objectives

By adopting a pragmatic stance, the researcher acknowledges that the value of knowledge lies in its practical utility, in this case, improving teaching effectiveness, curriculum relevance, and inclusive learning outcomes. Pragmatism's orientation toward outcomes and contextual responsiveness ensures that the study findings will be applicable to real classroom settings, teacher training programs, and policy reform initiatives aimed at decolonizing Biology education in Ethiopia.

3.2 Research approach

According to Saunders et al. (2019), the second layer of the research onion concerns the research approach, which specifies the strategy used to connect philosophical assumptions with procedures of data collection and analysis. The approach determines whether a study proceeds deductively, inductively, or through a combination of both. In this study, a concurrent embedded mixed-methods approach was employed to investigate the effects of IK-based instruction on Grade 8 students' achievement, attitude, engagement, and perception toward ecology within

Injibara City middle schools (Figure 2). The adoption of mixed methods was not merely methodological preference; rather, it was necessitated by the complex and multidimensional nature of the research problem.

The study examined not only measurable learning outcomes such as academic achievement, but also affective and behavioral constructs including attitude, engagement, and students' perceptions toward IK-based instruction. Such educational phenomena are inherently complex and cannot be adequately understood through a single methodological tradition (Creswell & Clark, 2018). Quantitative methods alone could determine whether statistically significant differences existed between the experimental and control groups; however, they could not sufficiently explain how students experienced the instructional intervention, why engagement improved, or how cultural relevance shaped classroom participation. Conversely, relying solely on qualitative inquiry would provide rich contextual descriptions but would not generate the empirical statistical evidence required to establish the effectiveness of the intervention. Therefore, integrating quantitative and qualitative approaches enabled the study to capture both the measurable effects and the underlying classroom processes associated with IK-based instruction.

The use of mixed methods is further justified by the pragmatic philosophical orientation underpinning the study. Pragmatism rejects the rigid separation between positivist and constructivist paradigms and instead emphasizes the use of methods that best address the research problem (Morgan, 2014). Since the current investigation sought both to test the effectiveness of an instructional intervention and to understand students' lived classroom experiences, methodological pluralism became essential. Pragmatism allowed the researcher to combine objective measurement of learning outcomes with subjective interpretation of participants' experiences, thereby generating a more comprehensive understanding of the phenomenon under investigation.

Specifically, the study adopted a concurrent embedded mixed-methods design (QUAN+qual), in which the quantitative component served as the dominant strand while qualitative data were embedded to support and enrich the interpretation of quantitative findings (Tashakkori & Teddlie, 2010; Creswell, 2014). The quantitative strand employed a quasi-experimental pretest–posttest non-equivalent control group design to determine whether IK-based instruction produced significant differences in students' academic achievement, engagement, and attitudes compared to conventional teaching methods. Statistical procedures such as independent-samples t-tests and ANCOVA were used to establish the magnitude and significance of the intervention effects.

However, educational interventions operate within social and cultural contexts that cannot be fully understood through numerical data alone. Thus, the qualitative strand was incorporated to explore students' perceptions of IK-based instruction, classroom interaction patterns, and culturally mediated learning experiences. Through FGD and classroom observations, the researcher obtained deeper insights into how students connected ecological concepts with indigenous practices, how classroom participation changed during instruction, and how culturally familiar examples influenced motivation and emotional engagement. These qualitative findings complemented the quantitative results by explaining the mechanisms through which IK integration influenced learning outcomes.

Another important justification for employing mixed methods relates to triangulation. Using multiple sources and forms of data enhanced the credibility, validity, and completeness of the findings (Denzin, 2012). For example, improvements in engagement identified quantitatively through the EEQ were corroborated qualitatively through classroom observations showing increased participation, collaborative discussion, questioning behavior, and enthusiasm during IK-related activities. Similarly, statistical improvements in attitude scores were reinforced by students' verbal expressions during FGDs, where they described Biology as becoming more meaningful, familiar, and relevant to their daily lives. This convergence of evidence strengthened the trustworthiness of the study's conclusions.

The mixed-methods approach was also necessary because the study aimed to evaluate culturally responsive pedagogy, which inherently involves both observable outcomes and subjective human experiences. IK-based instruction is not simply a technical teaching strategy; it is a culturally situated pedagogical process involving identity, belonging, language, prior experience, and community knowledge systems. Quantitative measures could reveal whether students achieved higher scores, but qualitative inquiry was essential to capture whether students felt culturally validated, whether classroom relationships became more inclusive, and whether learners perceived Biology as less foreign and more connected to their lived realities. Therefore, the integration of both approaches allowed the researcher to address the cognitive, affective, social, and cultural dimensions of learning simultaneously.

Moreover, the concurrent timing of data collection provided methodological advantages. Collecting quantitative and qualitative data during the same intervention period enabled real-time comparison and integration of findings. While statistical data identified patterns and trends, qualitative evidence provided contextual explanations for those patterns. For instance, if the experimental group demonstrated significantly higher achievement scores, classroom observations and FGDs helped explain that improvement through themes such as collaborative learning, contextualized examples, cultural familiarity, and increased learner confidence. This simultaneous integration enhanced interpretive depth and produced a more holistic understanding of the instructional intervention.

Finally, the use of mixed methods increased the practical and policy relevance of the study. Educational policymakers and curriculum developers often require quantitative evidence demonstrating effectiveness before adopting instructional reforms. At the same time, teachers and practitioners need contextual and experiential evidence explaining how such interventions function in actual classroom settings. By combining statistical evidence with qualitative insights, the study generated findings that are both empirically rigorous and pedagogically meaningful. Consequently, the mixed-methods approach was considered the most appropriate design for addressing the research objectives and for producing a comprehensive evaluation of IK-based instruction within the Ethiopian middle school context.

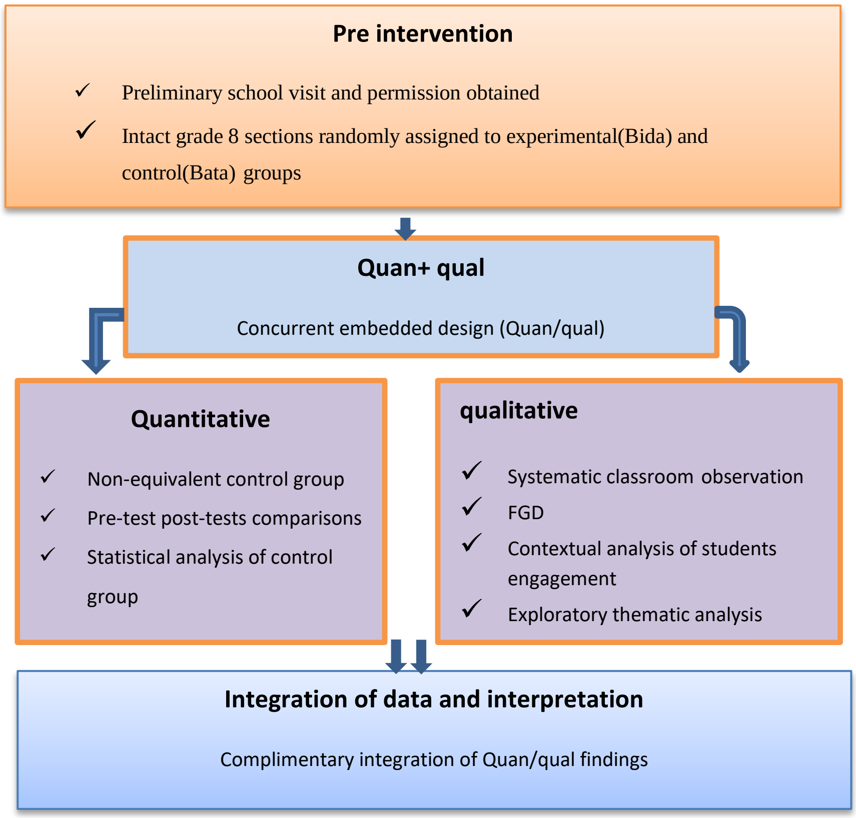

Figure 2 : Concurrent embedded mixed research design

3.3 Research design

The selection of a research design is a strategic bridge between theoretical inquiry and empirical evidence. Methodological choices are determined by the nature of the research problem, contextual realities, and the characteristics of the participants involved (Creswell & Clark, 2018; Saunders et al., 2019; Kelly & Cordeiro, 2020). To investigate the instructional effect of IK-based pedagogy on students' achievement, attitude, engagement, and perception in ecology, this study employed a quasi-experimental non-equivalent pretest–posttest control group design, as summarized in Table 2.

Although randomized controlled trials are widely regarded as the strongest design for establishing causal relationships, their application in school-based educational research is often constrained by ethical, administrative, and practical limitations (Cohen et al., 2018). In a true experimental design, students must be randomly assigned to treatment and control conditions. However, such randomization was not feasible in the present study because Grade 8 students in

Injibara City schools were already organized into intact classroom sections according to school administrative arrangements. Reassigning students randomly would have disrupted existing instructional schedules, classroom organization, and school routines. Moreover, separating students from their established peer groups for experimental purposes could have created ethical concerns related to fairness, emotional comfort, and equal instructional access.

A quasi-experimental approach was therefore considered more appropriate because it allows the researcher to examine instructional effects within naturally existing educational settings while preserving the authenticity of classroom processes (Best & Kahn, 2006). Unlike laboratory-based randomized experiments, quasi-experimental designs maintain ecological validity by studying teaching and learning under real school conditions where instructional interactions occur naturally (White & Sabarwal, 2014). Since the purpose of this study was to evaluate the practical effectiveness of IK-integrated instruction in actual middle school classrooms, preserving the natural educational environment was methodologically important.

The decision to employ a quasi-experimental design was also influenced by the nature of the intervention itself. IK-based instruction depends heavily on classroom culture, social interaction, language use, and locally grounded learning experiences. These contextual elements are difficult to isolate under the rigid controls required in randomized experiments. Implementing the intervention within intact classrooms enabled students to engage collaboratively with culturally familiar ecological practices and discussions in ways that reflected authentic classroom realities. Consequently, the design enhanced the contextual relevance and practical applicability of the findings.

Furthermore, educational researchers argue that quasi-experimental designs are particularly suitable when the objective is to evaluate instructional innovations in real-world school contexts rather than under artificially controlled conditions (Shadish et al., 2002). The present study sought to determine whether IK-based pedagogy could function effectively within ordinary Ethiopian middle school classrooms characterized by existing curricular structures, teacher practices, and sociocultural dynamics. Thus, the quasi-experimental design provided a balance between methodological rigor and contextual realism.

Nevertheless, the use of non-equivalent groups introduces potential threats to internal validity, especially selection bias, because participants are not randomly assigned (Campbell & Stanley, 1963). Students in the experimental and control groups may differ in prior achievement, motivation, or classroom behavior before the intervention begins. To minimize these threats and strengthen the credibility of the findings, several methodological controls were implemented.

First, pretests were administered to both groups before the intervention to establish baseline equivalence regarding academic achievement, engagement, and attitude toward ecology. The pretest results enabled the researcher to determine whether substantial initial differences existed between groups prior to treatment implementation.

Second, ANCOVA was employed during data analysis to statistically control for pre-existing differences between the groups. By treating pretest scores as covariates, ANCOVA adjusted posttest means and isolated the effect of the IK-based instructional intervention from variations attributable to prior learner characteristics (Field, 2018; White & Sabarwal, 2014). This statistical adjustment strengthened the internal validity of the study despite the absence of randomization.

Third, efforts were made to ensure reasonable comparability between the experimental and control conditions. The selected schools shared similar curricular structures, student socioeconomic backgrounds, language contexts, and administrative arrangements. Both groups consisted of Grade 8 students with relatively comparable class sizes and gender distributions. In addition, teachers assigned to each condition possessed similar academic qualifications, Biology specialization backgrounds, and teaching experience to reduce potential teacher-effect bias.

The quasi-experimental design was also preferred over randomized controlled trials because of concerns regarding contamination and treatment diffusion. In educational environments, students interact frequently inside and outside classrooms, making strict experimental isolation difficult. Rather than randomly assigning students within the same school to different instructional treatments, the study used separate intact classes from different schools to reduce interaction-related contamination while still maintaining realistic educational conditions.

Although quasi-experimental designs do not provide the same level of causal certainty as randomized controlled trials, they remain among the most robust and widely accepted approaches in educational intervention research where randomization is impractical (Fraenkel et al., 2019). The design permits cautious but meaningful interpretation of instructional effects by combining statistical controls with authentic classroom implementation.

Accordingly, the non-equivalent pretest–posttest control group design was considered the most suitable methodological option for this study because it enabled the researcher to examine the effectiveness of IK-based ecology instruction under real educational conditions while balancing ethical considerations, administrative feasibility, and methodological rigor. The design therefore provided a practical and contextually appropriate framework for evaluating how IK-integrated pedagogy influences students' academic achievement, engagement, attitudes, and perceptions within the Ethiopian middle school context.

Table 2: Structure of the quasi-experimental research design

Group	Pretest (O1)	Intervention (X)	Posttest (O2)
Experimental Group(Bida)	O1	X	O2
Control Group(Bata)	O1	—	O2

O_1 (Pretest): Measures of ecology achievement, engagement, and attitude administered prior to the intervention.

X (Intervention): Instruction integrating Indigenous Knowledge with formal Biology content on ecology and biodiversity conservation.

O_2 (Posttest): Measures of ecology achievement, engagement, and attitude administered after intervention.

3.4 Study Area description and indigenous knowledge Systems

This study was conducted in Injibara, the capital city of Awi Zone of the Amhara Region, Ethiopia. The Awi Zone is one of twelve administrative divisions within the region, bordered by West Gojam to the south and east, West Gondar to the north, and the Benishangul Gumuz region, as well as Sudan to the west. The research specifically focuses on Bida and Bata middle schools, which are under the authority of the Injibara city administration, situated in northwestern Ethiopia. Injibara is approximately 447 kilometers from Addis Ababa, the Ethiopian capital, and 118 kilometers from Bahir Dar, the seat of the Amhara regional state. Geographically, Injibara is positioned at 10°59'N and 36°55'E, with altitudinal variation between 2,540 meters and 3,000 meters above sea level (Zenebe, 2009).

The population of Injibara predominantly comprises individuals of Awi ethnic ancestry. The Awi, a subgroup within the broader Agew community, possess a distinct ethno-linguistic heritage historically associated with the Zagwe dynasty (Bahru, 2002; Finneran, 2007). The majority of the population speaks Agewigna, the language of the Awi people, which serves not only as a primary means of communication but also as a medium of instruction in primary schools within the zone. Beyond its educational function, Agewigna embodies and transmits indigenous ecological knowledge, cultural values, and traditional environmental practices across generations (Abbute, 2002). Over generations, Awi IK has evolved through sustained interaction with the local environment, encompassing a detailed understanding of natural resources, agricultural systems, and environmental management practices developed through empirical observation and collective experience (Asmare et al., 2021; Tadesse & Mehari, 2020).

Awi indigenous ecological knowledge is notably robust concerning biodiversity conservation and ecosystem management. As described by the Itse-Komole Cultural Medicinal Plant Growth and Conservation Association (IKMPGCA, 2001), traditional Awi practices promote sustainable interactions between people and their environment, thereby mitigating ecological disturbances and maintaining ecological equilibrium. The Awi people are especially recognized for their successful afforestation and reforestation initiatives, extensive use of composting, organic farming, and terracing, all of which have significantly curtailed soil erosion and water conservation. These practices have enabled the community to maximize land productivity while preserving environmental integrity (IKMPGCA, 2001).

Furthermore, the Awi possess sophisticated indigenous irrigation systems. For instance, local farmers have developed methods to divert streams using grooved logs and temporary structures assembled from organic debris and tree branches (Personal Communication, 2023). The community is also highly regarded for its traditional medicinal knowledge, employing plant-based remedies for both human and animal health (IKMPGCA, 2001).

Key indigenous agro-ecological practices in the Awi Zone include shifting cultivation, intercropping, minimal tillage, agroforestry, home gardening, and the conservation of sacred groves. Shifting cultivation, in particular, facilitates the sustainable management of agro biodiversity by cyclically utilizing the fertility of natural vegetation-soil complexes and conserving forest ecosystems, thereby safeguarding associated resources such as soil, water, and wildlife (Tizita, 2016). The integration of these techniques with additional land management methods has contributed to enhanced agricultural yields and environmental sustainability among the Awi community.

The Awi also demonstrate advanced ethno-biological knowledge, including the classification and utilization of soils, plants, animals, and microorganisms. For example, they designate 'Tikurafer' (black soil) as optimal for cultivating staple crops like teff and potatoes. Soil fertility assessments are conducted using sensory evaluation, including visual inspection and olfactory cues, to detect the presence of beneficial microorganisms such as decomposing bacteria (Nefisatka). The Awi also harness local biological resources, such as bamboo, in traditional craftsmanship, producing utilitarian items including umbrellas and household furniture.

Despite its richness and scientific relevance, Awi IK is insufficiently integrated into formal Biology education curricula. This knowledge gap underscores the necessity for systematic documentation, preservation, and curricular incorporation to ensure its transmission to future generations and to enhance culturally responsive Biology education (IKMPGCA, 2001; Tizita, 2016).

3.5 Sampling technique and procedures

The target population consisted of all primary and middle schools in Injibara City, which included six private and twelve government schools. The selection of Injibara City Administration as the research site was purposive, reflecting the researcher's familiarity with the local sociocultural context and prior professional experience in the area. Such purposive site selection is methodologically appropriate when contextual understanding enhances interpretive accuracy and when resource and logistical constraints limit random site selection (Ghosh, 2006). The city's rich Awi IK traditions, particularly in ecology and agriculture, also made it an ideal location for examining the integration of IK into Biology instruction.

Private schools were excluded from the study due to structural and pedagogical differences that could introduce confounding variables (Figure 3). As to my personal observation compared with government schools, private schools in Injibara possess superior instructional facilities, employ more highly qualified teachers, and use selective admission processes. They also provide supplementary subjects, including supplementary Mathematics, spoken English, and supplementary Science, which are not part of the standard national curriculum in government schools. These disparities in resources and student background would have threatened the internal validity of the quasi-experimental comparison; therefore, only government schools were retained for sampling.

From the twelve government schools, four schools were excluded based on contextual and logistical considerations. Two schools—Basa and Hidase—were excluded due to security issues during the data collection period, which could have disrupted the intervention's implementation. The other two schools—Kosober and Bahunk—were excluded because they were located in downtown Injibara and served student populations differing markedly in socioeconomic background and access to school resources compared with other schools. Excluding these schools helped maintain comparability among the remaining schools and minimized potential confounding effects. Consequently, eight government schools with relatively similar learner profiles, teacher qualifications, and access to Awi IK were identified as eligible.

A two-stage sampling procedure was then employed. In the first stage, the eight eligible government schools were subjected to simple random selection using a lottery method. The names of the schools were coded, written on identical slips of paper, mixed thoroughly, and drawn blindly. Through this procedure, Bida and Bata middle schools were randomly selected as the study sites. Random selection at the school level enhanced external validity and reduced selection bias, ensuring that each eligible school had an equal chance of inclusion.

In the second stage, sampling was conducted within schools at the classroom (cluster) level. In accordance with the nature of quasi-experimental research, intact Grade 8 classes were used to prevent disruption to established classroom structures and instructional routines. Quasi-experimental designs typically employ intact groups rather than randomly assigning individual participants because educational interventions are implemented in natural classroom contexts (Creswell & Guetterman, 2019). This approach preserves the ecological validity of the research while ensuring that all students within a given classroom experience the same instructional conditions.

Among the available Grade 8 sections, one class from each school was randomly assigned to either the experimental or control condition. Grade 8 Section "C" from Bida School was assigned as the experimental group, receiving instruction through the IK–based teaching method, while Grade 8 Section "A" from Bata School served as the control group, taught through conventional methods. This cluster randomization process (randomly assigning intact groups rather than individuals) is considered appropriate for school-based quasi-experimental research, as it minimizes contamination between treatment and control participants while maintaining the integrity of existing classroom arrangements (Creswell & Clark, 2018).

A total of 89 Grade 8 students participated in the study, comprising 44 females and 45 males. The control group included 46 students (51.7%), and the experimental group included 43 students (48.3%). This relatively balanced distribution of participants ensured gender representation and enhanced comparability between groups in evaluating the effects of the IK-based instructional approach on students' learning outcomes.

Grade 8 was deliberately chosen as the focus group because it represents a transitional academic stage between primary and secondary education. At this level, students begin to engage with more abstract scientific concepts, exhibit greater cognitive maturity, and develop increasing independence in learning. Research indicates that early adolescence is a critical period during which learners' engagement, motivation, and attitudes toward science undergo significant shifts (Meece, 2003). Grade 8 students, therefore, provided a developmentally appropriate cohort for assessing the impact of IK-based instruction on achievement, engagement, and attitude in ecology-related topics.

For the qualitative component, purposive intensity sampling was employed to select twelve participants (six males and six females) from the experimental group for FGDs. Participants were selected based on their post-intervention achievement scores to ensure representation from high-achieving learners across both genders. This strategy aimed to obtain rich, reflective insights from students who demonstrated the highest level of cognitive engagement with the IK-based instruction (Patton et al., 2015).

However, it is vital to explicitly acknowledge that selecting only high-achieving students introduces a potential selection bias. By focusing on this subgroup, the qualitative findings may represent an optimal case scenario, potentially overlooking the challenges or perceptions of students who struggled with the integration of indigenous and formal scientific frameworks. This limitation means the qualitative data reflects the experiences of those with high academic self-efficacy and may not be fully generalizable to the entire student cohort.

Despite this, the tiered integration of purposive site selection, random school and cluster assignment, and purposive FGD selection maintained methodological rigor by balancing ecological validity with the need for detailed, articulate perceptions (Creswell, 2014). Acknowledging this bias ensures transparency, situating the FGD results as an in-depth exploration of the intervention's potential among the most engaged learners while maintaining the study's overall validity within a quasi-experimental mixed-methods framework.

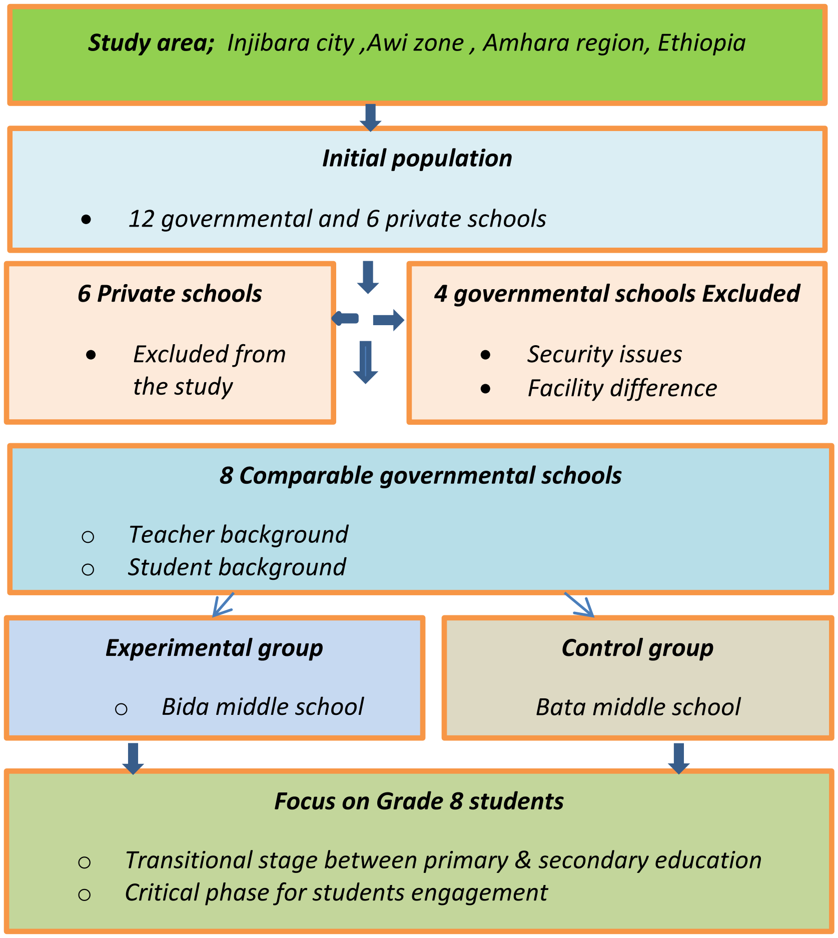

Figure 3 : Sampling procedures

3.6 Variables

Independent Variables: The primary independent variable in this study was the teaching method. Two distinct instructional strategies were employed across the research groups for comparative analysis: the experimental group received instruction in ecology concepts through an IK-based approach, wherein IK was explicitly integrated as a foundation for learning. By contrast, the control group was exposed to a conventional teaching strategy, relying on standard pedagogical methods without the explicit inclusion of IK. These instructional methods were intentionally manipulated in order to assess their impact on a range of student outcomes, specifically achievement in ecology, levels of engagement, perceptions, and attitudes towards ecology.

Dependent Variables: The dependent variables in this investigation refer to those outcomes hypothesized to be influenced by the manipulation of teaching methods. Specifically, this study focused on four dependent variables: students' achievement in ecology, engagement in learning activities, perceptions of ecology, and attitudes towards the ecology. Measurement of these variables enabled the evaluation of how the distinct instructional strategies (IK-based versus conventional teaching) influenced students' educational experiences and outcomes in ecology.

Moderating Variable: Gender was identified as a moderating variable in this study. Although not considered an independent variable, gender (categorized as male and female) has the potential to influence the dependent variables and, consequently, the study's results. This variable was acknowledged in the research design to account for its possible moderating effects on the relationship between teaching methods and student outcomes. The link between analytical function and category of each variable is summarized in Table 3

Table 3: Variable category and analytical function in the framework

Variable Category	Variable Name	Analytical Function in the Framework
Independent (IV)	IK-Based Instruction	The pedagogical driver; provides cognitive and cultural scaffolds.
Dependent (DV)	Academic Achievement	Measured outcome of meaningful subsumption and conceptual clarity.
Dependent (DV)	Student Engagement	Measured outcome of social interaction and identity validation.
Dependent (DV)	Student Attitude	Measured outcome of perceived relevance and self-efficacy.
Dependent (DV)	Students Perception	Measured perception of students about IK–based instruction
Moderating	Gender	The conditional filter that influences the magnitude of the IV to DV relationship.

3.7 Data gathering instruments

A careful selection of appropriate data collection tools is essential to enhance the reliability, validity, and overall robustness of the research outcomes. In this study, five instruments were employed to capture both quantitative and qualitative data: the ecology achievement test (EAT), the ecology attitude questionnaire (EAQ), the ecology engagement questionnaire (EEQ), FGDs, and Classroom Observation Checklists. These instruments were designed to align with the study objectives and were administered in English (EAT) and Awngi (EAQ & EEQ) to ensure linguistic accessibility and conceptual clarity for all participants. Translating the tools into local languages minimized language-related measurement error, particularly for attitudinal and engagement items that rely heavily on nuanced understanding.

Each instrument was carefully adapted and developed to ensure validity, reliability, and alignment with the research objectives and the Grade 8 Biology curriculum. The following section details the construction, validation, and reliability of each tool.

3.7.1 Ecology achievement test (EAT)

The EAT was developed by the researcher as a standardized and curriculum-aligned instrument to assess Grade 8 students' understanding of ecology concepts taught during the intervention period. The test was specifically designed to measure the cognitive learning outcomes associated with the ecology units contained in the Ethiopian Grade 8 General Science curriculum. The instrument was intended to evaluate students' conceptual understanding before and after exposure to IK-based instruction and conventional teaching approaches.

The development of the EAT was guided by the learning competencies and performance indicators specified in the Ethiopian Grade 8 General Science syllabus and textbook. The test covered major ecological concepts, including ecosystem structure and function, biotic and abiotic interactions, food chains and food webs, biodiversity, environmental conservation, nutrient cycling, and ecological balance. To ensure balanced representation of content areas and cognitive demands, the researcher prepared a detailed table of specifications (blueprint) based on Bloom's revised taxonomy of cognitive objectives (See Appendix B).

The blueprint ensured alignment between curriculum objectives, instructional content, and assessment items by distributing questions across different cognitive levels: remembering, understanding, applying, and analyzing. This approach minimized content underrepresentation and enhanced the validity of the instrument.

The EAT consisted of 25 multiple-choice items with four response alternatives each. Every item carried four marks, yielding a total possible score of 100 points. The use of multiple-choice items was considered appropriate because it allowed objective scoring, broad content coverage, and efficient assessment of different cognitive skills within the available instructional time.

The distribution of items across Bloom's cognitive levels was intentionally structured to measure both lower-order and higher-order thinking skills. Items at the remembering and understanding levels assessed students' factual and conceptual knowledge of ecological principles, while application and analysis items evaluated students' ability to relate scientific concepts to environmental situations and indigenous ecological practices encountered in their local context.

Both pretest and posttest versions of the EAT contained the same content coverage and cognitive distribution. However, the sequence of questions and response options was rearranged in the posttest version to minimize recall bias and reduce test familiarity effects. The pretest established baseline equivalence between the experimental and control groups before the intervention, whereas the posttest measured learning gains after the six-week instructional treatment.

To ensure validity, the initial item pool was subjected to face and content validation by experts. The validation panel included the researcher's advisors, two experienced Biology teachers, and one specialist in measurement and evaluation from Injibara college of teachers' education (ICTE). The reviewers examined the instrument for curriculum alignment, clarity of language, appropriateness of distractors, representativeness of content, and cognitive balance across Bloom's taxonomy. Suggestions provided during the review process were incorporated into the final version of the test.

A pilot study was conducted using 36 Grade 8 students from a school outside the actual study area but with similar socio-educational characteristics. The pilot testing helped identify ambiguous items and estimate item difficulty and discrimination indices. Items with poor discrimination power or unclear wording were revised accordingly.

The internal consistency reliability of the EAT was estimated using the Kuder–Richardson formula 20 (KR-20), which is appropriate for dichotomously scored multiple-choice items (Cohen et al., 2018). The reliability analysis yielded a coefficient of 0.83, indicating high internal consistency and suggesting that the instrument was sufficiently reliable for measuring students' achievement in ecology concepts. This value exceeds the minimum acceptable reliability threshold of 0.70 recommended in educational research (Fraenkel & Wallen, 2009).

Overall, the blueprint-guided development process, expert validation, pilot testing, and reliability analysis collectively strengthened the psychometric quality of the EAT and ensured that the instrument adequately measured the intended learning outcomes of the study.

3.7.2 Ecology attitude questionnaire (EAQ)

The EAQ was adapted from Mukuka (2019) and designed to measure students' attitudes toward ecology and biodiversity conservation within the context of IK-based instruction. The instrument consisted of 25 items rated on a five-point Likert scale, with response options ranging from Strongly Agree (SA) = 5 to Strongly Disagree (SD) = 1. Positive statements were scored from 5 to 1, whereas negatively worded items were reverse-coded to maintain consistency in interpretation. Since the scale ranged from 1 to 5, a cut-point mean score of 3.00 was used to interpret students' attitudes. Mean scores below 3.00 indicated unfavorable or low attitudes toward ecology and IK-based Biology instruction, whereas mean scores of 3.00 and above reflected favorable or positive attitudes toward ecology and IK-based Biology instruction.

The EAQ was administered to both experimental and control groups during the pre-test and post-test phases to measure changes in students' affective dispositions following the intervention. Because language barriers can substantially influence attitudinal responses, the questionnaire was translated into Awngi, the mother tongue of the students in these schools, and administered in this language. The translation process followed the forward–backward translation procedure to preserve conceptual equivalence and ensure linguistic clarity. The English version of the questionnaire was first translated into Awngi by bilingual experts familiar with Biology education terminology. A separate translator, unaware of the original wording, then back-translated the Awngi version into English. The two English versions were compared, and discrepancies were resolved through consensus among the translators and subject experts. This process minimized the risk of misinterpretation and ensured that students comprehended each item in its intended meaning, thus enhancing the accuracy and validity of attitudinal data.

The face and content validity of the EAQ were established through expert evaluation by the researcher’s academic advisors and two experienced Biology teachers from Injbara teachers Education College. These reviewers assessed the instrument’s clarity, age appropriateness, and cultural relevance. Reviewers suggested rewording ambiguous phrases, removing redundant items, and contextualizing certain statements to reflect classroom realities and local ecological practices. Based on these recommendations, items were revised to improve linguistic simplicity, contextual relevance, and conceptual precision, resulting in a more refined and content-valid tool.

Prior to the main data collection, the EAQ was piloted with a sample of 36 Grade 8 students from a neighboring middle school that was not included in the main study. The pilot test aimed to assess item clarity, internal consistency, and contextual appropriateness within the local setting. The pilot data were analyzed using Cronbach’s alpha (α) to estimate internal consistency reliability, yielding a coefficient of $\alpha = 0.79$.

According to methodological standards (Field, 2018), a Cronbach’s alpha coefficient between 0.70 and 0.90 is considered acceptable for social science research. Therefore, the obtained value of 0.79 demonstrates good reliability, indicating that the EAQ items were sufficiently interrelated to measure a coherent construct, students’ attitudes toward ecology, without being redundant. Cronbach’s alpha was appropriate for this instrument because it is specifically designed to assess internal consistency for Likert-scale items, where each statement reflects an aspect of a common underlying construct. Given that the EAQ employed multiple ordinal items designed to capture different dimensions of students’ ecological attitudes, Cronbach’s alpha provided a suitable and statistically sound estimate of reliability.

3.7.3 Ecology engagement questionnaire (EEQ)

The EEQ was adapted from Pierre (2022) and designed to measure students' engagement in ecology learning, particularly within the context of IK–based instructional practices. The EEQ comprised 25 items rated on a five-point Likert scale, with response categories ranging from Strongly Agree (5) to Strongly Disagree (1). Positively phrased items were scored from 1 to 5, whereas negatively phrased statements were reverse-coded to maintain scoring consistency. Higher mean scores indicated stronger engagement levels in ecology and biodiversity lessons.

The EEQ was administered to both the experimental and control groups during pretest and posttest phases to assess changes in students' engagement following the instructional intervention. Because engagement is an affective and behavioral construct highly sensitive to linguistic nuance and contextual interpretation, the questionnaire was administered in Awngi, the mother tongue of all the study participant students. Administering the EEQ in the local language helped minimize misinterpretation of attitudinal and emotional expressions that might occur if students were asked to respond in Amharic or English.

The face and content validity of the EEQ were evaluated by academic advisors and two experienced biology teachers who were familiar with both the Grade 8 ecology curriculum and IK pedagogical principles. The reviewers assessed each item's clarity, age appropriateness, cultural relevance, and alignment with the study's learning objectives. Feedback resulted in revisions that included rewording ambiguous statements, merging overlapping items, and contextualizing examples to reflect local ecological practices such as terrace farming, composting, and biodiversity conservation. These modifications enhanced the content validity and contextual relevance of the instrument, ensuring that it effectively captured the behavioral, emotional, and cognitive dimensions of engagement in IK-based biology instruction.

Before the main data collection, the EEQ was piloted with 36 Grade 8 students from a neighboring middle school not included in the main study. The pilot test aimed to evaluate the clarity, internal consistency, and contextual appropriateness of the questionnaire items. Responses from the pilot were analyzed using Cronbach's alpha, which yielded a coefficient of $\alpha = 0.81$.

According to methodological standards (Field, 2018), Cronbach's alpha values between 0.70 and 0.90 indicate acceptable to high internal consistency reliability for instruments measuring psychological or educational constructs. Therefore, the obtained alpha value of 0.81 confirms that the EEQ demonstrated good reliability, suggesting that the items consistently measured related aspects of engagement without redundancy. Cronbach's alpha was the most appropriate reliability estimate for this instrument because it is specifically designed to assess internal consistency among Likert-scale items, each representing a facet of a unidimensional latent construct.

3.7.4 Focus group discussion (FGD)

To complement the quantitative data and provide deeper insight into students' perceptions of IK–based instruction, FGDs were conducted following the classroom intervention. The FGDs served as a qualitative data collection method designed to explore students' experiences, interpretations, and reflections on how the integration of IK influenced their engagement, attitudes, and understanding of ecology and biodiversity conservation. This approach aligns with Creswell and Clark's (2018) recommendation that qualitative data in mixed-methods studies be used to elaborate, interpret, and explain quantitative results, thereby enhancing the overall validity and contextual depth of the findings.

Seven item semi-structured FGD guide, titled IK based instruction discussion Guide, was adopted and modified by the researcher to direct the discussion process. The guide was initially prepared in English to align with academic and conceptual precision and subsequently translated into Awngi, the native language of the students in Injibara city. Conducting the FGDs in Awngi ensured that participants could freely and accurately express their thoughts, emotions, and experiences without linguistic barriers.

A total of 12 students (six males and six females) from the experimental group participated in the FGDs. Participants were purposively selected based on their post-intervention performance on the EAT, ensuring that high-achieving students were included. This selection strategy was intentional, as high-achieving students were expected to articulate their learning experiences with greater clarity and reflection, while balanced gender representation ensured inclusivity and the potential to capture gender-based differences in perception (Krueger & Casey, 2015).

Each FGD session involved six participants and was conducted in a quiet classroom setting within the experimental school to encourage open and comfortable interaction among participants. Two separate FGDs were organized to maintain manageability and promote active participation. Each session lasted approximately 90 minutes. The researcher served as the moderator and guided the discussions using semi-structured, open-ended questions aligned with the study objectives.

With participants' consent, all discussions were audio-recorded to ensure the accuracy and completeness of the data collected. In addition to the audio recordings, field notes were taken during each session by a trained research assistant to capture participants' non-verbal expressions, group dynamics, and key discussion points that might not be fully reflected in the recordings. The combined use of audio recording and note-taking enhanced the credibility and dependability of the qualitative data.

3.7.5 Classroom observation

To triangulate the quantitative and qualitative findings, systematic classroom observations were conducted in both the control and experimental groups throughout the intervention period. Observations focused on the students' behavioral, emotional, and cognitive engagement, and teacher–student interactions.

A structured classroom observation checklist was adapted and contextualized from existing instruments used in educational engagement studies (Cohen et al., 2018) to align with the objectives and context of the present study. Rather than being entirely developed by the researcher, the instrument was modified to reflect the instructional features of IK-integrated Biology classrooms. The checklist included clearly defined indicators of student engagement and classroom interaction, such as participation in group activities, attentiveness during lessons, questioning behavior, collaboration with peers, and responsiveness to IK-based instructional examples. The adapted instrument was reviewed by experts in science education and educational measurement to ensure contextual relevance and content appropriateness for the study setting.

Observations were non-participant in nature, meaning that the researcher did not interfere with instructional activities. This approach was selected to reduce the Hawthorne effect, where participants alter their behavior due to awareness of being observed, and to capture naturalistic classroom interactions (Creswell & Clark, 2018).

A total of 12 observation sessions were conducted in participating schools (six in the experimental group and six in the control group). Each session lasted 40 minutes, corresponding to an instructional period in the participant middle school timetable. The observations were conducted over the six-week intervention period, covering different stages of the instructional sequence (introduction, concept development, and review stages).

The experimental group was observed while being taught through the IK–based instructional approach, which emphasized contextualized ecological examples (such as terrace farming, and composting). The control group was observed during conventional teacher-centered lessons, which relied primarily on textbook explanations and lecture-based instruction.

During each session, the observers systematically recorded student behaviors, teacher–student interactions, and instructional methods using the observation checklist and detailed field notes. Particular attention was given to how students responded to local IK examples, their participation in discussions, and the emotional tone of the classroom.

To enhance objectivity and reliability, two trained observers independently conducted the classroom observations. Both observers were experienced Biology teachers fluent in Awngi and English, enabling accurate interpretation of classroom interactions, instructional language, and student behaviors. Prior to the actual observations, the observers participated in a training and calibration session designed to standardize their understanding of the observation checklist, scoring procedures, and operational definitions of each indicator.

During data collection, each observer completed the checklist independently to minimize observer bias. After each observation session, the ratings from both observers were compared to assess consistency. In cases where minor discrepancies occurred, the observers reviewed the relevant observation notes together and reached consensus through discussion based on the predefined checklist criteria. Where agreement could not be immediately achieved, the researcher moderated the discussion and made the final decision using the operational definitions established during the training phase. The final observation scores and qualitative notes used for analysis were therefore based on consensus ratings, thereby improving the reliability and credibility of the classroom observation data.

3.8 Pilot study

A pilot study was conducted at non-participating school with similar characteristics to the study sample. The primary objectives were to assess the difficulty and discrimination guides of the test items as well as to establish the reliability and validity of the research instruments prior to their implementation in the main intervention. Consistent with the recommendations of Morris and Cohen (2008), a pilot test serves as a preliminary study that enables the researcher to identify the strengths and limitations of the instruments, to determine the internal consistency and reliability of questionnaire items, and to estimate the time required for participants to complete each instrument. Moreover, piloting facilitates the evaluation of whether the intended respondents can comprehend and adequately respond to the items.

3.8.1. Piloting the instruments

The pilot testing encompassed the EAT, the EEQ, and the EAQ. These instruments were administered to a cohort of 36 Grade 8 students who were not included in the main study sample. The data derived from this pilot group were subsequently subjected to item analysis and reliability assessment (Table 4).

The reliability of the EAT was evaluated using the Kuder–Richardson Formula 20 (KR-20), resulting in a coefficient of 0.83, which signifies a high level of reliability for this instrument. For the engagement and attitude questionnaires, reliability was determined utilizing Cronbach's alpha. The EEQ produced an alpha coefficient of 0.81 and the EAQ 0.79, both indicating good internal consistency (Boopathiraj & Chellamani, 2013).

Item difficulty, defined as the proportion of students who answered a given item correctly, was calculated for each test item. An optimal item difficulty index (p-value) ranges from 0.3 to 0.7, where values below 0.3 denote difficult items and values above 0.7 indicate easy items (Boopathiraj & Chellamani, 2013). In this study, the ecology achievement test exhibited an average difficulty index of 0.4, suggesting a moderate level of difficulty for the sample group

(Table 4). Most items fell within the recommended range, although several were revised following analysis.

Item discrimination reflects an item's efficacy in distinguishing between high- and low-achieving respondents. According to Allen and Yen (2001), a discrimination index of 0.3 or above is generally acceptable, with values above 0.4 considered desirable , and values from 0.25 to 0.39 judged as good, while values at or above 0.4 are excellent (Singamaneni, 2011). The mean item discrimination for the ecology achievement test was above 0.3, indicating adequate discriminative power. Items not meeting the minimum thresholds—specifically, items 5, 16, and 28 with difficulty indices below 0.3, and items 16, 22, 28, and 30 with discrimination indices below 0.2 were removed.

Based on these analyses, items 5, 16, 22, 28, and 30 were excluded from the final version of the achievement test. Consequently, a revised 25-item ecology achievement test demonstrated to be reliable and valid was adopted for administration to both the intervention and control groups in the main study.

Table 4: Item difficulty (P) and discrimination index (D) for ecology achievement test

Test item type	**Difficulty indices (p)**	**No. of items**	**Discrimination indices (D)**	**No. of items**
Ecology Achievement test	(0.4 < P < 0.7)	23	D > 0.4	2
	(0.3 < P < 0.4)	4	0.3 < D > 0.39)	19
	(0.2 < P < 0.29)	3	(0.2 < D < 0.29)	5
	(P < 0.2)	0	(D < 0.2)	4
	Mean = 0.4	30	Mean = 0.3	30

3.9 Validity and reliability of the instruments

Reliability and validity are foundational to the efficacy of any data collection process in educational research (Best & Kahn, 2006). While validity pertains to the extent to which an instrument accurately measures what it is intended to measure, reliability refers to the consistency of the instrument in producing stable and repeatable results under identical conditions. In essence, validity concerns accuracy, whereas reliability addresses consistency.

Validity refers to the quality of an instrument that enables it to measure the construct it is designed to assess. In this study, several steps were undertaken to ensure the validity of the research instruments. Subject matter experts, including academic advisors, two Biology teachers and one specialists in test measurement from Injibara college of teachers education, rigorously reviewed and validated the instruments (EAT, EAQ, & EEQ) to confirm their relevance and representativeness with respect to the intended learning outcomes.

To support the internal validity of group comparisons, experimental and control groups were carefully matched according to school context, classroom size, gender composition, and cultural background. Preliminary piloting of the EAT; EAQ, & EEQ were conducted to further evaluate the appropriateness, clarity, and content validity of the items, as advised by Morris and Cohen (2008). Analysis of pilot test data confirmed that the instrument effectively measured the targeted knowledge domains.

Reliability denotes the degree to which the instrument yields consistent results across repeated administrations. In this research, instrument reliability was evaluated as follows: The internal consistency of the EAT was established using the Kuder-Richardson Formula 20 (KR-20), producing a reliability coefficient of 0.83, which reflects a high degree of reliability (Boopathiraj & Chellamani, 2013). The reliability of the EEQ and the EAQ was assessed using Cronbach's alpha, resulting in coefficients of 0.81 and 0.79, respectively, both falling within accepted thresholds for educational instruments (Hinkle et al., 2003).

For the EAT, correct responses were assigned a score of 1, and incorrect responses a score of 0; thus, the maximum possible score equaled the total number of items, and the minimum was zero. For the engagement and attitude instruments, a five-point Likert scale was employed, with responses ranging from 1 ("strongly disagree") to 5 ("strongly agree") for positively framed statements. For negatively worded items, the scoring was reversed to preserve interpretive consistency. Given that all calculated reliability coefficients met or exceeded commonly accepted standards, and the validity of instruments was established through expert review and pilot testing, it was determined that the employed instruments were both reliable and valid for use in this study.

3.10 Intervention procedures

Prior to the beginning of the intervention, the researcher conducted preliminary visits to the participating schools to establish rapport, explain the purpose of the study, and obtain official permission from school administrators and relevant educational authorities (Figure 4). Two intact Grade 8 sections from comparable middle schools were selected and randomly assigned at the class level as either the experimental group (Bida School) or the control group (Bata School). Because the study employed intact classrooms within natural school settings, cluster assignment was considered more practical and ethically appropriate than individual randomization. Informed consent was obtained from all participating students after clearly explaining the objectives of the study, the voluntary nature of participation, confidentiality procedures, and the right to withdraw at any stage without academic consequences. To maintain baseline equivalence, both groups studied the same ecology content, used the same curriculum objectives, completed similar assessment procedures, and received equal instructional time. The only planned difference between the two groups was the mode of instruction: the experimental group received IK-integrated instruction, whereas the control group was taught using conventional lecture-oriented methods.

Before the classroom implementation began, the teacher assigned to the experimental group participated in an intensive five-day professional training program facilitated by the researcher. The training aimed to strengthen the teacher's pedagogical competence in integrating IK into ecology instruction while maintaining alignment with the Grade 8 Biology curriculum. The first phase of the training focused on conceptual orientation, including discussions on culturally responsive pedagogy, constructivist learning theory, and the educational significance of IK systems in science teaching. During this phase, the researcher was introduced to the objectives of the intervention, the expected classroom procedures, methods of facilitating inquiry-based discussions, and approaches for linking local ecological practices with formal scientific concepts.

The second phase of the training concentrated on the identification, documentation, and instructional alignment of local Awi Indigenous ecological practices relevant to ecology topics included in the Grade 8 Biology curriculum. The researcher and teacher collaboratively identified culturally familiar examples from the Awi community and mapped them onto specific ecological concepts (Table 5). For example, indigenous terracing systems practiced on steep farmlands were linked to concepts of soil erosion prevention, watershed management, and environmental conservation. Traditional mixed-cropping practices were associated with biodiversity, interdependence among organisms, and nutrient cycling. Local practices of compost preparation and manure application were connected to decomposition and soil fertility restoration, while community-based protection of sacred tree species was linked to biodiversity conservation and ecosystem stability. Indigenous weather prediction methods based on animal behavior, wind direction, and cloud patterns were also incorporated into discussions of environmental adaptation and ecological observation. We had discussed how these practices could be transformed into classroom learning activities.

Table 5 : Some of the IK Identified and related to ecological concepts

Indigenous Practice	**Related ecological Concept**
Terrace farming	Soil conservation and erosion control
Intercropping legumes	Nitrogen fixation and nutrient cycling
Composting animal dung	Soil fertility management
Community protection of sacred trees	Biodiversity conservation
Seasonal water harvesting pits	Water conservation
Traditional weather prediction	Environmental observation
Crop rotation	Ecosystem sustainability

In the final phase of the training, the researcher and teacher collaboratively prepared an IK-integrated instructional package designed specifically for the ecology units taught during the intervention period (See Appendix G). The instructional package included detailed learning objectives, culturally contextualized classroom activities, guiding discussion questions, student group tasks etc. Each lesson was explicitly aligned with curriculum competencies and Bloom's taxonomy of cognitive objectives. The teacher additionally participated in microteaching and rehearsal sessions where sample lessons were practiced and evaluated to ensure consistency, pedagogical clarity, and effective integration of IK with scientific explanations.

Before implementation pretest was conducted to check the baseline difference among experimental and control groups. The intervention was implemented over a six-week period, with four 40-minute lessons conducted each week. Instruction in the experimental group followed a structured pedagogical sequence grounded in constructivist and culturally responsive teaching principles. Each lesson generally followed five instructional phases (Table 6): **Introduction and Motivation phase;** each lesson began with an introductory activity intended to activate students' prior cultural and environmental experiences related to the ecological topic under discussion. The teacher typically initiated lessons through probing questions, storytelling, local proverbs, community examples, or short discussions based on students' observations from their daily lives. This introductory phase aimed to create cognitive bridges between students' Indigenous experiences and formal scientific concepts.

For example, during a lesson on soil conservation and ecosystem sustainability, students were first asked to describe traditional farming practices used by their families to prevent soil erosion in hilly areas around Injibara. Students discussed practices such as terracing, grass strip planting, contour farming, and the application of composted animal manure. Following this discussion, the teacher guided students to analyze how these practices reduce runoff, improve soil fertility, and maintain ecosystem balance. Scientific concepts such as nutrient recycling, soil conservation mechanisms, and sustainable land management were then introduced and linked directly to the Indigenous practices identified by students.

Similarly, during lessons on food chains and ecological interactions, the teacher incorporated local folktales and community narratives that illustrated relationships among plants, animals, and humans. Students worked in small groups to identify organisms mentioned in the stories and construct food chains and food webs based on local ecological systems familiar to them. In another activity related to biodiversity conservation, students discussed traditional community taboos against cutting specific tree species and examined how such practices contribute to species preservation and ecological sustainability. Through these activities, students were encouraged to compare Indigenous explanations with scientific interpretations, identify similarities and differences, and collaboratively construct ecological understanding.

Elicitation of Indigenous Knowledge phase; Students were encouraged to share experiences from their families and communities related to farming, conservation, interaction, and environmental management. Sample teacher prompts included:

- "How do farmers in your village prevent soil erosion?"
- "Why are certain tree species protected in your community?"
- "How do local farmers restore soil fertility after harvest?"

This phase validated students' cultural experiences and positioned them as active contributors to classroom learning.

Linking IK with Scientific Concepts phase; the teacher guided students in comparing Indigenous practices with formal ecological principles. Examples included:

- Compost application linked to nutrient cycling
- Crop rotation connected to soil nitrogen replenishment
- Sacred forest preservation linked to biodiversity conservation
- Traditional irrigation systems connected to water resource management

Visual diagrams, questioning techniques, and guided discussions were used to scaffold conceptual understanding.

Collaborative Learning Activities phase; Students worked in small groups to:

- Analyze local environmental problems
- Compare IK and scientific explanations
- Prepare posters and presentations
- Construct food webs using local species examples
- Conduct mini field observations around the school environment

For instance, students developed ecosystem maps using local plants, insects, domestic animals, and agricultural activities familiar to their communities.

Reflection and Consolidation phase; Lessons concluded with reflective discussions and teacher synthesis integrating scientific terminology with local ecological understanding. Students summarized how Indigenous practices reflected scientific ecological principles.

Table 6 : Sample IK-integrated lesson activity

Lesson Component	Activity
Introduction	Teacher displays images of terraced farmlands in Awi Zone
IK Elicitation	Students discuss how their families prevent soil erosion
Scientific Link	Teacher explains erosion, nutrient loss, and nutrient cycling
Group Task	Students compare terracing and composting with scientific conservation methods
Reflection	Students explain why traditional methods are ecologically sustainable

The experimental classroom emphasized learner-centered instructional strategies such as cooperative learning, guided inquiry, reflective discussion, peer explanation, questioning, and collaborative problem-solving. The teacher assumed the role of facilitator rather than information transmitter, encouraging students to actively participate in discussions and connect classroom concepts with local environmental realities. Classroom activities included group presentations, observations around the school environment, analysis of local farming practices, interpretation of Indigenous ecological proverbs, and problem-solving tasks grounded in community experiences.

In contrast, the control group received instruction through conventional teacher-centered approaches commonly practiced in the study area. Lessons primarily relied on textbook explanations, lecture methods, note-taking, and direct teacher exposition. Students in the control classroom had limited opportunities for discussion, contextual exploration, collaborative inquiry, or integration of local ecological experiences into classroom learning. Although the same curricular content and learning objectives were covered, the instructional process lacked culturally contextualized examples and IK integration.

To ensure fidelity of implementation, the researcher conducted regular classroom monitoring throughout the six-week intervention period. Classroom observations, lesson plan reviews, and instructional supervision were carried out to verify that the experimental teacher consistently implemented the IK-based instructional procedures. A structured fidelity checklist was used to assess adherence to planned instructional procedures, including the integration of IK examples, facilitation of student-centered activities, and promotion of classroom interaction. Feedback and supportive guidance were provided to the experimental teacher whenever necessary to maintain consistency across lessons.

In addition to quantitative data collection, classroom observations were systematically conducted in both groups to capture qualitative evidence regarding student engagement and classroom interaction. Observations were guided by a structured twelve-item checklist developed around the behavioral, emotional, and cognitive dimensions of student engagement.

Observation notes were recorded during lessons, transcribed immediately after classroom sessions, and repeatedly reviewed to identify recurring interaction patterns and engagement behaviors. Qualitative analysis followed thematic coding procedures combining deductive coding based on predefined engagement categories with inductive coding emerging directly from classroom data. The analysis generated major themes related to engagement levels (behavioral, emotional, and cognitive dimensions). These qualitative findings were triangulated with quantitative results obtained from the ecology engagement questionnaire and achievement assessments to provide a deeper and more comprehensive understanding of how IK-based instruction influenced students' academic achievement, attitudes, engagement, and perceptions toward ecology learning.

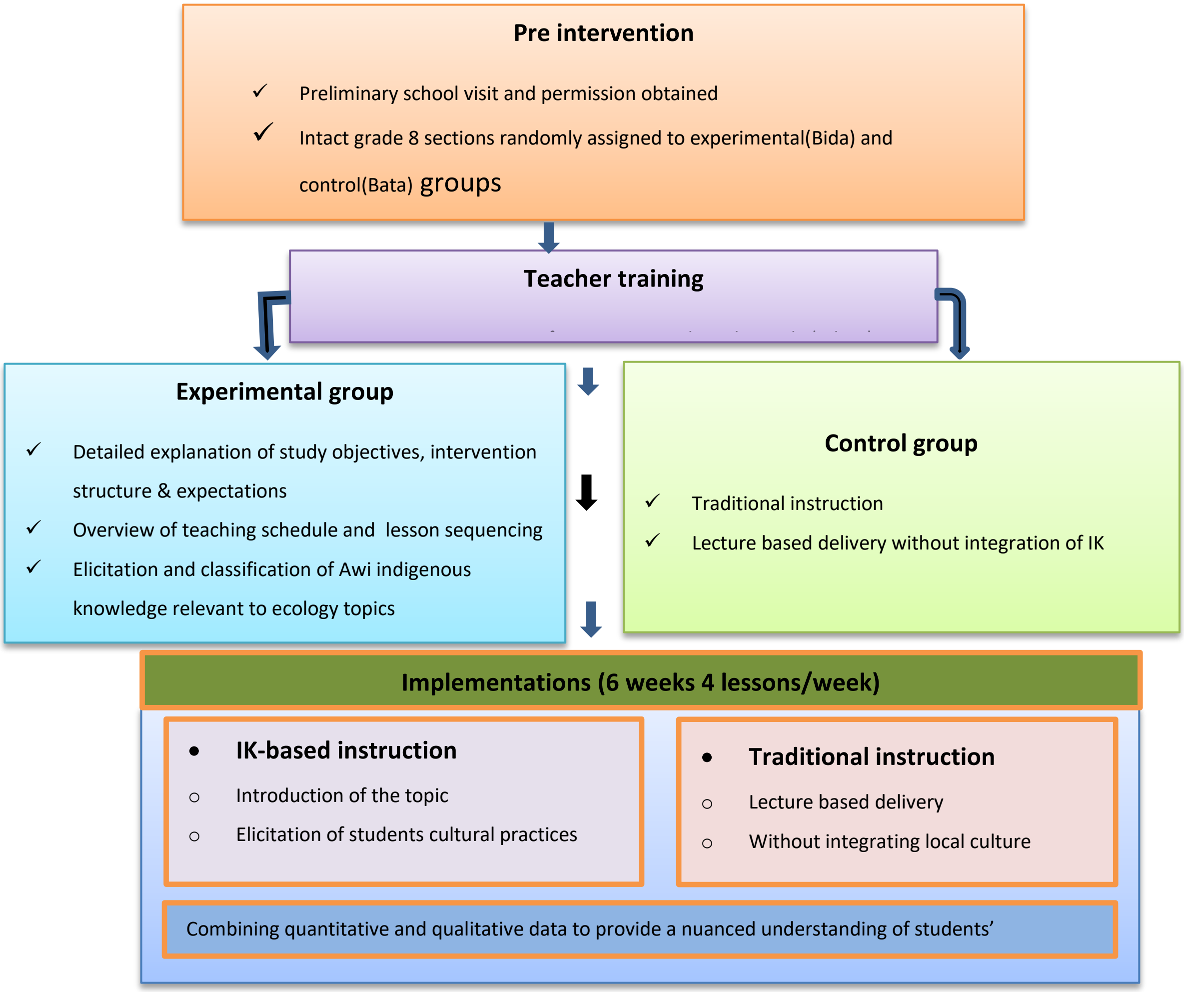

Figure 4 : Intervention procedures

3.11 Data analysis methods

According to Saunders et al. (2019), the data analysis stage within the research onion framework transforms raw data into meaningful insights that respond directly to the research objectives and questions. In this study, data analysis was guided by the pragmatic philosophical stance and mixed-methods approach underpinning the design. The analysis aimed to determine whether integrating IK into Biology instruction significantly influenced students' learning outcomes specifically, their academic achievement, engagement, and attitudes, and to examine whether gender moderated these relationships.

The study employed both quantitative and qualitative analytical techniques to ensure a comprehensive understanding of the phenomenon. Quantitative data from pretest and posttest measures of the EAT; EEQ, and EAQ were analyzed using the statistical package for the social sciences (SPSS version 26). Complementary qualitative data from FGDs and classroom observations were analyzed through thematic analysis to provide contextual depth and triangulation.

The first stage of the quantitative analysis involved descriptive statistics, including measures of central tendency and variability specifically, means and standard deviations (SDs). These were computed for all variables (achievement, engagement, and attitude) to summarize pretest and posttest performance within and between the experimental and control groups.

Descriptive statistics provided a general overview of the data distribution, highlighting trends and differences before inferential testing (Pallant, 2020). Mean values indicated the central performance level of each group, while standard deviations captured the degree of variability in students' scores. These measures were instrumental in detecting overall changes in learning outcomes attributable to IK-based instruction. Using descriptive summaries aligns with the first research objective to assess whether integrating IK enhances students' learning outcomes by offering an initial, transparent view of observed patterns before applying inferential tests to confirm statistical significance.

To determine whether observed group differences were statistically significant, the study employed inferential statistical techniques, specifically independent-samples t-tests and Analysis of Covariance (ANCOVA). The independent-samples t-test was used to compare mean differences in achievement, engagement, and attitude between the control and experimental groups at the pretest stage. This test established baseline equivalence and ensured that both groups were comparable before the intervention (Field, 2018). The t-test was chosen for its simplicity and robustness in comparing two independent groups when the dependent variable is continuous and normally distributed, a common requirement in quasi-experimental educational designs (Cohen et al, 2018).

The primary inferential analysis utilized ANCOVA to compare posttest mean scores between groups while controlling for pretest performance as a covariate. This procedure allowed for a more precise estimation of the intervention's effect by adjusting for any initial differences between the groups. ANCOVA was selected because it provides stronger internal validity than a simple posttest comparison by statistically controlling for confounding variables (Pallant, 2020). In this study, ANCOVA tested whether IK-based instruction had a significant impact on students' post-intervention achievement, engagement, and attitude, independent of pre-existing variations. Additionally, two-way ANCOVA was used to examine the moderating effect of gender, addressing whether male and female students benefited differently from IK-based instruction.

Before conducting inferential analyses, all key statistical assumptions were rigorously tested to ensure the validity and reliability of the results. Specifically, the normality of data distribution was assessed using measures of skewness and kurtosis, supplemented. Homogeneity of variances across groups was examined using Levene's test to confirm that variability in scores was consistent between the experimental and control groups. Additionally, for the Analysis of Covariance (ANCOVA), the assumptions of linearity and homogeneity of regression slopes were verified to ensure that the relationship between covariates and dependent variables was uniform across conditions. The details of the ANCOVA and independent sample t test assumptions are discussed in result section. These diagnostic procedures were essential for maintaining the robustness of the statistical analyses and reducing the likelihood of errors. Only after confirming that all assumptions were adequately met were the inferential tests performed and interpreted. A significance threshold of $p < .05$ and a 95% confidence interval were adopted to determine statistically significant differences, in line with widely accepted standards in educational research (Field, 2018).

Qualitative data obtained from the FGDs and classroom observations were analyzed using thematic analysis procedures. Since the FGDs were conducted in Awngi to allow participants to express their views freely and naturally, the audio-recorded discussions were first transcribed verbatim in Awngi and subsequently translated into English by the researcher, who is fluent in both languages and familiar with the local sociocultural context. To enhance translation accuracy and preserve the original meanings of participants' responses, the translated transcripts were independently reviewed by an experienced bilingual language expert. In addition, backward translation procedures were employed for selected excerpts, whereby portions of the English translations were translated back into Awngi to verify semantic consistency and minimize meaning distortion during translation.

The translated transcripts and classroom observation notes were read repeatedly to achieve familiarity with the data and to identify recurring patterns relevant to the research objectives. Manual coding procedures were employed, and the primary units of analysis consisted of meaningful words, phrases, sentences, and short statements that reflected participants' experiences, perceptions, attitudes, and observed classroom behaviors related to IK-based instruction. Similar codes were grouped into broader categories and subsequently organized into emergent themes. Major themes focused on students' perceptions of IK integration, classroom participation, engagement behaviors, and perceived relevance of ecology instruction, collaborative learning experiences, and challenges encountered during the implementation of IK-based teaching approaches. The use of repeated reading, systematic coding, and thematic categorization strengthened the credibility and trustworthiness of the qualitative findings.
The choice of descriptive and inferential statistical methods was guided by the research objectives and the quasi-experimental design. Descriptive statistics were appropriate for summarizing data patterns and distributions, while t-tests and ANCOVA provided the necessary inferential rigor to determine the causal effect of instructional approaches. ANCOVA, in particular, is widely recommended for educational intervention studies where random assignment is not feasible, as it effectively adjusts for baseline differences (Cohen et al., 2018). Its use here ensures a fair comparison between intact classroom groups typical of quasi-experimental school-based research.

3.12 Controlling extraneous variables

To minimize the influence of extraneous variables that could introduce bias into the study, the researcher implemented several control strategies across distinct domains:

(a) Teacher variable

Recognizing that differences in teacher practices can influence students' learning outcomes, deliberate measures were undertaken to minimize teacher-related variability and ensure instructional consistency across the experimental and control groups. Prior to the implementation of the intervention, the experimental group teacher participated in a structured pre-experimental orientation organized by the researcher. This session introduced the study objectives, clarified the instructional procedures, and provided guidance on lesson delivery. The experimental group teacher received specific training on the integration of IK within the ecology lessons, ensuring that such integration remained pedagogically sound and aligned with curriculum objectives. Conversely, the control group teacher was employed usual teaching approach as typically practiced in the school, thus maintaining the ecological validity of the comparison.

During the instructional phase, the researcher was conducted observations to monitor adherence to the designated teaching approach. To further control for confounding effects related to teacher background, both instructors had comparable qualifications, subject specialization in Biology, and almost similar years of teaching experience.

(b) Subject interaction

To minimize the possibility of cross-group contamination, the experimental and control groups were selected from different schools within Injibara city. Although the schools were located in the same city, they operated independently with separate classroom settings, teaching staff, schedules, and student cohorts, which reduced frequent academic interaction between participants across groups. This arrangement substantially lowered the likelihood of direct instructional information exchange related to the intervention.

However, the researcher recognizes that completely eliminating contamination in educational field settings is difficult, particularly when schools are geographically proximate. Therefore, rather than claiming the absolute absence of contamination, the study implemented practical measures to reduce its potential influence. These measures included assigning different teachers to each group, conducting the intervention simultaneously, restricting the distribution of intervention materials to the experimental group, and selecting intact classes from separate school environments. Consequently, while minor informal interaction among students outside the classroom could not be entirely ruled out, the procedures employed were considered sufficient to minimize contamination effects to an acceptable level and preserve the internal validity of the study.

(c) Intergroup variable

Although a pretest was administered to establish baseline equivalence, initial non-random group assignment could still lead to differences between groups. To mitigate the impact of any such non-equivalence, the researcher employed ANCOVA during data analysis. ANCOVA was utilized to statistically adjust for any initial disparities among participants, thereby enhancing the internal validity of the comparative results (Field, 2018).

(d) Effect of pre-test on post-test

To minimize the potential influence of pre-testing on post-test performance, a seven-week interval was maintained between the administration of the pre-test and post-test. This procedure was informed by methodological recommendations in quasi-experimental educational research, which suggest that providing an adequate time gap between repeated assessments can help reduce testing effects, memory recall, and test sensitization threats to internal validity (Creswell & Clerks, 2018; Fraenkel et al., 2019). Given the instructional duration of the intervention and the cognitive demands of the ecology content, the seven-week interval was considered sufficiently long to lessen the likelihood that students would remember specific test responses from the pre-test administration.

In addition, the post-test items were presented in a reshuffled order relative to the pre-test to further minimize recall bias and response pattern memorization. This reshuffling procedure was applied to the EAT as well as to the EEQ and EAQ. The content, difficulty level, and learning objectives measured by the instruments remained unchanged; only the sequencing of items and response arrangements were modified.

The researcher deliberately retained the same validated test items rather than constructing an entirely different equivalent form of the achievement test. This decision was based on methodological and psychometric considerations. Using the same instrument in pre-test and post-test conditions enhances score comparability and ensures that any observed differences are more likely attributable to the instructional intervention rather than variations in test difficulty or content coverage (Ary et al., 2018). Developing a separate equivalent test form would require extensive additional piloting and statistical equating procedures to establish parallel reliability, content equivalence, and difficulty comparability, which was beyond the scope of the present study. Therefore, employing the same validated instrument with reshuffled item order and an adequate testing interval was considered a more practical and methodologically defensible approach for maintaining measurement consistency while minimizing testing threats.

3.13 Ethical consideration

This study was conducted with rigorous attention to the ethical principles governing research involving human participants, in accordance with the guidelines articulated by Best and Kahn (2006). The safety, dignity, and rights of both students and teachers were prioritized throughout every phase of the research process.

Prior to data collection, formal ethical clearance was secured from the college of science ethical review committee (Ethical clearance approval form Ref: PRCSVD/632/2023, dated February 28, 2023). Additional permission to access schools was granted by the Biology department, facilitating cooperation from relevant institutional authorities and course instructors at the selected participating middle schools.

All participants in the study were thoroughly briefed regarding the research objectives, procedures, and anticipated value of the study. The confidentiality of all collected information was strictly maintained; data were anonymzed by instructing participants to use identification codes rather than names on all test instruments and questionnaires. This measure further supported the assignment of participants to either the control or experimental group while protecting their individual identities.

Written informed consent was obtained from each participant following a detailed explanation of the voluntary nature of participation, the right to withdraw at any point, and the intended use of collected data solely for research and statistical analysis (Best & Kahn, 2006). Both oral and written consent procedures were implemented, as documented in the appended consent forms.

At the conclusion of the intervention, the study maintained ethical parity by ensuring that students in the control group also received instruction on the relevant topics through IK-based methods, thus safeguarding their access to equitable educational opportunities.

In summary, all phases of this study adhered strictly to approved ethical protocols, with particular focus on informed consent, confidentiality, and the welfare of participants in line with standard research ethics (Best & Kahn, 2006).

CHAPTER FOUR: RESULTS

Introduction

This study examined the effects of integrating IK into Biology instruction in comparison to conventional teaching methods on students' academic achievement in ecology. Furthermore, it investigated whether the instructional approach significantly influenced students' engagement, perception, and attitudes towards ecology, as well as assessed potential differences in achievement, engagement, and attitudes based on gender. Consequently, this chapter presents a comprehensive analysis of both quantitative and qualitative data pertaining to students' achievement, engagement, and attitudes toward ecological subject matter, disaggregated by instructional group and gender. The results are systematically organized according to the research questions and hypotheses that framed the study. Prior to conducting the main statistical analyses, the assumptions underlying the independent samples t-test and ANCOVA were thoroughly evaluated.

Assumption testing for the independent samples *t*-test

Prior to conducting the independent samples *t*-tests, the assumptions of normality and homogeneity of variances were systematically examined to ensure the appropriateness of parametric analysis. The results of these diagnostic checks are summarized in Table 7, which presents skewness and kurtosis statistics alongside Levene's test of equality of variances for all relevant variables.

Normality

The assumption of normality was assessed using skewness and kurtosis indices for each variable, including pretest and posttest measures of EAT, EEQ, and EAQ. As reported in Table 7, all skewness and kurtosis values ranged between −1 and +1. According to commonly accepted guidelines (George & Mallery, 2010), values within this range indicate an approximately normal distribution. This pattern was consistent across all six variables, supporting the fulfillment of the normality assumption required for the independent samples *t*-test.

Homogeneity of variances

The assumption of homogeneity of variances was evaluated using Levene's test of equality of variances. As shown in Table 7, the Levene's test results for all variables were non-significant (p > 0.05), indicating that the variances of scores were statistically equivalent across the comparison groups. This confirms that the assumption of equal variances was satisfied for all pretest and posttest measures included in the analysis

In summary, the results presented in Table 7 demonstrate that both the normality and homogeneity of variance assumptions were adequately met for all variables examined. These findings justify the use of the independent samples *t*-test to compare group mean differences in ecology achievement, engagement, and attitudes at the pre-intervention stage.

Table 7 : Assumption checking for normality and homogeneity of variances of t-test

Variables	N	Skewness	Kurtosis	Levene test of homogeneity of variance	
				F	***p***
Pretest EAT	89	.366	-.553	.002	.968
Pretest EEQ	89	-.242	-.499	.171	.680
Pretest EAQ	89	.342	-.797	.301	.585
Posttest EAT	89	.358	-.870	.342	.068
Posttest EEQ	89	-.103	-.667	.057	.813
Posttest EAQ	89	.037	-.918	.128	.260

Assumption testing for ANCOVA

Prior to conducting the ANCOVA, the underlying statistical assumptions were systematically examined to ensure the validity and interpretability of the inferential results. Consistent with established methodological guidelines (Field, 2018; Tabachnick & Fidell, 2019), the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, independence of observations, and reliability of the covariate were evaluated. The results of these diagnostic procedures are reported below.

Normality of the Dependent Variable

The assumption of normality requires that the dependent variable (posttest scores) is approximately normally distributed within each group after accounting for the covariate. Normality was assessed using descriptive statistics (skewness and kurtosis). As shown in Table 8 across groups, skewness and kurtosis values fell within the acceptable range of ±1.0. These results indicate no substantial departures from normality. Therefore, the assumption of normality was considered satisfactorily met.

Homogeneity of regression slopes

The homogeneity of regression slopes assumption requires that the relationship between the covariate and the dependent variable is equivalent across groups. This assumption was tested by examining the interaction between the covariate (pretest scores) and the grouping variable (instructional method). As presented in Table 8**,** the interaction term was not statistically significant ($p > .05$), indicating that the regression slopes for the experimental and control groups did not differ significantly. This finding confirms that the effect of the covariate on posttest scores was consistent across instructional conditions, thereby satisfying the assumption of homogeneity of regression slopes.

Homogeneity of variances

The assumption of homogeneity of variances requires that the error variances of the dependent variable are equal across groups. This assumption was tested by using Levene's test of equality of error variances. As reported in Table 8**,** the results of Levene's test were not statistically significant ($p > .05$), indicating that the variance of posttest scores did not differ significantly between the experimental and comparison groups. Thus, the assumption of homogeneity of variances was met.

Table 8 : Assumption checking for ANCOVA

Variables	N	Skewness	Kurtosis	Levene test of homogeneity of variance		Homogeneity of regression slopes
				F	***P***	
Posttest EAT	89	.358	-.870	2.87	.098	.201
Posttest EEQ	89	-.103	-.667	2.59	.276	.406
Posttest EAQ	89	.037	-.918	1.19	.17	.422

Linearity between the covariate and the dependent variable

Another critical assumption underlying the use of Analysis of Covariance (ANCOVA) is linearity, which requires a linear relationship between the covariate (pretest achievement) and the dependent variable (posttest achievement) within each instructional group. This assumption ensures that the adjustment of posttest scores based on the covariate is statistically valid and comparable across groups.

As illustrated in Figure 5, scatterplots of posttest achievement scores against pretest achievement scores for both the experimental and comparison groups demonstrate clear linear trends. The fitted regression lines for each group show a consistent positive linear relationship between pretest and posttest achievement, with no evidence of curvilinear patterns or deviations from linearity. The relatively high coefficients of determination ($R^2 = 0.777$ for the experimental group and $R^2 = 0.890$ for the comparison group further indicate that a substantial proportion of variance in posttest achievement is explained by pretest scores within each group.

These visual and statistical indicators confirm that the assumption of linearity between the covariate and the dependent variable has been satisfactorily met for both instructional conditions. Consequently, the use of ANCOVA to compare adjusted posttest achievement scores between the experimental and comparison groups is justified, and the resulting estimates can be interpreted with confidence (Field, 2018).

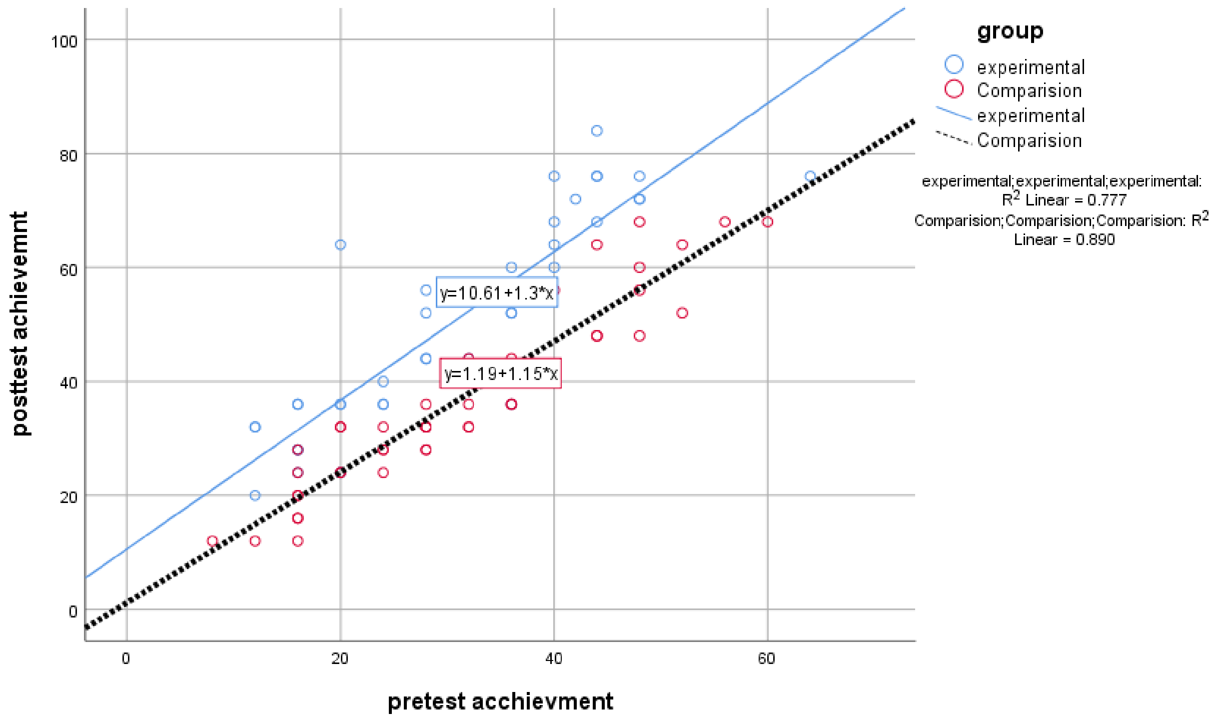

Figure 5 : Assumption checking for linearity (ANCOVA).

Independence of observations

The final assumption of ANCOVA pertains to the independence of observations. This assumption requires that each participant’s response is independent of others’ responses, ensuring no influence during data collection. In the present study, standardized testing conditions were maintained across all groups to uphold this assumption. Specifically, each participant group was assessed under consistent treatment conditions, with intact classes selected from their respective schools to preserve independence. Furthermore, the identical questionnaire was administered concurrently to all groups, minimizing the possibility of inter-participant influence during the assessment process. Consequently, it can be reasonably concluded that the independence assumption was satisfied, as participants were unlikely to affect each other’s responses during the administration of the tests (Field, 2018).

Reliability of the covariate

For ANCOVA to yield unbiased estimates, the covariate must be measured reliably. In this study, the pretest achievement, engagement and attitude scores used as the covariate were obtained using a standardized EAT, EEQ, and EAQ, which demonstrated acceptable internal consistency. This level of reliability indicates that the covariates were measured with sufficient precision to justify its inclusion in the ANCOVA model.

In summary, all key assumptions required for the valid application of ANCOVA were rigorously examined and met. No significant violations were detected that would compromise the interpretation of the adjusted group comparisons. Consequently, ANCOVA was deemed an appropriate and robust analytical technique for evaluating the effect of the IK-based instructional strategy on students' posttest outcomes while controlling for pretest differences.

4.1 Achievement of students in ecology

4.1.1 Effects of integrating IK on the academic achievement of students

Pretest comparison of ecology achievement scores

To establish baseline equivalence in ecology achievement between the experimental and control groups, a pretest was administered prior to the instructional intervention. An independent samples *t*-test was conducted to determine whether a statistically significant difference existed between the groups' pretest achievement scores. As shown in Table 9, the experimental group ($M = 30.47$, $SD = 12.35$, $n = 43$) and the control group ($M = 31.04$, $SD = 12.82$, $n = 46$) did not differ significantly on the pretest, $t\,(87) = -0.216$, $p = .829$. This finding indicates that the two groups were statistically comparable in terms of ecology achievement prior to the intervention.

To further quantify the magnitude of the group difference, effect size was estimated using eta squared (η^2). Based on the obtained t value and group sizes, η^2 was calculated as 0.0049, representing a negligible effect size. This result confirms that the observed difference in pretest achievement scores was trivial and not practically meaningful.

Taken together, the results reported in Table 9 support the assumption of baseline homogeneity in ecology achievement between the experimental and control groups. Consequently, any statistically significant differences observed in posttest achievement can be more confidently interpreted as being associated with the instructional intervention rather than pre-existing group differences.

Table 9 : Independent samples t-test on pretest ecology achievement

Test	**Group**	**N**	**Mean**	**SD**	**SDE**	**Df**	**T**	***p***	**η^2**
Pretest	Experimental	43	30.47	12.353	1.885	87	-.216	.829	.0049
	Control	46	31.04	12.822	1.890				

Eta squared $\eta^2 = t^2 / (t^2 + (N_1 + N_2 - 2))$, where t = -0.216 and group sizes were $N_1 = 43$ and $N_2 = 46$, yielding $\eta^2 = 0.0049$

Descriptive comparison of pretest and posttest ecology achievement scores

Following the six-week instructional period, students' academic achievement in ecology was assessed using the EAT. The experimental group received instruction through the IK–based strategy, while the control group was taught using conventional teaching methods. As shown in Table 10, the control group recorded a pretest mean score of 31.04 (SD = 12.88) and a posttest mean score of 36.78 (SD = 15.59), reflecting a mean gain of 5.74 points. In contrast, the experimental group demonstrated a pretest mean score of 30.47 (SD = 12.36) and a substantially higher posttest mean score of 50.33 (SD = 18.27), corresponding to a mean gain of 19.86 points.

The descriptive results presented in Table 10 indicate that both groups showed improvement in ecology achievement following instruction; however, the magnitude of improvement was notably greater for students in the experimental group. This pattern suggests that students exposed to the IK-based instructional approach achieved higher post-intervention gains relative to their counterparts taught using conventional methods. These descriptive trends provide preliminary support for the potential effectiveness of the IK-based approach and warrant further examination through inferential statistical analysis.

Table 10 : Descriptive statistics of pretest and posttest ecology achievement

Group	Variable	N	Mean	SD	Min	Max	Skew.	Kurt.	Mean. Gain
Experimental	Pre-test	43	30.47	12.358	12	64	.344	-.383	
	Post-test	43	50.33	18.273	20	84	.088	-1.261	19.86
Control	Pre- test	46	31.04	12.882	8	60	.392	-.634	
	Post-test	46	36.78	15.586	12	68	.499	-.448	5.74

One-way ANCOVA results for ecology achievement

HO1: There is no statistically significant difference in academic achievement between students taught using IK system strategy and those taught using the conventional method.

One-way ANCOVA was conducted to examine the effect of teaching method on students' posttest ecology achievement scores, while statistically controlling for pretest achievement. The dependent variable was posttest achievement, the fixed factor was teaching method (TM), and the covariate was pretest achievement. After adjusting for pretest achievement, the main effect of TM was statistically significant, $F(1, 86) = 87.85$, $p < .005$, partial $\eta^2 = .505$. This large effect size suggests that the teaching method accounted for approximately 50.5% of the explained variance in posttest achievement beyond the contribution of prior achievement. Students who received IK-based instruction achieved significantly higher adjusted posttest scores than those taught using conventional methods. The results presented in Table 11 provide strong empirical evidence that the IK-based instructional approach had a statistically significant and practically meaningful effect on students' ecology achievement after controlling for baseline differences. Accordingly, the null hypothesis stating that there is no statistically significant difference in achievement between students taught using IK-based instruction and those taught using conventional methods is rejected.

Table 11 : One-way ANCOVA for posttest ecology achievement

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected Model	24616.769	2	12308.385	239.768	.000	.848
Intercept	459.184	1	459.184	8.945	.004	.094
Pre achievement	20540.487	1	20540.487	400.129	.000	.823
TM	4509.479	1	4509.479	87.845	.000	.505
Error	4414.781	86	51.335			

4.1.2 Effects of integrating IK on achievement score of male and female students

The descriptive statistics comparing pretest and posttest ecology achievement scores of male and female students within the experimental group are presented in Table 12. Male students (n = 21) recorded a mean pretest score of 32.19 (SD = 12.99) and a mean posttest score of 53.90 (SD = 17.96), yielding a mean gain of 21.71 points. Female students (n = 22) achieved a mean pretest score of 28.82 (SD = 11.78) and a mean posttest score of 46.91 (SD = 18.31), corresponding to a mean gain of 18.08 points. The results displayed in Table 12 indicate that both male and female students demonstrated substantial improvements in ecology achievement following instruction using the IK-based approach. Although male students showed a slightly higher mean gain than female students, the difference in gain scores was modest. The overall pattern of results suggests comparable post-intervention achievement trends across gender within the experimental group, with no clear evidence of gender-based disparity in learning outcomes at the descriptive level. These findings provide preliminary support for the gender-inclusive nature of the IK-based instructional approach and are further examined through inferential analysis in subsequent sections.

Table 12 : Comparison of pretest and posttest EAT by gender in the EG

Group	Test	Male				Female			
		N	**M**	**SD**	**Mean gain**	**N**	**M**	**SD**	**Mean gain**
Experimental	Pretest	21	32.19	12.99	21.71	22	28.82	11.78	18.08
	Posttest		53.90	17.96			46.91	18.31	

HO2: There is no statistical significant difference between the performance of male and female students exposed to IK teaching strategy.

To examine whether ecology achievement differed by gender among students taught using the IK–based instructional approach, a one-way ANCOVA was conducted, with posttest achievement scores as the dependent variable, gender as the fixed factor, and pretest achievement scores entered as the covariate. As shown in Table 13, after statistically controlling for pretest achievement, gender did not have a statistically significant effect on posttest ecology achievement scores, F (1, 40) = 0.971, p = .330, η^2 = .024. This effect size indicates a small and practically negligible gender effect. In contrast, the covariate (pretest achievement) exerted a strong and statistically significant influence on posttest scores, F(1, 40) = 137.001, p < .001, η^2 = .774, confirming that prior knowledge was a substantial predictor of post-intervention achievement. The non-significant gender effect reported in Table 13 indicates that, when initial differences in achievement were adjusted for, male and female students achieved comparable levels of academic performance under the IK-based instructional strategy. Accordingly, the null hypothesis stating that there is no statistically significant difference in ecology achievement between male and female students exposed to IK-based instruction is retained.

Table 13 : One-way ANCOVA comparing posttest EAT by Gender in the EG

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected model	10973.145a	2	5486.573	71.948	.000	.782
Intercept	720.115	1	720.115	9.443	.004	.191
Pretest achievement	10447.331	1	10447.331	137.001	.000	.774
Gender	74.037	1	74.037	.971	.330	.024
Error	3050.296	40	76.257			

4.1.3 Interaction effect of instructional strategies and gender on students' achievement.

Table 14 presents the posttest mean achievement gains of male and female students in both the experimental and control groups. Within the experimental group, male students recorded a mean gain of 21.71 points, while female students achieved a comparable mean gain of 18.08 points. In contrast, substantially smaller mean gains were observed in the control group, where male and female students improved by 5.34 and 6.18 points, respectively. Overall, students exposed to the IK–based instructional approach demonstrated markedly higher achievement gains than those taught using conventional methods, irrespective of gender.

The relatively similar gain patterns between male and female students within each instructional condition suggest that gender did not differentially influence students' achievement outcomes. Rather, the magnitude of improvement appears to be primarily associated with the instructional strategy employed. This pattern is consistent with the ANCOVA results, which indicated no statistically significant gender effect after controlling for pretest scores. Collectively, these findings suggest that the IK-based instructional approach enhances students' ecological achievement in an equitable manner, benefiting both male and female learners without evidence of gender bias.

Table 14 : Comparison of mean achievement scores between males and females

Group	Test	Male				Female			
		N	**M**	**SD**	**Mean gain**	**N**	**M**	**SD**	**Mean gain**
Experimental	Pretest	21	32.19	12.99	21.71	22	28.82	11.78	18.08
	Posttest		53.90	17.96			46.91	18.31	
Control	Pretest	24	33.33	13.27	5.34	22	28.55	12.11	6.18
	Posttest		38.67	15.22			34.73	16.06	

HO3: There is no interaction effect of instructional strategies and gender on students' achievement in ecology.

Two-way ANCOVA was conducted to examine the main and interaction effects of TM and gender on students' posttest ecology achievement scores, while statistically controlling for pretest achievement. The results, as presented in Table 15, indicated that gender had no statistically significant main effect on students' ecology achievement after adjustment for pretest scores, $F(1, 88) = 2.487$, $p > .05$, $\eta^2 = .001$,. The associated effect size for gender was negligible ($\eta^2 \approx .001$), suggesting that gender accounted for an insignificant proportion of the variance in posttest achievement. Furthermore, the interaction effect between instructional strategy and gender was not statistically significant, $F(1, 84) = 2.487$, $p > .05$. This finding indicates that the effect of instructional strategy on students' ecology achievement did not differ significantly between male and female students. In other words, gender did not moderate the relationship between instructional approach and posttest achievement outcomes.

Taken together, these results suggest that the IK–based instructional strategy was equally effective for both male and female students. The absence of a statistically significant interaction effect supports the conclusion that the instructional intervention was gender-equitable and did not advantage or disadvantage students based on gender. Accordingly, the null hypothesis stating that there is no interaction between instructional strategy and gender on students' ecology achievement is retained.

Table 15 : Two ways ANCOVA for gender and TM on EAT

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected model	24747.493	4	6186.873	121.310	.000	.852
Intercept	454.481	1	454.481	8.911	.004	.096
Pretest achievement	19967.267	1	19967.267	391.510	.000	.823
TM	4500.204	1	4500.204	88.238	.000	.512
Gender	5.231	1	5.231	.103	.750	.001
TM*Gender	126.827	1	126.827	2.487	.119	.029
Error	4284.058	84	51.001			

4.1.4 Qualitative Findings: Students' Perceptions of IK-Based Instruction

The qualitative findings presented in this section were derived from FGDs conducted with students from the experimental group after the six-week instructional intervention. The purpose of the qualitative inquiry was to complement and explain the quantitative findings related to students' achievement, attitude, and engagement outcomes under the IK-based instructional approach. The analysis followed a thematic procedure involving transcription, repeated reading, coding, categorization, and interpretation of participants' responses.

The findings revealed that students perceived the IK-based instructional approach as cognitively meaningful, emotionally supportive, culturally affirming, and highly engaging. Two interrelated themes emerged from the analysis: (1) IK-based instruction as a facilitator of meaningful and contextualized learning, and (2) IK-based instruction as a catalyst for emotional engagement, participation, and cultural identity validation. These themes not only explain how students experienced the intervention but also provide qualitative confirmation of the significant quantitative improvements observed in achievement, attitude, and engagement scores.

Theme 1: IK-based instruction as a facilitator of meaningful and contextualized learning

A dominant perception among participants was that the integration of IK transformed ecology from an abstract and difficult subject into a meaningful and understandable learning experience. Students repeatedly explained that ecology concepts became easier to comprehend because lessons were connected to familiar environmental practices, community experiences, and indigenous ecological knowledge systems already embedded within their daily lives.

One participant explained:

"IK systems and practices enrich our understanding; this method provided deeper insights about the topic and real-life examples from our surroundings." (S1)

Another participant similarly stated:

"Previously, ecology lessons were difficult because they were only theoretical, but when the teacher explained concepts using our local farming practices, the lessons became easier to understand and remember." (S4)

These responses suggest that students perceived IK as a cognitive bridge linking prior cultural experiences with formal scientific concepts. This finding strongly supports the quantitative achievement results, where students exposed to IK-based instruction demonstrated significantly higher posttest achievement scores than those taught using conventional methods. The qualitative data indicate that improved achievement was not merely the result of exposure to new content, but rather the consequence of contextualized conceptual understanding. Students were able to internalize ecological concepts because instruction was grounded in familiar indigenous experiences such as terraced farming, compost preparation, mixed cropping, indigenous biodiversity protection, and traditional soil fertility management.

For instance, several participants described how indigenous composting and manure application practices helped them understand decomposition, nutrient recycling, and soil fertility restoration scientifically. One student noted:

"When the teacher explained nutrient cycling using the way our families use animal manure and compost on farmland, I understood the lesson clearly because I had already seen it at home." (S5)

This perception reflects Ausubel's (1963) theory of meaningful learning, which argues that new knowledge becomes meaningful when connected to learners' prior cognitive structures. Rather than memorizing isolated ecological definitions, students constructed scientific understanding through culturally familiar examples. The findings also align with Vygotsky's (1978) social constructivist perspective, which emphasizes that learning occurs through socially and culturally mediated experiences.

Importantly, students described the IK-based approach as reducing the "foreignness" traditionally associated with science education. Participants repeatedly indicated that ecology no longer appeared disconnected from their community life. One participant explained:

"The lesson became less confusing because the examples came from our own environment. I realized that ecology is not something separate from our community life." (S6)

This perception is analytically significant because it explains the substantial improvement observed in students' attitudes toward ecology in the quantitative phase of the study. The integration of local ecological knowledge appeared to reduce the psychological and cultural distance between school science and students' lived realities. Students no longer perceived ecology as an imported or purely textbook-based subject, but as knowledge directly connected to their environment and community practices.

Several participants further emphasized the practical usefulness of the lessons. Students reported that they could apply ecological concepts in real-life environmental activities such as soil conservation, water management, biodiversity protection, and sustainable farming practices. One participant remarked:

"Lessons were meaningful because I can now explain scientifically why our traditional practices help conserve the environment." (S3)

Another student added:

"Now I understand that the things our community practices every day are related to science and environmental protection." (S2)

These findings indicate that students developed not only conceptual understanding but also perceived utility value and self-efficacy regarding ecology learning. The instructional approach therefore enhanced students' cognitive engagement by encouraging them to actively interpret, analyze, and apply scientific concepts within authentic environmental contexts. This qualitative evidence helps explain the large quantitative effect size reported for engagement outcomes under the IK-based instructional condition.

Overall, the findings under this theme demonstrate that students perceived IK-based instruction as a pedagogical approach that transformed ecology learning from abstract memorization into meaningful, contextualized, and applicable understanding. The integration of IK enabled students to connect scientific theories with lived ecological realities, thereby strengthening conceptual comprehension, retention, and transfer of learning.

Theme 2: IK-based instruction as a catalyst for emotional engagement, participation, and cultural identity validation

The second major theme emerging from the FGDs concerned the emotional, social, and participatory dimensions of students' learning experiences. Participants consistently described the IK-based instructional approach as interactive, motivating, culturally respectful, and emotionally supportive. Students perceived that the instructional strategy validated their indigenous identities, encouraged active participation, and created a more inclusive classroom environment compared to conventional lecture-based instruction.

One participant explained:

"I was happy to see that the knowledge from our parents and community was important in learning science." (S2)

Another participant stated:

"Before this, I thought only textbook knowledge was scientific, but now I understand that our local practices also have scientific value." (S3)

These statements reveal that the intervention produced more than academic improvement; it also generated cultural recognition and emotional affirmation. Students perceived themselves not merely as passive recipients of externally imposed knowledge, but as active contributors whose community experiences possessed scientific legitimacy. This finding directly supports the significant improvement observed in students' attitude scores in the quantitative analysis. The IK-based approach appeared to positively influence students' emotional relationship with ecology by validating their cultural backgrounds within the formal learning process.

The findings also strongly illuminate the behavioral engagement outcomes reported quantitatively. Students consistently described the classroom atmosphere as participatory and collaborative. Unlike conventional lecture-oriented instruction, the IK-based approach involved discussion, peer interaction, home-based inquiry, group presentation, and collaborative problem-solving activities.

One participant explained:

"Before the lesson, we were asked to ask our families about local conservation practices, and during class we discussed them together. This made the lesson interesting and enjoyable." (S1)

Another student noted:

"Everyone wanted to contribute because the discussion was related to our daily life experiences." (S5)

These responses indicate that students experienced a heightened sense of ownership and involvement during classroom activities. Because instructional discussions were rooted in familiar cultural and environmental experiences, students felt more confident participating, questioning, and expressing ideas. This qualitative evidence complements the quantitative finding showing significantly higher engagement levels among students exposed to IK-based instruction, with a large practical educational effect.

Students additionally emphasized that the lessons created a relaxed and less intimidating learning environment. Several participants contrasted the intervention with conventional science lessons, which they characterized as teacher-dominated, note-centered, and examination-focused. One participant remarked:

"In normal classes we mostly listen and copy notes, but in this method we discussed, shared ideas, and understood concepts better." (S4)

Another participant added:

"This approach reduced fear and stress because we already knew some examples from our environment." (S6)

The reduction in fear, stress, and classroom anxiety suggests that culturally responsive instruction may lower psychological barriers associated with science learning. Students appeared more emotionally secure because the instructional process began with familiar cultural knowledge before introducing formal scientific explanations.

Furthermore, students repeatedly used emotionally expressive terms such as "interesting," "participatory," "amazing," "motivating," and "unforgettable" to describe the learning experience. Such expressions indicate strong emotional engagement and intrinsic motivation toward ecology learning. Students were not only cognitively involved but also emotionally invested in the instructional process.

Collectively, these findings provide strong qualitative support for the quantitative results of the study. The integration of IK created a culturally responsive and learner-centered instructional environment that improved not only academic performance but also students' attitudes, participation, motivation, and sense of cultural belonging within science classrooms.

4.2 Attitudes of students towards ecology

4.2.1 Effect of IK-based instruction on students' attitudes towards ecology

This section presents the descriptive statistics of the pre- and post-intervention attitude scores categorized by group. Prior to data collection, a pretest was administered to both the experimental and control groups to assess baseline equivalence in students' attitudes towards ecology. The experimental group obtained a mean pretest score of 71.81 (SD = 13.48), which was closely comparable to the control group's mean of 72.61 (SD = 15.79). These results indicate that both groups possessed similar attitudes toward ecology before the implementation of the intervention. Therefore, any observed differences in posttest outcomes can be attributed to the impact of the IK-based instructional strategy. The descriptive statistics of the pretest scores for both groups are detailed in Table 16.

Table 16 : Descriptive statistics of pretest scores in the CG and EG

Group	**Variable**	**N**	**Mean**	**SD**	**Min**	**Max**	**Skewness**	**Kurtosis**	**Mean Gain**
Experimental	Pre-test	43	71.81	13.48	41	108	.492	1.795	0.8
Control	Pre- test	46	72.61	15.79	43	106	-.10	-.277	

An independent-samples *t*-test was conducted to examine whether a statistically significant difference existed between the experimental and control groups in students' attitudes toward ecology at the pre-intervention stage. As reported in Table 17, the analysis yielded a non-significant result, t (87) = −0.255, p = .799, which exceeds the conventional alpha level of .05. This finding indicates that there was no statistically significant difference in mean pretest attitude scores between the two groups. The absence of a baseline difference supports the assumption of initial equivalence between the experimental and control groups with respect to ecological attitudes and provides a sound basis for subsequent post-intervention comparisons.

Table 17 : Independent samples t-test to compare CG and EG on pretest

Test	**Group**	**N**	**Mean**	**SD**	**SDE**	**Df**	**T**	***p***
Pretest	Experimental	43	71.81	13.42	2.056	87	-.255	.799
	Control	46	72.61	15.73	2.321			

Following the implementation of the instructional intervention, a posttest was administered to both the experimental and control groups to assess students' attitudes toward ecology. As presented in Table 18, students in the experimental group recorded a higher mean posttest attitude score (M = 86.12, SD = 14.33) than those in the control group (M = 74.70, SD = 14.33). These descriptive statistics indicate a notable difference in post-intervention attitude scores between the two groups, with the experimental group exhibiting more positive attitudes toward ecology. However, as these findings are based solely on descriptive measures, inferential statistical analysis is required to determine whether the observed difference is statistically significant and not attributable to random variation.

Table 18 : Mean of students' scores in EG and CG

Group	Variable	N	Mean	SD	Min	Max	Skewness	Kurtosis	Mean Gain
Experimental	Pre-test	43	71.81	13.48	41	108	.344	1.79	
	Post-test	43	86.12	14.33	59	112	-.16	-.78	14.31
Control	Pre- test	46	72.61	15.73	43	15	-.10	-.27	
	Post-test	46	74.70	14.33	43	108	-.31	-.23	2.09

H_{04}: There is no statistically significant difference in students' attitudes towards ecology between those instructed using an IK–based strategy and those taught through conventional methods.

To test this hypothesis, one-way ANCOVA was conducted on posttest attitude scores toward ecology, with instructional strategy as the independent variable and pretest attitude scores entered as the covariate. As reported in Table 19 the results indicated a statistically significant main effect of instructional strategy on students' posttest attitude scores after adjusting for baseline differences, $F(1, 86) = 14.15$, $p < .05$, $\eta^2 = .141$. The associated effect size (partial η^2 = .141) suggests a moderate practical effect according to conventional benchmarks (Cohen, 1988), indicating that a meaningful proportion of variance in posttest attitudes was attributable to the instructional approach.

Specifically, students who received IK-based instruction demonstrated higher adjusted mean attitude scores toward ecology than their peers who were taught using conventional methods. Given that no statistically significant differences were observed between the groups at the pretest stage, the ANCOVA results provide evidence that the observed post-intervention differences are associated with the instructional strategy rather than initial attitudinal disparities. Accordingly, the null hypothesis (H_{04}) is rejected. These findings indicate that integrating IK into ecology instruction is associated with more positive student attitudes toward the subject, relative to conventional teaching approaches.

Table 19 : One way ANCOVA for attitude post test scores in groups

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected model	3001.430a	2	1500.715	7.261	.001	.144
Intercept	19506.332	1	19506.332	94.374	.000	.523
TM	2926.501	1	2926.501	14.159	.000	.141
Pretest attitude	102.644	1	102.644	.497	.483	.006
Error	17775.514	86	206.692			

4.2.2 Effects of integrating IK on the attitude score of male and female students

The post-intervention ecology attitude scores of male and female students who received the IK–based instructional strategy were examined to explore potential gender-related differences. As presented in Table 20 female students in the experimental group recorded a higher mean posttest attitude score (M = 88.95, SD = 15.01) than their male counterparts (M = 83.14, SD = 13.29). Although these descriptive statistics indicate a modest difference in favor of female students, subsequent inferential analysis revealed that the difference was not statistically significant ($p >$ .05). This finding suggests that the observed variation in posttest attitude scores between male and female students is not sufficient to conclude a gender-related effect and may reflect random variation rather than a systematic influence of gender under the IK-based instructional condition.

Table 20 : Comparison of mean achievement scores between males and females

Group	Test	Male				Female			
		N	M	SD	Mean gain	N	M	SD	Mean gain
Experimental	Pretest	21	71.52	12.76	11.62	22	72.09	14.29	16.86
	Posttest		83.14	13.29			88.95	15.01	
Control	Pretest	24	73.25	14.86	2.42	22	71.23	16.79	2.41
	Posttest		75.67	13.16			73.64	15.75	

H_{05}: There is no statistically significant difference between the attitudes of male and female students exposed to the IK–based teaching strategy.

To test this hypothesis, one-way ANCOVA was conducted to examine whether students' post-intervention attitude scores toward ecology differed by gender under the IK-based instructional approach while controlling for pretest attitude scores. As presented in Table 21, The ANCOVA results revealed no statistically significant gender difference in students' posttest attitude scores under the IK-based instructional approach $F(1, 40) = 1.737$, $p > .05$, $\eta^2 = .042$, with a small effect size, indicating minimal practical significance and suggesting that the intervention produced relatively comparable positive attitude improvements among male and female students."

Educationally, the finding is important because it demonstrates that the IK-based instructional approach provided a relatively equitable learning environment for both male and female students. The intervention appeared to foster similarly positive attitudes toward ecology regardless of gender, implying that culturally responsive pedagogy can support inclusive participation and affective engagement in science education. Although minor differences in mean scores were observed descriptively, the magnitude of improvement across genders was sufficiently similar to indicate that both groups benefited comparably from the instructional intervention.

Table 21 : One-way ANCOVA for attitude scores between males and females in the EG

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected Model	472.490a	2	236.245	1.158	.324	.055
Intercept	8580.438	1	8580.438	42.061	.000	.513
Pretest attitude	109.598	1	109.598	.537	.468	.013
Gender	354.294	1	354.294	1.737	.195	.042
Error	8159.928	40	203.998			

HO6: There is no statistically significant interaction effect between instructional strategy and gender on students' attitudes toward ecology.

Two-way ANCOVA was conducted to examine the interaction effect between instructional strategy and gender on students' posttest attitude scores toward ecology while controlling for pretest attitude scores. As presented in Table 22, the interaction effect between instructional strategy and gender on students' attitude scores was not statistically significant, $F(1, 84) = 1.638$, $p = .204$, with a small effect size ($\eta^2 = .019$), indicating minimal practical significance. This suggests that the IK-based instructional approach improved students' attitudes toward ecology similarly for both male and female students.

The obtained effect size ($\eta^2 = .019$) indicates a small interaction effect based on Cohen's (1988) guidelines, where values around .01 are considered small. This means that only about 1.9% of the variance in students' posttest attitude scores was explained by the combined interaction of instructional strategy and gender, demonstrating minimal practical significance. Educationally, the result suggests that the IK-based instructional approach was similarly effective for both male and female students in promoting positive attitudes toward ecology. The absence of a significant interaction effect implies that neither gender benefited disproportionately from the intervention. Instead, the instructional strategy appeared to create an inclusive and culturally responsive learning environment that supported comparable attitudinal improvement among both groups.

The small magnitude of the interaction effect further indicates that gender did not meaningfully alter the effectiveness of the IK-based pedagogy. Thus, the intervention can be considered gender-equitable in terms of fostering positive attitudes toward ecology learning.

Table 22 : Two ways ANCOVA testing for the interaction of gender and TM

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected Model	3309.058a	4	827.265	3.978	.005	.159
Intercept	21146.514	1	21146.514	101.690	.000	.548
Pre attitude	.065	1	.065	.000	.986	.000
Gender	79.305	1	79.305	.381	.539	.005
TM	2883.519	1	2883.519	13.866	.000	.142
Gender*TM	340.533	1	340.533	1.638	.204	.019
Error	17467.885	84	207.951			

4.3 Engagement of students during ecology learning

4.3.1 Effect of IK based instruction on students engagement in ecology lesson

A pretest was administered to both the experimental and control groups to assess baseline levels of student engagement in ecology prior to the implementation of the IK–based instructional intervention. After confirming that the assumptions required for subsequent inferential analyses (independent-samples *t*-test and ANCOVA) were satisfactorily met, descriptive statistics were computed for the pretest engagement scores. As presented in Table 23, the experimental group recorded a mean engagement score of $M = 68.77$ ($SD = 11.83$), while the control group obtained a closely comparable mean score of $M = 68.50$ ($SD = 10.35$). These results indicate that students in both groups demonstrated similar levels of engagement prior to the intervention. The observed similarity in baseline engagement scores suggests that the two groups were comparable at the outset of the study, thereby providing an appropriate basis for examining post-intervention differences in engagement associated with the instructional approach.

Table 23 : Descriptive statistics of pretest scores in the CG and EG

Group	**Variable**	**N**	**Mean**	**SD**	**Min**	**Max**	**Skewness**	**Kurtosis**	**Mean Gain**
Experimental	Pre-test	43	68.77	11.83	46	92	-.072	-.866	0.22
Control	Pre- test	46	68.50	10.35	47	88	-.217	-.605	

An independent-samples *t*-test was conducted to examine whether a statistically significant difference existed between the experimental and control groups in terms of classroom engagement prior to the implementation of the instructional intervention. As reported in Table 24, the analysis revealed no significant difference between the two groups on the pre-intervention engagement measure, $t\ (87) = -0.114$, $p = .910$. This result indicates that the mean engagement scores of students in the experimental group ($M = 68.77$, $SD = 11.83$) and the control group ($M = 68.50$, $SD = 10.35$) were statistically comparable at baseline. Accordingly, the null hypothesis of no difference in pretest engagement levels between the groups was retained. The absence of a statistically significant baseline difference supports the assumption that the two groups were equivalent with respect to classroom engagement prior to the intervention, thereby providing a sound basis for subsequent analyses of post-intervention engagement outcomes.

Table 24 : Independent samples t-test to compare CG and EG on the pretest

Test	**Group**	**N**	**Mean**	**SD**	**SDE**	**Df**	**T**	***p***
Pretest	Experimental	43	68.77	11.83	2.254	87	.114	.910
	Control	46	68.50	10.35	2.365			

Following the instructional intervention, students' classroom engagement levels were reassessed for both the experimental and control groups. The experimental group received ecology instruction through the IK–based teaching strategy, whereas the control group continued to receive conventional lecture-based instruction. Descriptive analyses of post-intervention engagement scores were conducted to examine patterns of change across groups. As presented in Table 25, the experimental group recorded a mean engagement score of $M = 68.77$ ($SD = 11.83$)

at pretest, which increased to *M* = 87.05 (*SD* = 13.78) at posttest, yielding a mean gain of 20.28 points. In contrast, the control group demonstrated a more modest increase, with mean scores rising from *M* = 68.50 (*SD* = 10.35) at pretest to *M* = 72.67 (*SD* = 4.87) at posttest, corresponding to a gain of 6.17 points.

These descriptive findings indicate a substantially larger improvement in engagement scores among students exposed to the IK-based instructional approach compared to those taught using conventional methods. While inferential statistical analysis is required to determine the statistical significance of these observed differences, the magnitude of the mean gains suggests a positive association between the IK-based teaching strategy and enhanced student engagement in ecology learning.

Table 25 : Mean of students' engagement scores in CG and EG

Group	**Variable**	**N**	**Mean**	**SD**	**Min**	**Max**	**Skewness**	**Kurtosis**	**Mean. Gain**
Experimental	Pre-test	43	68.77	11.83	46	92	-.072	-.866	
	Post-test	43	87.05	13.78	52	114	-.492	.180	20.28
Control	Pre- test	46	68.50	10.35	47	88	-.217	-.605	
	Post-test	46	72.67	4.87	63	82	.183	-.763	6.17

HO7: There is no statistically significant main effect of the IK–based teaching strategy on students' classroom engagement in ecology.

One-way ANCOVA was conducted to examine the main effect of instructional strategy on students' posttest engagement scores while controlling for pretest engagement levels. The results, as presented in Table 26, the ANCOVA results revealed a statistically significant main effect of instructional strategy on students' engagement scores, $F(1, 84) = 45.80$, $p < .05$, with a large effect size ($\eta^2 = .351$), indicating large educational improvement associated with IK-based instruction. This means that approximately 35.1% of the variance in students' posttest engagement scores was explained by the instructional strategy after controlling for pretest engagement differences. Such a large effect size demonstrates substantial practical and educational significance. From an educational perspective, the finding suggests that IK-based instruction considerably improved students' behavioral, emotional, and cognitive engagement in ecology lessons compared to the conventional lecture-based approach. Students in the experimental group participated more actively in classroom discussions, demonstrated greater interest and enthusiasm toward learning activities, and engaged more deeply in linking scientific concepts with indigenous ecological experiences. The magnitude of improvement indicates that the integration of culturally relevant examples and participatory learning activities created a more meaningful and motivating learning environment.

Table 26 : One-way ANCOVA for students' engagement post-test scores in the EG

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected Model	5097.326a	2	2548.663	25.649	.000	.374
Intercept	19921.228	1	19921.228	200.478	.000	.700
TM	4627.528	1	4627.528	46.569	.000	.351
Pre engagement	506.330	1	506.330	5.095	.077	.006
Error	8545.685	86	99.368			

4.3.2 Effects of IK on male and female students' engagement

The descriptive statistics presented in Table 27 summarize pretest and posttest engagement scores by gender and instructional group. Within the experimental group, male students recorded a mean engagement score of 68.24 (SD = 10.06) at pretest, which increased to 88.29 (SD = 15.37) at posttest, yielding a mean gain of 20.05 points. Female students in the same group obtained a pretest mean of 69.27 (SD = 13.57) and a posttest mean of 85.86 (SD = 12.32), corresponding to a mean gain of 16.89 points. Although male students demonstrated a slightly higher gain than female students, both genders exhibited substantial improvements in engagement following IK-based instruction.

In contrast, students in the control group showed comparatively modest changes in engagement. Male students in the control group achieved a pretest mean of 67.63 (SD = 11.09) and a posttest mean of 72.46 (SD = 4.97), resulting in a gain of 4.97 points. Female students recorded a pretest mean of 69.45 (SD = 9.65) and a posttest mean of 72.67 (SD = 4.87), reflecting a gain of 3.22

points. Posttest engagement scores for both male and female students in the control group remained notably lower than those observed in the experimental group.

Overall, both male and female students exposed to the IK-based instructional strategy demonstrated markedly greater improvements in engagement compared to their counterparts taught using conventional methods. While minor gender-related differences in gain scores were observed descriptively, these differences were small and do not suggest a meaningful interaction between gender and instructional strategy with respect to student engagement. This pattern supports the interpretation that the observed improvements in engagement are primarily associated with the instructional approach rather than gender.

Table 27 : Comparison of mean engagement scores between males and females

Group	**Test**	**Male**				**Female**			
		N	**M**	**SD**	**Mean gain**	**N**	**M**	**SD**	**Mean gain**
Experimental	Pretest	21	68.24	10.06	20.05	22	69.27	13.57	16.59
	Posttest		88.29	15.37			85.86	12.32	
Control	Pretest	24	67.63	11.09	4.79	22	69.45	9.65	3.22
	Posttest		72.46	4.97			72.67	4.85	

Two way ANCOVA was conducted to examine the effects of instructional strategy and gender on students' engagement in ecology lessons while controlling for pretest engagement scores. As presented in Table 28, there was a statistically significant main effect of instructional strategy on students' engagement scores, $F(1, 84) = 45.80$, $p < .05$, $\eta^2 = .351$. In contrast, the main effect of gender was not statistically significant, $F(1, 84) = 1.00$, $p = .753$, $\eta^2 = .001$. The effect size was negligible, indicating that gender accounted for only 0.1% of the variance in engagement scores. This finding suggests that male and female students demonstrated relatively similar levels of engagement during the intervention, implying that the IK-based instructional approach was equally supportive for both genders. Similarly, the interaction effect between instructional strategy and gender was not statistically significant, $F(1, 84) = 0.509$, $p = .477$, $\eta^2 = .006$. The very small effect size indicates minimal practical significance, showing that the effectiveness of the instructional strategy on engagement did not differ meaningfully between male and female students. In other words, both genders benefited comparably from the IK-based instructional approach.

Overall, the findings suggest that instructional strategy was the strongest determinant of student engagement, whereas gender had little influence on engagement outcomes. The IK-based pedagogy produced substantial educational improvement in students' classroom engagement regardless of gender, supporting its value as an inclusive and culturally responsive instructional approach in ecology education.

Table 28 : Two way ANCOVA testing on the interaction of gender and TM

Source	**Sum square**	**Df**	**Mean square**	***F***	**Sig**	**Eta Square**
Corrected Model	5157.461[a]	4	1289.365	12.764	.000	.378
Intercept	19813.715	1	19813.715	196.140	.000	.700
Pre engagement	501.103	1	501.103	4.961	.029	.056
Gender	10.077	1	10.077	.100	.753	.001
TM	4626.710	1	4626.710	45.801	.000	.353
Gender * TM	51.444	1	51.444	.509	.477	.006
Error	8485.550	84	101.018			

4.3.3 Classroom Observation

Classroom observation data were analyzed thematically to examine how IK-integrated instruction influenced students' learning outcome during ecology lessons. Observations were conducted systematically in both experimental and control classrooms using a structured twelve-item observation checklist supplemented by detailed field notes. The checklist was developed around the three dimensions of engagement identified in the literature, behavioral, cognitive, and emotional engagement (Fredricks et al., 2004). The qualitative observation findings were further triangulated with the quantitative results obtained from the EEQ, achievement test scores, and attitude questionnaire results. This integration enabled a deeper interpretation of how and why IK-based instruction influenced students' learning experiences and outcomes.

The observation findings revealed clear instructional and interactional differences between the IK-integrated classrooms and the conventionally taught classrooms. Three major themes emerged from the analysis: (1) Behavioral engagement through IK-based learning, (2) Cognitive engagement through IK-based learning, and (3) Emotional engagement through IK-based learning. Collectively, these themes provide process-level evidence supporting the statistically significant quantitative improvements observed in students' achievement, engagement, and attitudes under the IK-based instructional condition.

Theme 1: Behavioral engagement through IK-based learning

Behavioral engagement refers to students' visible participation in classroom activities, including attentiveness, questioning, collaboration, classroom interaction, persistence, and involvement in assigned learning tasks (Fredricks et al., 2004). Observation findings demonstrated substantial differences between the experimental and control classrooms regarding students' active participation during ecology lessons.

In the experimental classrooms, students consistently displayed high levels of behavioral engagement throughout the intervention period. Learners actively contributed ideas, initiated questions, participated in peer discussions, and engaged enthusiastically in collaborative group activities. Classroom interaction was dynamic and continuous, with students frequently exchanging ideas with teachers and peers during lesson discussions.

For example, during lessons on soil conservation and ecosystem sustainability, students voluntarily shared indigenous ecological practices such as terrace farming, grass-strip planting, mixed cropping, crop rotation, compost preparation, and indigenous water management systems practiced within the Awi community. These indigenous examples stimulated extended classroom discussions linking local practices with scientific ecological concepts such as nutrient cycling, soil fertility conservation, erosion control, and ecosystem balance.

Observation notes recorded that students frequently raised their hands to contribute examples from home and community experiences. One observation note stated: *"Almost all groups were actively discussing local farming practices and relating them to the ecology lesson. Students appeared eager to explain experiences from their villages and frequently requested opportunities to present their ideas."*

Teachers in the experimental group adopted facilitative and learner-centered instructional roles rather than relying exclusively on lecture-based teaching. They organized collaborative learning activities, encouraged peer interaction, guided classroom inquiry, and allowed students to explain scientific concepts using culturally familiar examples. Students confidently presented group findings, debated ecological ideas, and participated actively in classroom questioning sessions.

These observation findings strongly support the quantitative engagement results, where ANCOVA analysis revealed a statistically significant effect of instructional strategy on students' engagement scores, $F(1, 86) = 46.57$, $p < .05$, $\eta^2 = .351$. The large effect size indicates that approximately 35.1% of the variance in posttest engagement scores was attributable to the IK-based instructional intervention. The observation data help explain this substantial quantitative improvement by revealing how IK integration transformed students from passive listeners into active participants within the learning process.

In contrast, behavioral engagement in the control classrooms appeared comparatively limited and teacher-dependent. Instruction was predominantly lecture-oriented, with most classroom time devoted to textbook explanation, note copying, and teacher-centered questioning. Students generally remained passive listeners, rarely initiated classroom questions, and demonstrated minimal interaction during lessons.

Although occasional group activities were observed, participation remained highly structured and superficial. Students typically waited for teacher direction rather than initiating discussion independently. Observation notes repeatedly described students as "silent," "note-focused," and "passively attentive." One observation note stated: *"Most students remained quiet during the lesson and focused mainly on copying notes from the blackboard. Very few students participated voluntarily in discussions."*

The contrast between the two instructional conditions suggests that IK-integrated instruction significantly enhanced behavioral engagement by creating opportunities for participation, collaborative inquiry, discussion, and experiential learning, whereas conventional instruction largely promoted passive classroom behavior and limited interaction.

Theme 2: Cognitive engagement through IK-based learning

Cognitive engagement refers to the degree of students' mental investment in learning activities, including conceptual understanding, reflective thinking, problem-solving, critical analysis, and meaningful knowledge construction (Fredricks et al., 2004). Observation findings revealed that students in the experimental classrooms demonstrated substantially deeper conceptual engagement with ecology concepts compared to students in the control classrooms.

Teachers in the experimental group consistently employed culturally contextualized questioning strategies that encouraged students to connect Indigenous ecological practices with formal Biology concepts. Rather than simply presenting textbook definitions, teachers initiated lessons by eliciting students' prior knowledge and indigenous experiences before guiding them toward scientific explanations.

For instance, during a lesson on nutrient cycling and the nitrogen cycle, the teacher asked:

"How do farmers in your community restore soil fertility after harvesting crops repeatedly?"

Students responded by describing local practices such as manure application, fallowing, crop rotation, compost preparation, and intercropping legumes. The teacher then scaffolded students' responses by linking these indigenous practices to scientific explanations involving nitrogen replenishment, decomposition, and nutrient recycling.

Observation notes indicated that students were not merely recalling facts mechanically; rather, they were actively interpreting, comparing, and analyzing scientific concepts through culturally familiar ecological experiences. One observation note stated:

"Students attempted to explain scientifically why traditional farming practices improve soil fertility. Several students compared indigenous methods with textbook explanations and justified local practices using scientific reasoning."

Similarly, during lessons on biodiversity conservation, students discussed Indigenous cultural beliefs and taboos related to protecting specific tree species and wildlife. They then linked these practices to ecological concepts such as species conservation, ecosystem stability, and sustainable resource management. Such classroom discussions demonstrated students' ability to contextualize scientific theories within local environmental realities.

These qualitative findings strongly explain the significant quantitative improvement observed in students' achievement scores under the IK-based instructional condition. The achievement results indicated that students exposed to IK-based instruction performed significantly better than those taught conventionally, with a meaningful educational effect size. The observation findings suggest that this improvement emerged because students engaged cognitively with ecology concepts through meaningful, contextualized, and culturally grounded learning processes.

The findings further support constructivist and sociocultural learning theories, particularly Vygotsky's (1978) argument that meaningful learning occurs when new knowledge is constructed upon learners' prior experiences and social interactions. IK functioned as a cognitive scaffold that reduced conceptual abstraction and enabled students to internalize scientific concepts more effectively.

In contrast, cognitive engagement in the control classrooms appeared comparatively shallow and memorization-oriented. Teachers relied heavily on textbook explanations and factual presentation of concepts without linking instruction to students' local experiences or indigenous ecological knowledge systems. Students rarely engaged in reflective questioning, conceptual reasoning, or analytical discussion.

Observation notes indicated that many students struggled to connect abstract ecological concepts with real-life environmental practices. One observation note recorded:

"Students repeated textbook definitions when questioned but showed difficulty explaining how ecological concepts relate to practical environmental situations."

This suggests that conventional instruction promoted surface-level learning and factual recall rather than deeper conceptual understanding and critical thinking.

Theme 3: Emotional engagement through IK-based learning

Emotional engagement refers to students' affective responses toward learning activities, including interest, enthusiasm, motivation, confidence, enjoyment, and sense of belonging within the classroom environment (Fredricks et al., 2004). Observation findings revealed substantial differences between the emotional climates of the experimental and control classrooms.

The IK-integrated classrooms were characterized by a highly interactive, supportive, and culturally inclusive learning atmosphere. Students appeared enthusiastic during discussions and demonstrated confidence when sharing Indigenous ecological knowledge from their communities. Teachers consistently acknowledged students' cultural experiences as valuable learning resources, creating an environment where learners felt respected, recognized, and encouraged to participate.

One observation note stated:

"The teacher acted more as a facilitator than a lecturer, encouraging students to explain why traditional ecological practices work scientifically. Students appeared excited when discussing examples from their own communities."

Students visibly demonstrated enthusiasm and curiosity during lessons involving indigenous ecological practices. Many learners smiled, laughed, debated ideas openly, and voluntarily participated in classroom discussions. Observation notes frequently described the classrooms as *"energetic," "interactive," and "enthusiastic."*

These emotionally supportive interactions appear closely linked to the significant quantitative improvement observed in students' attitudes toward ecology. The quantitative findings showed that students exposed to IK-based instruction developed significantly more positive attitudes toward ecology compared to those in the control group. The classroom observations help explain this outcome by demonstrating how cultural validation and participatory learning increased students' emotional connection to science learning.

Importantly, students appeared emotionally secure because instructional discussions began with familiar cultural experiences before introducing formal scientific concepts. This reduced classroom anxiety and increased students' willingness to contribute ideas. One observation note explained:

"Students who were usually quiet during conventional lessons participated actively when discussions focused on local environmental practices familiar to them."

The observations therefore suggest that IK integration reduced the psychological distance between students and school science.

In contrast, emotional engagement in the control classrooms appeared comparatively low. The classroom atmosphere was predominantly passive and compliance-oriented, with limited opportunities for discussion, cultural expression, or collaborative interaction. Several students appeared inattentive or disengaged during lessons, occasionally displaying boredom, fatigue, or off-task behavior.

Observation notes described students as *"quiet," "detached," and "minimally expressive"* during instructional activities. The emotionally distant classroom climate appeared to reinforce students' perception of Biology as abstract, difficult, and disconnected from their lived experiences.

Synthesis of observation findings

Overall, the classroom observation findings provide strong qualitative support for the quantitative results of the study. The observations demonstrate that IK-integrated instruction positively influenced all three dimensions of student engagement—behavioral, cognitive, and emotional engagement. The experimental classrooms were characterized by active participation, collaborative inquiry, contextualized conceptual understanding, cultural validation, and emotionally supportive interactions.

The large quantitative effect size obtained for engagement ($\eta^2 = .351$) is strongly supported by the observation evidence, which illustrates how IK integration transformed the classroom from a predominantly transmissive learning environment into a participatory, culturally responsive, and intellectually engaging learning space. Students became active contributors to knowledge construction rather than passive recipients of information.

Furthermore, the observation findings help explain the significant improvements observed quantitatively in students' achievement and attitudes toward ecology. The integration of IK reduced conceptual abstraction, strengthened meaningful learning, increased cultural relevance, and fostered positive emotional connections to science learning.

Conversely, the control classrooms demonstrated the limitations of decontextualized and lecture-dominated instruction. The absence of cultural relevance, collaborative interaction, and contextualized learning opportunities appeared to reduce students' participation, conceptual engagement, emotional involvement, and motivation toward ecology learning.

Taken together, the observation findings provide compelling process-oriented evidence that integrating IK into Biology instruction can substantially improve students' classroom engagement, conceptual understanding, emotional involvement, and overall learning experience within ecology education.

CHAPTER FIVE: DISCUSSION

Introduction

This section presents a comprehensive discussion of the principal findings derived from both quantitative and qualitative data analyses. The chapter interprets the results outlined in chapter 4 by situating them within the broader context of existing literature and the theoretical constructs outlined in the study's conceptual framework. The primary objective of the research was to examine the effect of IK integration on students' academic achievement, attitudes toward ecology, and engagement during ecology instruction. In addition, the study explored differential effects based on gender, assessing both the independent and interaction effects of gender and instructional approach on student performance, engagement, and attitudinal outcomes in ecology instruction.

Furthermore, the investigation aimed to assess students' perceptions of the IK-based instructional method within the ecology curriculum. This analysis contributes to the growing body of learning on culturally responsive pedagogy and its implications for science education (Banks et al., 2005; Aikenhead & Michell, 2011). The discussion of findings is organized under the following thematic subheadings to provide a structured and in-depth interpretation of the results.

5.1 Effect of IK on students' achievement in ecology.

The findings of this study revealed that Grade 8 students who were exposed to IK-based ecology instruction achieved significantly higher posttest scores than students taught using conventional lecture method. The quantitative analysis demonstrated not only statistical significance but also meaningful educational improvement, indicating that the integration of IK substantially enhanced students' conceptual understanding of ecology. The observed achievement gains suggest that contextualizing scientific concepts within learners' sociocultural and environmental realities can improve both comprehension and retention of biological knowledge.

The improved achievement observed in the experimental group may be explained by the cognitive and pedagogical mechanisms embedded within the IK-based instructional approach. Unlike conventional instruction, which largely emphasized abstract textbook explanations and rote memorization, the IK-based lessons connected ecological concepts to familiar environmental practices and indigenous experiences already embedded within students' daily lives. Concepts such as nutrient recycling, biodiversity conservation, ecosystem balance, decomposition, and soil fertility were explained using locally recognized practices including terrace farming, crop rotation, compost preparation, mixed cropping, and traditional watershed management systems practiced within the Awi community.

This contextualization appears to have reduced the conceptual abstraction traditionally associated with ecology instruction. Students were able to anchor unfamiliar scientific concepts onto existing IK structures, thereby facilitating meaningful learning. This finding strongly aligns with Ausubel's (1963) theory of meaningful learning, which argues that new knowledge is more effectively learned when it is connected to learners' prior cognitive structures. Similarly, the findings reflect Vygotsky's (1978) sociocultural theory, which emphasizes that learning occurs most effectively when instruction is mediated through culturally meaningful experiences and social interaction.

The qualitative findings further lighten how IK integration contributed to improved academic achievement. Students consistently reported that ecology concepts became "easier," "clearer," and "more understandable" when teachers used examples drawn from their own communities and environmental experiences. For example, students explained that indigenous soil conservation methods helped them understand ecological balance and nutrient recycling more concretely than textbook descriptions alone. Such findings suggest that IK functioned as a cognitive scaffold that bridged the gap between local experiential knowledge and formal scientific concepts.

The classroom observation findings revealed that the IK-based instructional approach simultaneously enhanced behavioral, emotional, and cognitive engagement. Students in the experimental classrooms actively participated in discussions, collaborated in group activities, reflected critically on ecological practices, and confidently linked indigenous explanations with scientific reasoning. This multidimensional engagement likely strengthened conceptual processing and knowledge retention, thereby contributing to higher achievement outcomes.

The findings therefore indicate that achievement improvement was not an isolated outcome but rather the product of interconnected instructional and psychological processes. Students who perceived the lessons as culturally meaningful and emotionally supportive became more motivated to participate cognitively and behaviorally in learning activities. Consequently, the significant improvement in achievement appears closely linked to the simultaneous enhancement of students' engagement and attitudes toward ecology observed in the study.

The findings of this study are consistent with several international and African studies demonstrating the effectiveness of culturally responsive and ethno-science instructional approaches in science education. For instance, Ugwu and Diovu (2016) found that integrating IK into chemistry instruction significantly improved students' conceptual understanding and academic performance. Similarly, Nwankwo (2021) reported that ethno-science pedagogy positively influenced students' achievement in Basic Science because instruction was aligned with learners' cultural realities and lived experiences. The present findings also corroborate Chongo and Baliga (2019), who reported significantly higher achievement among students exposed to ethno-physics instruction compared to those taught conventionally.

Likewise, the findings align with the work of Ajayi et al. (2023), who found that ethno-Biology-based instruction improved students' academic performance more effectively than conventional lecture methods. According to Ajayi et al., the integration of culturally familiar examples enabled students to internalize biological concepts more meaningfully and apply them to real-life situations. Similarly, Liyas (2019) reported that integrating IK into Biology instruction promoted practical understanding and improved students' ability to relate scientific concepts to everyday experiences.

Within the Ethiopian context, the findings are also supported by emerging local studies emphasizing the educational value of contextualized and culturally responsive science instruction. Tadesse and Mehari (2020) argued that one major challenge of Ethiopian science education is the disconnection between school science and students' sociocultural realities, which often results in low conceptual understanding and weak academic performance. Similarly, Worku and Abate (2022) found that students in the Amhara Region struggled to relate ecological concepts to their immediate environmental experiences because classroom instruction remained largely abstract and textbook-oriented. The present study extends these findings by providing empirical evidence that integrating IK into ecology instruction can address this contextual gap and significantly improve achievement outcomes.

Furthermore, the findings resonate with Alemayehu's (2018) documentation of Indigenous ecological practices in the Awi Zone. Although Alemayehu's work was primarily descriptive rather than intervention-based, it demonstrated that the Awi community possesses rich ecological knowledge related to biodiversity conservation, soil fertility management, and sustainable agriculture. The current study operationalized such local ecological knowledge pedagogically and empirically demonstrated its effectiveness in improving students' learning outcomes within formal Biology instruction.

The findings also contribute to resolving the descriptive–interventionist gap identified in Ethiopian IK research. Much previous Ethiopian literature has focused mainly on documenting Indigenous practices without empirically examining how such knowledge can be transformed into effective classroom pedagogy. By employing a quasi-experimental design, this study moved beyond ethnographic description to provide evidence regarding the direct educational impact of IK-based instruction on achievement outcomes.

However, the findings partially contrast with studies suggesting that culturally integrated instruction alone may not automatically improve academic performance unless teachers possess adequate pedagogical competence and instructional support. For example, Nyoni (2022) argued that attempts to integrate IK into African science classrooms often face implementation challenges due to inadequate teacher preparation, limited instructional materials, and curriculum rigidity. The strong achievement gains observed in the present study may therefore be partly attributed to the structured teacher training, carefully designed IK instructional package, and systematic alignment of Indigenous practices with curriculum objectives. This suggests that the effectiveness of IK integration depends not merely on the inclusion of local examples, but on the quality and pedagogical coherence of implementation.

Another important analytical implication emerging from the findings concerns the role of cultural validation in learning. The qualitative evidence suggests that students experienced a sense of pride, recognition, and ownership when their community knowledge was acknowledged within formal classroom instruction. This emotional validation likely strengthened students' self-confidence and motivation toward ecology learning, thereby indirectly contributing to achievement improvement. Thus, the achievement gains observed in this study appear to reflect not only cognitive enhancement but also affective and motivational transformation.

Overall, the findings demonstrate that IK-based instruction appears as an effective culturally responsive pedagogical strategy for improving students' academic achievement in ecology. By connecting scientific concepts with learners' indigenous experiences, the instructional approach reduced conceptual abstraction, strengthened meaningful learning, increased engagement, and enhanced students' confidence in science learning. The results therefore suggest that IK should not be viewed as peripheral to formal Biology education, but rather as a valuable pedagogical resource capable of enriching conceptual understanding and improving educational outcomes within Ethiopian Biology classrooms.

5.2 Effect of IK-based instruction on students' achievement based on gender

The findings of the present study revealed that there was no statistically significant difference between male and female students in ecological achievement when both genders were exposed to IK-based instruction. Although minor variations in mean scores were observed descriptively, inferential analysis demonstrated that these differences were not statistically meaningful. Furthermore, the interaction effect between instructional strategy and gender on students' ecological achievement was not significant, indicating that the effectiveness of IK-based instruction did not vary according to gender. In practical terms, the instructional approach improved achievement for both male and female learners equally.

These findings suggest that IK-based pedagogy provides a gender-inclusive and equitable learning environment within ecology instruction. Unlike some conventional science teaching approaches that may unintentionally privilege particular participation styles or prior experiences often associated with male students, the IK-integrated strategy appeared to create broader opportunities for participation, contextual understanding, and conceptual engagement across genders. The absence of significant gender differences indicates that the instructional benefits of IK integration were distributed relatively uniformly among learners.

A plausible explanation for this outcome lies within the sociocultural context of the study area. In the Awi community, both boys and girls are actively exposed to indigenous ecological practices from early childhood through family, agricultural, and community participation. Students commonly engage in activities such as farming, compost preparation, water management, livestock care, biodiversity conservation, and environmental maintenance regardless of gender, although specific responsibilities may vary culturally. Consequently, both male and female students entered the classroom with relatively shared ecological experiences and culturally embedded environmental knowledge that could serve as cognitive entry points during instruction.

The IK-based instructional approach therefore may have reduced the knowledge asymmetry often associated with formal science learning. Since the lessons drew heavily on familiar community practices and lived experiences, both male and female students were able to participate confidently in classroom discussions and conceptual activities. This finding aligns with sociocultural learning theory, particularly Vygotsky's (1978) argument that learning becomes more effective when instruction is mediated through socially shared cultural experiences. Because IK was socially distributed within the students' community context, the instructional strategy may have minimized gender-related differences in prior conceptual access to ecology content.

The qualitative classroom observation findings further support this interpretation. Observations revealed that both male and female students actively contributed indigenous ecological examples during classroom discussions, participated collaboratively in group activities, and engaged confidently in explaining local environmental practices scientifically. Female students were observed discussing indigenous conservation practices, composting methods, and traditional environmental management strategies with the same level of participation and enthusiasm as male students. This suggests that the IK-based learning environment reduced classroom hierarchies commonly associated with teacher-dominated science instruction and instead promoted collaborative participation and shared knowledge construction.

The present findings are consistent with studies reporting no significant gender differences in achievement under culturally responsive or IK-based instructional approaches. For instance, Ugwu and Diovu (2016) found no statistically significant gender difference in students' academic performance when IK was integrated into chemistry instruction. Similarly, Oluboyo (2021) reported that instructional strategy did not interact significantly with gender in influencing science achievement outcomes. These studies, like the present research, suggest that culturally contextualized science instruction may help neutralize traditional gender disparities by creating more inclusive and participatory learning environments.

The findings are further supported by local Ethiopian research emphasizing the importance of contextualized instruction for inclusive learning. Alemayehu (2018) documented that Indigenous ecological knowledge within the Awi Zone is deeply embedded in community life and transmitted intergenerationally across both male and female roles. Although men and women may possess different forms of ecological expertise within the community, both groups maintain substantial experiential knowledge regarding environmental management and agricultural sustainability. The present findings suggest that incorporating these shared indigenous experiences into classroom instruction can support equitable academic participation and achievement in male and female learners.

However, the findings of this study contradict studies conducted by Chongo and Baliga (2019) and Mukuka (2019), which reported significant gender differences favoring male students in science achievement under culturally contextualized instructional approaches. Several contextual and methodological factors may explain these inconsistencies. First, sociocultural differences across study settings may influence how male and female students access and participate in IK systems. In some cultural contexts, boys may have greater exposure to outdoor environmental activities or public knowledge-sharing spaces, thereby gaining advantages during context-based science instruction. In contrast, the Awi sociocultural setting appears to provide relatively broader ecological participation opportunities for both genders, particularly in agricultural and environmental practices central to the ecology curriculum.

Second, differences in instructional implementation may also account for the variation in findings. The present study involved structured teacher training, carefully aligned lesson planning, collaborative learning activities, and explicit facilitation strategies designed to encourage equal participation among students. Such pedagogical scaffolding may have minimized gender disparities that could otherwise emerge under less structured implementations.

Third, differences in subject focus and educational level may contribute to inconsistent findings across studies. Some previous studies reporting gender differences focused on physics or mathematically intensive science topics traditionally associated with gender stereotypes. Ecology instruction, however, may naturally lend itself more readily to contextualized environmental experiences shared by both male and female learners within rural Ethiopian communities.

Importantly, the absence of significant gender interaction effects in this study should not be interpreted to mean that gender-related inequities no longer exist within science education generally. Rather, the findings suggest that culturally responsive pedagogies such as IK integration may serve as mechanisms for reducing participation and achievement gaps traditionally associated with conventional science instruction. The instructional approach appears to have created equitable cognitive access to scientific concepts by valuing diverse cultural experiences and encouraging collaborative engagement.

Overall, the findings demonstrate that IK-based instruction enhanced ecological achievement without introducing gender bias or unequal instructional benefits. The results therefore reinforce the pedagogical value of IK integration as an academically effective and socially inclusive approach to Biology education. By grounding ecology instruction within culturally shared experiences, the IK-based approach enabled both male and female students to engage meaningfully with scientific concepts, thereby promoting equitable learning gains within the Ethiopian middle school context.

5.3 Students' perceptions of the IK-based teaching approach

The qualitative findings of this study provide important explanatory insight into the quantitative improvements observed in students' achievement, attitude, and engagement scores following exposure to IK-based instruction. The FGDs revealed that students perceived the IK-based approach as meaningful, culturally relevant, interactive, and cognitively supportive. These perceptions suggest that the effectiveness of the intervention extended beyond content delivery and influenced how learners emotionally, socially, and intellectually positioned themselves within the learning process. The findings indicate that students' perceptions acted as an important mediating variable linking instructional practice to improved learning outcomes.

A dominant pattern emerging from the discussions was the perception that IK-based instruction reduced the abstract and foreign nature of ecology. Many students explained that ecological concepts became easier to understand when teachers connected scientific explanations with familiar indigenous practices These perceptions are significant because they demonstrate that learning occurred through contextualization rather than rote memorization. In conventional science classrooms, students often encounter ecology as detached theoretical content presented through textbook definitions and generalized examples that rarely reflect local realities. However, the IK-based strategy appeared to reduce this disconnect by situating scientific concepts within the sociocultural experiences of learners.

This finding strongly supports constructivist and sociocultural theories of learning. According to Ausubel's (1963) theory of meaningful learning, new knowledge becomes understandable when connected to learners' prior experiences and cognitive structures. In the present study, indigenous ecological practices functioned as cognitive anchors that enabled students to interpret abstract scientific ideas through familiar experiences. For example, when students linked traditional composting practices with nutrient recycling and decomposition, or connected terrace farming with soil conservation and ecosystem management, scientific concepts became cognitively accessible and easier to retain. The FGDs therefore suggest that IK promoted conceptual transfer by bridging the gap between prior cultural knowledge and formal school science.

The findings also support Vygotsky's (1978) sociocultural perspective, which emphasizes that learning is socially mediated and culturally situated. Students perceived the classroom not merely as a place for receiving information, but as a social environment where their home experiences and community knowledge were recognized as legitimate intellectual resources. This recognition appeared to strengthen learners' confidence and sense of belonging during classroom participation. In contexts such as Ethiopia, where school science is frequently perceived as western-oriented and culturally detached (Semela, 2010), the validation of IK is pedagogically significant.

The findings further revealed that students perceived the IK-based lessons as highly engaging and participatory. Unlike conventional teacher-centered instruction, the intervention involved collaborative discussions, inquiry-based activities, storytelling, group work, home-based investigations, and classroom presentations linked to local ecological practices. Students explained that these activities encouraged active participation because they could contribute ideas based on their lived experiences. This perception aligns closely with the quantitative findings of the study, where students exposed to IK-based instruction demonstrated significantly higher engagement scores than students taught through conventional methods. The large effect size reported in the quantitative analysis suggests that the instructional approach produced substantial practical improvement in classroom engagement. The qualitative findings help explain this statistical outcome by showing that students became more behaviorally, emotionally, and cognitively invested when classroom instruction reflected their cultural realities.

Behaviorally, students perceived that the instructional approach encouraged participation, questioning, and collaborative interaction. Emotionally, they described the classroom atmosphere as enjoyable, motivating, and less stressful than conventional science lessons. Cognitively, they reported that the lessons stimulated deeper understanding and reflection because ecological ideas were connected to real-life environmental practices. These findings reinforce Fredricks et al.'s (2004) multidimensional conception of engagement, which conceptualizes engagement as the integration of behavioral, emotional, and cognitive involvement in learning. The FGDs therefore demonstrate that IK-based instruction improved not only students' academic performance but also the quality of their classroom learning experiences.

Another important finding concerns the relationship between IK integration and students' attitudes toward ecology. Participants consistently reported that the lessons increased their interest and appreciation for ecology because the content reflected familiar environmental practices and community values. This perception corresponds with the quantitative findings showing significantly improved attitude scores among students in the experimental group. Students no longer viewed ecology as merely a difficult school subject; instead, they perceived it as relevant to environmental sustainability, agriculture, and everyday life within their communities. Such findings suggest that culturally responsive pedagogy can positively influence students' affective orientation toward science by increasing perceived relevance and reducing alienation.

The findings of the present study are consistent with several previous studies conducted in African and international science education contexts. Ugwu and Diovu (2016) reported that ethnoscience-based instruction improved students' motivation and classroom participation because learners could relate scientific concepts to cultural experiences. Similarly, Zidny and Eilks (2020) found that integrating indigenous contexts into science instruction helped students perceive science as more transparent, practical, and socially meaningful. The current findings extend these earlier studies by providing qualitative evidence from the Awi sociocultural context showing how IK integration reshapes students' perceptions of science learning.

Overall, the qualitative findings demonstrate that students perceived IK-based instruction as academically meaningful, emotionally supportive, culturally validating, and pedagogically engaging. These perceptions provide an important explanatory foundation for the quantitative improvements observed in achievement, attitude, and engagement outcomes. By bridging students' indigenous experiences with formal ecological science, the intervention transformed learning from abstract memorization into meaningful knowledge construction grounded in sociocultural reality.

5.4 Effect of IK-based instruction on students' attitude towards ecology

The findings of the present study revealed that students exposed to IK-based ecology instruction developed significantly more positive attitudes toward ecology than those taught through conventional lecture-based methods. The statistically significant difference in posttest attitude scores between the experimental and control groups indicates that the integration of IK into ecology instruction positively influenced students' affective orientation toward Biology. This finding demonstrates that the value of IK-based pedagogy extends beyond improving cognitive achievement; it also reshapes how students emotionally relate to scientific learning and how they perceive the relevance of ecology within their everyday lives.

The attitudinal improvement observed in the experimental group appears to be closely associated with the cultural relevance and contextual familiarity embedded within the instructional process. Unlike the conventional classroom, where ecology concepts were largely presented through abstract textbook explanations, the IK-based lessons connected scientific ideas with indigenous ecological practices familiar to students' home and community experiences.

In many Ethiopian science classrooms, students are often positioned as recipients of externally constructed scientific knowledge, while local ecological knowledge remains marginalized or excluded from formal instruction (Semela, 2010; Tadesse & Mehari, 2020). Such instructional disconnection can contribute to feelings of alienation, reduced confidence, and negative attitudes toward science. However, in the present study, students experienced a different pedagogical relationship with science. Indigenous ecological practices that students previously associated only with community life became recognized as scientifically meaningful within the classroom. This recognition appeared to generate feelings of pride, ownership, and emotional connection to ecology learning.

The classroom observations and FGDs strongly reinforce this interpretation. Students in the experimental group demonstrated visible excitement, curiosity, and enthusiasm during lessons involving indigenous examples. Several participants expressed surprise when they discovered that practices used by their parents and communities had scientific explanations related to ecology. These reactions suggest that the IK-based approach fostered epistemic recognition, where students perceived their local knowledge not as inferior to scientific knowledge, but as a legitimate foundation for understanding ecological concepts. Such validation likely contributed to stronger emotional engagement and more positive attitudes toward ecology.

The findings of this study are consistent with previous research demonstrating that culturally contextualized science instruction positively influences students' attitudes toward science. Shishigu et al. (2021), in the Ethiopian context, reported that integrating indigenous perspectives into Biology instruction facilitated smoother border crossing between students' everyday knowledge and formal science, thereby improving learners' attitudes and classroom participation. Similarly, Chongo and Baliga (2019) found that ethno-science-based instruction significantly enhanced students' attitudes toward physics because learners could connect scientific concepts with familiar cultural experiences. Abonyi (2002) also reported that ethnoscience instructional strategies increased students' interest and positive attitudes toward science by making abstract concepts more culturally meaningful and comprehensible.

The present findings further align with Mukuka (2019), who found that ethnobiology-based teaching improved both students' attitudes and academic performance in ecology-related topics. The current study extends these findings by demonstrating that positive attitudes emerged not only from conceptual understanding but also from emotional recognition and cultural inclusion.

However, the findings differ from studies by James (2006) and Ivowi (2014), which reported no significant improvement in student attitudes following culturally oriented instructional interventions. Several factors may explain these contradictions. First, the effectiveness of IK-based instruction depends largely on the depth and authenticity of integration. In some studies, cultural elements may have been included superficially without meaningful conceptual linkage to scientific content. In contrast, the present study employed a systematically designed instructional package where indigenous ecological practices were explicitly aligned with curriculum objectives, lesson activities, and classroom discussions. This structured integration likely strengthened the attitudinal impact of the intervention.

Second, contextual differences may also explain the divergence in findings. In the study area, indigenous ecological knowledge remains actively practiced within agriculture, environmental management, and community life. Students therefore possessed strong prior familiarity with many of the ecological examples used during instruction. This cultural proximity may have increased students' emotional identification with the content and strengthened their positive responses toward ecology learning. In contexts where indigenous practices are less visible or less socially valued, the attitudinal effects of IK integration may be less pronounced.

A critical reflection emerging from the findings is that conventional science instruction may unintentionally contribute to negative attitudes toward ecology by excluding learners' cultural experiences from classroom learning. In the control classrooms, ecology lessons were dominated by teacher explanations, note-taking, and textbook-driven instruction, with minimal opportunities for contextual discussion or learner participation. Observation findings indicated lower enthusiasm, reduced interaction, and passive learning behaviors among students in these classrooms. This suggests that decontextualized instruction may reinforce students' perception of science as difficult, distant, and disconnected from their everyday realities. By contrast, IK-based instruction appeared to humanize science learning and create emotionally supportive learning environments that promoted curiosity, confidence, and sustained interest.

The findings suggest an important interrelationship between attitude, engagement, and achievement. Students who developed positive attitudes toward ecology were also more likely to participate actively in classroom discussions, collaborate with peers, and demonstrate deeper conceptual understanding during lessons. This supports the argument by Craker (2006) and Adesoji (2008) that attitude functions as a motivational mechanism influencing engagement and academic success. In the present study, improved attitudes likely contributed indirectly to the higher engagement and achievement outcomes observed among students in the experimental group.

Overall, the findings demonstrate that IK-based instruction positively transformed students' attitudes toward ecology by making science culturally meaningful, emotionally engaging, and socially relevant. The integration of indigenous ecological practices into classroom instruction fostered curiosity, confidence, participation, and appreciation for ecology among learners. Unlike conventional approaches that often position science as detached from students' lived realities, IK-based pedagogy enabled students to perceive ecology as both scientifically valuable and culturally connected, thereby promoting more positive and enduring attitudes toward Biology learning.

5.5 Effect of IK on students' attitude towards ecology based on gender

This section of the study examined whether there was a statistically significant difference in the attitude scores of male and female students taught using an IK-based instructional approach. The results revealed that the difference in the mean attitude scores between male and female students was not statistically significant. This indicates that gender did not influence students' interest or attitude toward ecology when instructed through IK pedagogy. In essence, the IK-based approach proved to be equally effective for both genders, affirming its suitability for use in mixed-gender classrooms to foster interest across all learners. Additionally, the study found no significant interaction effect between teaching methods and gender on students' interest scores in ecology. In other words, gender did not mediate or modify the influence of the teaching method on students' attitudes toward ecology. Although the IK-based method demonstrated superiority over the conventional approach in enhancing interest for both male and female students, no interaction effect was observed between gender and instructional method.

These findings are consistent with those of Chongo and Baliga (2019), who found the ethno-physics instructional approach to be gender-inclusive. Their study reported that both male and female students in Zambia exhibited similarly positive attitudes when exposed to IK-based instruction, as the learning activities reflected culturally familiar practices evenly distributed across gender roles in households. Likewise, Collins et al. (2023) observed no significant difference in the mean interest scores of male and female senior secondary school students in agricultural science when taught using either an ethno-science teaching strategy or traditional lecture methods. Similarly, Ugwu (2018) reported that gender was not a significant factor in determining students' interest when exposed to an ethno-chemistry-based curriculum delivery strategy.

However, these findings contradicts with those of Peni (2015), who found that female students demonstrated significantly higher attitude scores than their male counterparts, attributing this to a greater affinity among females for culturally familiar practices used in the instructional process. Similarly, Abonyi (2002) noted that, while differences in mean scores between male and female students were not statistically significant, female students did exhibit slightly higher levels of interest. He posited that the integration of cultural practices more familiar to female students may have contributed to their enhanced engagement with science content.

Additional studies have also produced contradictory findings. For example, Nbina and Wagbara (2012) reported that female students demonstrated positive attitude towards physics. Conversely, Madu (2004) and Iweka (2006) found that male students held more favorable attitudes toward science subjects. Other scholars, such as Onimisi (2006) and Okeke (2007) concluded that gender had an insignificant effect on students' attitudes toward science.

Chang (2003) observed a narrowing gender gap in science performance but acknowledged that female representation in science remains comparatively low. This persistent issue of gender disparity in science interest has generated diverse and often contradictory findings across various educational contexts. As a result, the role of gender in shaping students' attitudes in science continues to be a subject of ongoing debate and inquiry within the field of science education.

In conclusion, the current study demonstrates that the IK-based instructional approach positively influenced students' attitudes toward ecology, irrespective of gender. While some prior studies highlight gender-based differences, the evidence here supports the assertion that culturally responsive pedagogy can serve as a gender-inclusive method to enhance interest in science education across diverse student populations.

5.6 Effect of IK-based instruction on students' engagement

One of the central objectives of this study was to examine whether the integration of IK into ecology instruction could improve students' engagement in classroom learning processes. The findings demonstrated that students exposed to the IK-based instructional approach achieved significantly higher engagement scores than students taught through conventional lecture method. Beyond statistical significance, the effect size indicated that instructional strategy explained a substantial proportion of the variation in engagement outcomes, implying that the intervention generated meaningful pedagogical change rather than marginal classroom improvement. The findings therefore suggest that IK-based instruction has strong potential to influence the behavioral, cognitive, and emotional dimensions of student engagement simultaneously.

The observed improvement in engagement appears to have emerged from the restructuring of classroom power relations and participation patterns. In the conventional classrooms, learning was largely organized around teacher explanation, textbook interpretation, and note-taking activities, where students functioned primarily as receivers of information. In contrast, the IK-based instructional environment repositioned students as contributors, interpreters, and negotiators of knowledge. This pedagogical shift altered the social dynamics of the classroom by legitimizing students' home experiences and community ecological knowledge within formal science learning. As a result, students became more willing to speak, question, argue, and participate because the instructional process acknowledged forms of knowledge already familiar within their sociocultural environment.

Importantly, the present findings suggest that engagement improvement was not merely a product of interest or entertainment. Rather, IK-based instruction appeared to enhance students' epistemic participation in science learning. Students were cognitively engaged because they were required to compare Indigenous explanations with scientific concepts, interpret ecological relationships critically, and contribute contextual examples during classroom discussions. This kind of engagement differs substantially from passive attentiveness often observed in lecture-based classrooms. It involved academic participation, interpretive reasoning, and collaborative meaning-making. The frequent student questions, peer debates, and contextual explanations observed during the intervention indicate that the classroom increasingly functioned as a dialogic learning community rather than a unidirectional instructional space.

The qualitative classroom observations further reinforce this interpretation. Students in the experimental group demonstrated sustained attention during lessons, volunteered examples confidently, and participated more actively in group tasks than students in the control group. This suggests that IK-based instruction reduced the psychological distance between learners and scientific knowledge. In many Ethiopian classrooms, students often perceive science as externally imposed and disconnected from local realities (Semela, 2010). Such perceptions can weaken participation because learners struggle to see the relevance of scientific ideas to their own experiences. However, when ecology concepts were linked with familiar practices such as soil conservation, compost preparation, watershed management, and biodiversity preservation, students appeared to develop a stronger sense of ownership over the learning process. The classroom became less hierarchical and more participatory because students recognized that they possessed valuable experiential knowledge relevant to scientific discussion.

These findings are consistent with studies emphasizing the role of culturally responsive pedagogy in strengthening student engagement. Anor et al. (2022) reported that IK-integrated Chemistry instruction enhanced students' concentration, inquiry behaviors, and collaborative problem-solving. Similarly, Fasuyi et al. (2022) found that science instruction connected to students' lived experiences increased classroom participation and sustained learner involvement. Devkota and Timilsena (2023) further observed that students perceived Indigenous-contextualized science instruction as more engaging because it allowed them to connect scientific ideas with local cultural practices. The present study extends these findings by demonstrating that the influence of IK is not limited to motivational stimulation alone; rather, it restructures how learners position themselves within the scientific learning process.

The findings also align with Ethiopian educational research highlighting the importance of contextual relevance in science teaching. Shishigu et al. (2021) found that integrating Indigenous perspectives into Biology instruction improved learner interaction and participation by making scientific concepts culturally accessible. Likewise, Semela (2010) argued that the alienation many Ethiopian learners experience in science classrooms is partly rooted in the exclusion of local knowledge and sociocultural realities from formal instruction. The current findings provide empirical support for this argument by showing that when students' cultural experiences are validated within classroom discourse, participation becomes more sustained, confident, and cognitively meaningful.

Nevertheless, the findings of this study differ from studies that reported limited effects of culturally responsive approaches on engagement and participation. For example, some studies conducted within highly examination-oriented educational systems found that culturally contextualized instruction did not significantly alter classroom participation patterns because teachers continued to prioritize syllabus coverage and memorization practices over interaction and inquiry. The divergence between such findings and the present study may be explained by differences in implementation fidelity, instructional design, and contextual relevance. In the current intervention, IK was not presented as supplementary cultural information added superficially to lessons; rather, it functioned as an organizing framework for teaching ecological concepts. Students actively investigated community knowledge, discussed Indigenous practices, and linked these practices with scientific explanations. This deeper level of integration may explain why the instructional approach generated stronger engagement outcomes than studies where cultural references remained peripheral.

Another important implication emerging from the findings is that IK-based engagement appears to operate through emotional validation and identity recognition. Students participated more actively not only because lessons were understandable, but because the instructional process legitimized their communities, languages, and environmental experiences within formal education. In contexts where school science traditionally privileges western knowledge systems while marginalizing local epistemologies, students may disengage because they perceive their cultural identities as academically irrelevant. The IK intervention appeared to challenge this hierarchy by demonstrating that local ecological knowledge possesses explanatory and educational value. Consequently, students became emotionally invested in classroom activities because participation no longer required abandoning their cultural realities at the classroom door.

From a pedagogical perspective, the findings challenge the continued dominance of transmission-oriented science teaching in Ethiopian schools. The evidence suggests that engagement in science education is not simply determined by student motivation alone, but also by the extent to which instructional approaches create opportunities for participation, dialogue, contextual interpretation, and cultural recognition. Conventional lecture-based methods may limit engagement because they position learners as passive recipients of externally produced knowledge. In contrast, IK-based pedagogy transforms learning into a socially negotiated and contextually meaningful process where students actively construct understanding through interaction between school science and community knowledge.

Overall, the study concludes that IK-based instruction significantly enhanced student engagement because it transformed ecology learning into a participatory, culturally situated, and intellectually interactive process. The instructional approach strengthened students' behavioral participation, emotional investment, and cognitive involvement by integrating scientific learning with socially meaningful ecological experiences. Through this process, students became active agents in knowledge construction rather than passive consumers of information. These findings therefore provide strong support for culturally responsive science pedagogy as an effective strategy for improving engagement and meaningful learning within Ethiopian secondary school science education.

5.7 Effect of IK-based instruction on students' engagement based on gender

One of the most important findings of the present study was the absence of a statistically significant interaction effect between gender and instructional strategy on students' engagement in ecology lessons. Although the IK-based instructional approach significantly improved overall engagement levels, both male and female students benefited in relatively similar ways from the intervention. The quantitative findings revealed that gender alone accounted for only a negligible proportion of the variance in engagement outcomes, while the interaction between gender and instructional strategy also demonstrated a very small effect size. This suggests that the effectiveness of the IK-based approach in enhancing engagement was largely independent of gender differences. In practical terms, the intervention created an inclusive learning environment in which both male and female students participated actively, demonstrated comparable levels of cognitive involvement, and showed similar emotional investment in ecology learning.

The finding also suggests that culturally responsive pedagogy may function as an equity-oriented instructional approach in biology education. The IK-based lessons intentionally incorporated examples and practices that reflected the collective ecological experiences of the community rather than relying solely on textbook-centered scientific representations. This inclusiveness may have strengthened students' sense of belonging within the classroom and reduced gender-based participation barriers. Observation findings support this interpretation, as both male and female students were observed contributing actively during group discussions, sharing local ecological examples confidently, and participating in classroom presentations without noticeable differences in enthusiasm or involvement.

The present findings are consistent with studies reporting that culturally contextualized instruction can reduce gender disparities in science participation and engagement. Ugwu and Diovu (2016), for example, found no significant gender differences in students' responses to ethnoscience-based instruction in Nigeria, concluding that culturally grounded teaching strategies create more inclusive learning environments. Similarly, Mohammed et al. (2014) argued that culturally responsive science instruction enhances participation among groups traditionally marginalized within science classrooms by validating their social identities and community experiences.

However, the findings differ from studies that reported significant gender variations in science engagement. King (2016) and Ayub et al. (2017), for instance, found that female students often demonstrate lower behavioral participation in science classrooms despite showing positive attitudes toward learning. Similarly, Nguyen (2018) observed that male and female students may engage differently depending on classroom structure and instructional design. The divergence between those studies and the present findings may be attributed to contextual and pedagogical differences. Many earlier studies were conducted in conventional or partially inquiry-based science classrooms where cultural relevance was not systematically integrated into instruction. In contrast, the current intervention intentionally incorporated learners' cultural experiences, local ecological practices, and collaborative inquiry processes into classroom activities. Such contextualization may have minimized the social and psychological barriers that frequently shape gendered participation patterns in science learning.

The findings also carry important pedagogical implications for science education in Ethiopia. The absence of gender differences suggests that IK-based instruction may serve as a practical strategy for promoting inclusive engagement in STEM-related subjects. By contextualizing science within local cultural realities, teachers may be able to increase participation among learners who might otherwise feel disconnected from school science. This is especially important in rural and culturally diverse settings where conventional science curricula are often perceived as abstract, externally imposed, and disconnected from students' everyday experiences.

Overall, the results indicate that the IK-based instructional approach enhanced student engagement in ecology without producing gender-based differences in participation or involvement. The intervention appears to have fostered an inclusive and culturally responsive classroom environment in which both male and female students experienced comparable opportunities for interaction, inquiry, and cognitive engagement. These findings reinforce the argument that meaningful science engagement can be strengthened when instruction recognizes students' cultural identities, values community knowledge systems, and creates participatory learning environments that are socially and culturally accessible to all learners.

CHAPTER SIX: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary of the study

This study investigated the effect of IK-based Biology instruction on Grade 8 students' achievement, attitude, engagement, and perceptions toward ecology in Injibara City, Ethiopia. In addition, the study examined whether the effectiveness of the instructional approach differed by gender and whether interaction effects existed between instructional strategy and gender across the dependent variables. The study further explored students' perceptions and classroom experiences regarding the implementation of IK-based ecology instruction. The investigation was guided by seven research questions and corresponding null hypotheses tested at the 0.05 level of significance.

Methodologically, the study employed a non-equivalent pretest–posttest control group quasi-experimental design within a concurrent embedded mixed-methods framework (QUAN+qual). Quantitative data constituted the dominant strand, while qualitative data were embedded to enrich and explain the statistical findings. Students in the experimental group were taught ecology using an IK-based instructional approach that integrated local ecological practices, Indigenous environmental knowledge, and culturally familiar examples into classroom instruction. In contrast, the control group received conventional teacher-centered instruction. The intervention lasted six weeks. Data were collected using the EAT, EAQ), EEQ, FGDs, and classroom observation protocols. Quantitative data were analyzed using descriptive statistics and inferential techniques, including independent samples t-tests and one-way and two-way ANCOVA, whereas qualitative data were analyzed thematically.

Concerning students' academic achievement in ecology, the findings revealed that students exposed to IK-based instruction achieved significantly higher posttest scores than those taught through conventional methods, even after controlling for pretest differences. The results demonstrated that integrating Indigenous ecological examples and culturally familiar environmental practices enhanced students' conceptual understanding of ecological concepts. The instructional strategy enabled learners to connect scientific ideas with their lived experiences, thereby facilitating meaningful learning, deeper comprehension, and improved academic performance. The findings suggest that IK-based instruction functioned as a cognitive bridge between school Biology and students' everyday ecological realities.

Regarding gender differences in achievement, the findings showed no statistically significant difference between male and female students taught through the IK-based instructional approach. Similarly, no significant interaction effect was found between instructional strategy and gender. This indicates that the effectiveness of the IK-based approach in improving ecology achievement was not dependent on gender. Both male and female students benefited equally from the culturally contextualized instructional environment, suggesting that IK-based pedagogy provides an inclusive and equitable framework for Biology learning.

With respect to students' attitudes toward ecology, the study found that learners in the experimental group developed significantly more positive attitudes toward ecology than students in the control group. The IK-based approach increased learners' interest, appreciation, and emotional connection to ecological concepts by presenting Biology content through culturally relevant and familiar contexts. Students perceived ecology as more meaningful, practical, and connected to their community experiences. Consequently, the instructional strategy improved learners' motivation and reduced the perception of Biology as abstract and difficult.

Similarly, the findings regarding attitude based on gender revealed no statistically significant difference between male and female students. The interaction between gender and instructional strategy was also not statistically significant. These findings imply that the IK-based instructional approach was equally effective in fostering positive attitudes toward ecology among both genders. The culturally inclusive nature of the instructional activities appears to have minimized gender-related disparities commonly associated with science learning environments.

In relation to student engagement, the findings demonstrated that students taught using the IK-based approach exhibited significantly higher levels of behavioral, emotional, and cognitive engagement compared to students taught through conventional instruction. Classroom observations and quantitative results consistently showed that the experimental group participated more actively in discussions, collaborative learning activities, problem-solving tasks, and classroom interactions. The integration of Indigenous ecological practices and community-based examples increased students' curiosity, classroom participation, sustained attention, and willingness to contribute to learning activities. The findings indicate that IK-based instruction transformed students from passive recipients of information into active participants in the learning process.

Concerning engagement based on gender, the results indicated no statistically significant difference between male and female students' engagement levels within the IK-based instructional environment. In addition, no significant interaction effect was observed between gender and instructional strategy. This suggests that the IK-based approach promoted equitable participation and involvement among both male and female learners. The culturally responsive nature of the instructional activities may have reduced traditional gender barriers associated with science classroom participation.

The qualitative findings obtained through FGDs and classroom observations further enriched and validated the quantitative results. Students in the experimental group consistently reported that IK-based instruction made ecology lessons more understandable, interactive, relevant, and enjoyable. Participants emphasized that the use of local examples, Indigenous environmental practices, familiar cultural experiences, and community knowledge enabled them to relate classroom learning to their daily lives. Many students reported increased confidence, improved participation, and stronger interest in ecology lessons because the instructional approach acknowledged and valued their cultural backgrounds and lived experiences.

The qualitative findings also revealed that students perceived the IK-based approach as more collaborative and learner-centered than conventional methods. Students appreciated opportunities to discuss local ecological issues, share community knowledge, and engage in group-based learning activities. Classroom observations confirmed higher levels of peer interaction, questioning behavior, attentiveness, and sustained engagement during IK-based lessons. These findings suggest that students' perceived IK integration not merely as an alternative teaching technique, but as a meaningful and culturally responsive learning experience that enhanced both their understanding of ecology and their sense of inclusion within the science classroom.

Overall, the findings of this study demonstrate that IK-based Biology instruction positively influenced students' achievement, attitudes, engagement, and perceptions toward ecology. The study further established that the instructional approach benefited male and female students equally, with no significant gender interaction effects observed across the measured variables. The convergence of quantitative and qualitative findings provides strong evidence that integrating IK into ecology instruction can improve the relevance, inclusiveness, and effectiveness of Biology education within culturally diverse educational contexts such as Ethiopia.

6.2 Conclusion

This study investigated the effect of IK-based Biology instruction on Grade 8 students' achievement, engagement, and attitude, toward ecology in Injibara, Ethiopia. It also examined whether the effectiveness of the instructional approach varied by gender. Using a mixed-methods quasi-experimental design, the study generated both quantitative and qualitative evidence regarding the educational value of integrating Indigenous ecological knowledge into formal Biology instruction.

The findings of the study demonstrated that students who learned ecology through IK-based instruction performed significantly better academically than students taught through conventional teacher-centered methods. The integration of culturally familiar ecological practices into classroom instruction enabled students to connect abstract scientific concepts with real-life environmental experiences. This contextual linkage enhanced conceptual understanding, interpretation of ecological relationships, and meaningful learning. The findings suggest that IK-based instruction functions as an effective pedagogical bridge between learners' sociocultural experiences and formal scientific knowledge, thereby improving achievement in ecology.

The study further established that IK-based instruction positively influenced students' attitudes toward ecology. Students exposed to the intervention developed more favorable dispositions toward Biology learning than those in the control group. The culturally relevant nature of the instructional examples appeared to reduce learners' perception of ecology as abstract or foreign and instead promoted a sense of relevance, familiarity, and personal connection with the subject matter. The findings indicate that when students recognize their community knowledge and environmental practices within school science, they become more interested, motivated, and emotionally connected to learning.

Similarly, the results confirmed that IK-based instruction significantly enhanced students' classroom engagement. Students in the experimental group demonstrated higher levels of behavioral participation, emotional involvement, and cognitive investment during ecology lessons. The instructional activities encouraged interaction, collaborative learning, questioning, observation, reflection, and discussion, which transformed students from passive recipients of information into active participants in knowledge construction. The study therefore concludes that IK integration promotes learner-centered classroom environments that strengthen participation and sustained engagement in Biology learning.

The qualitative findings further revealed that students perceived the IK-based instructional approach positively. Learners reported that ecology lessons became more understandable, meaningful, interactive, and connected to their everyday lives. Students particularly valued the inclusion of local ecological practices, Indigenous environmental knowledge, and culturally familiar examples in classroom instruction. These perceptions suggest that IK-based instruction enhances learners' sense of identity, belonging, and confidence within science classrooms. The findings also indicate that students viewed Indigenous knowledge not as separate from science, but as complementary to scientific understanding.

Regarding gender, the study found no statistically significant differences between male and female students in achievement, attitude, or engagement under the IK-based instructional approach. Likewise, no significant interaction effects were observed between gender and instructional strategy across the major dependent variables. These findings suggest that the IK-based approach provided an inclusive and equitable learning environment that benefited both male and female students similarly. The instructional strategy appeared to minimize traditional barriers associated with science learning by utilizing culturally accessible and socially shared knowledge systems familiar to all learners.

Taken together, the findings demonstrate that the integration of IK into Biology instruction produces a holistic educational impact. Rather than improving only academic performance, the approach simultaneously strengthened students' cognitive understanding, emotional connection, classroom participation, and perceptions of science learning. The interrelationship among these variables suggests that meaningful learning occurs more effectively when instruction is culturally contextualized and socially relevant. Improved perceptions enhanced engagement; increased engagement supported conceptual understanding; and stronger understanding contributed to improved achievement and positive attitudes toward ecology.

Overall, this study concludes that IK-based Biology instruction is an educationally effective, culturally responsive, and gender-inclusive pedagogical approach for teaching ecology in Injibara middle schools. The findings provide empirical support for integrating Indigenous ecological knowledge into formal science education as a means of improving both the quality and relevance of Biology learning. The study therefore underscores the importance of aligning school science with learners' sociocultural realities in order to promote meaningful, participatory, and sustainable learning outcomes.

6.3 Recommendations

Based on the major findings of this study, several practical and strategic recommendations are proposed to improve the quality, relevance, and inclusiveness of Biology education through the integration of IK. The recommendations are directed toward teachers, curriculum developers, schools, teacher education institutions, universities, policymakers, and researchers.

1. Recommendation for teachers

Biology teachers should integrate locally relevant Indigenous ecological knowledge into classroom instruction to improve students' achievement, engagement, attitudes, and conceptual understanding. Rather than relying solely on textbook-based explanations, teachers should use familiar environmental practices and community experiences to explain ecological concepts. Teachers are encouraged to use local examples such as terrace farming, compost preparation, soil conservation, agroforestry, traditional weather prediction, and biodiversity management when teaching ecology; Such practices can help learners connect scientific concepts with their lived experiences, thereby improving meaningful learning and sustained classroom engagement.

2. Recommendation for schools and educational leaders

Schools should establish formal partnerships with local communities to support the integration of IK into science education. Since the study found that students learned more effectively when community knowledge was incorporated into instruction, schools need mechanisms that allow local ecological knowledge holders to contribute to educational activities. For example school principals and cluster supervisors should invite local elders, farmers, herbal practitioners, and environmental experts to share Indigenous ecological practices relevant to Biology topics.

3. Recommendation for curriculum developers and textbook writers

The findings revealed that students achieved better learning outcomes when ecological concepts were linked with culturally familiar examples. Therefore, curriculum developers should move beyond superficial references to local contexts and systematically integrate IK into the formal Biology curriculum and textbooks. Specifically, illustrations, case studies, and exercises in the text books should reflect local cultural and environmental realities. Curriculum content should balance scientific concepts with culturally relevant applications to support contextualized learning. This would help to reduce the disconnect between school science and students' sociocultural experiences.

4. Recommendation for teacher education Colleges and Universities

Teacher education institutions should strengthen pre-service and in-service training on culturally responsive pedagogy and IK integration in science education. The findings of this study demonstrate that effective IK-based instruction requires teachers who are pedagogically prepared to connect scientific knowledge with local cultural contexts. Teacher education colleges and universities should therefore:

- Incorporate courses and training modules on IK systems, culturally responsive pedagogy, and contextualized science teaching into teacher education programs;
- Train pre-service Biology teachers to design IK-integrated lesson plans and classroom activities;
- Encourage action research and practicum experiences focusing on local ecological knowledge integration;

5. Recommendation for the ministry of education and regional education offices

The successful implementation of IK-based instruction requires clear policy direction and institutional support. The Ministry of Education (MoE) and Regional Education Offices should therefore establish frameworks that promote the integration of IK into science education at different educational levels. Specifically, policymakers should develop national and regional guidelines for integrating IK into science teaching and curriculum implementation; They should also support curriculum reforms that emphasize contextualized and learner-centered approaches to Science education. Such policy support is essential for ensuring the sustainability and wider implementation of IK-based pedagogy in Ethiopian schools.

6. Recommendation for researchers:

This study focused on Grade 8 ecology instruction in Injibara city administration. Further research is needed to expand understanding of the educational impact of IK integration across different contexts and disciplines.

Future researchers should:

- Conduct longitudinal studies to examine the long-term effects of IK-based instruction on retention and scientific literacy;
- Investigate the effectiveness of IK integration in other science subjects such as Chemistry and Physics;
- Explore teachers' perceptions, readiness, and challenges regarding IK integration;
- Compare IK-based instructional practices across different cultural and linguistic communities in Ethiopia; and
- Examine how IK integration influences environmental awareness, conservation behavior, and critical thinking skills.

Such studies would contribute to the development of evidence-based culturally responsive science education policies and practices.

Overall, the findings of this study suggest that IK should not be treated as supplementary cultural content but as an important pedagogical resource for improving science learning. Integrating IK into Biology education can enhance students' academic achievement, engagement, attitudes, and perceptions simultaneously while promoting culturally meaningful and inclusive learning environments. Therefore, stakeholders at all levels of the Ethiopian education system should work collaboratively to institutionalize culturally responsive and context-based science instruction.

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Appendices

Appendix A: ecology achievement test

Department of Science and Mathematics Education

Ecology Achievement Test for Grade Eight Students

Dear students;

The purpose of this test is to assess students' academic achievement in ecology and environmental conservation. The results of this assessment will be used solely for research purposes and may contribute to improving the teaching and learning of the concept ecology in middle school science education.

All information provided will be treated with strict confidentiality. Students' responses will be used only for academic research, and no individual student will be identified or evaluated based on the results.

Please read the following instructions carefully before beginning the test:

1. Answer all questions honestly and to the best of your ability.
2. Do not write your name on the test paper.
3. Each question is a multiple-choice item with four alternatives (A–D). Choose the one best answer and circle the corresponding letter.
4. Each correct answer carries one (1) mark. There is no penalty for incorrect answers.
5. Attempt all questions. Unanswered items will be scored as incorrect.
6. The total time allowed to complete the test is 50 minutes.

Please complete the following information accurately:

Gender: ☐ Male ☐ Female

Section: ___________________

Group: ___________________

Code______________________

1. Which of the following human activities contributes most to the extinction of wildlife species?

A. Selective farming B. Illegal hunting

C. Seasonal migration D. Soil conservation

2. Which of the following is NOT a benefit of biodiversity?

A. Source of medicine B. Agricultural sustainability

C. Ecotourism D. Deforestation

3. Which component of an ecosystem shows a unidirectional flow?

A. Nitrogen B. Carbon

C. Phosphorus D. Energy

4. All plants, animals, and microorganisms living together in Munesa Forest are best described as a:

A. Population B. Community

C. Ecosystem D. Biome

5. Which practice would most positively affect biodiversity conservation in Ethiopia?

A. Overgrazing rangelands B. Logging for fuel wood

C. Protecting natural habitats D. Clearing forests for farming

6. Which conservation strategy ensures the protection of soil, plants, water, and wildlife together?

A. Wildlife conservation B. Soil conservation

C. Plant conservation D. Watershed conservation

7. Which of the following is NOT a role of microorganisms in ecosystems?

A. Decomposition B. Nitrogen fixation

C. Energy recycling D. Nutrient cycling

8. Which ecological interaction is harmful to at least one organism involved?

A. Mutualism B. Commensalism

C. Competition D. Cooperation

9. Growing legumes in crop rotation mainly improves soil levels of:

A. Carbon B. Sulfur

C. Nitrogen D. Phosphorus

10. Nitrogen-fixing bacteria are found mainly in the:

A. Root tips B. Root hairs

C. Root nodules D. Root caps

11. Organisms at the third trophic level are classified as:

A. Primary consumers B. Secondary consumers

C. Producers D. Decomposers

12. Which one is the largest ecological unit?

A. Population B. Community

C. Ecosystem D. Biome

13. The primary long-term benefit of Ethiopia's tree-planting initiatives is that they:

A. Increase global temperature B. Reduce atmospheric carbon dioxide

C. Destroy natural habitats D. Increase ozone depletion

14. Green plants help reduce the greenhouse effect mainly by:

A. Releasing oxygen B. Removing carbon dioxide from the atmosphere

C. Increasing evaporation D. Producing heat

15. Which combination is best improves and maintains soil fertility?

A. Crop rotation only B. Manure application only

C. Mixed farming only D. All of the above

16. Which statement about the nitrogen cycle is correct?

A. Animals fix nitrogen directly from air B. Plants obtain nitrogen mainly through animals

C. Animals depend on plants for nitrogen D. Nitrogen is permanently removed from soil

17. Which of the following is a biotic factor in an ecosystem?

A. Rainfall amount B. Soil type

C. Carnivorous animals D. Air pressure

18. Which process removes carbon dioxide from the atmosphere?

A. Respiration B. Combustion

C. Decomposition D. Photosynthesis

Answer the following questions based on the food chain and the trophic level below

Maize → Mouse → Snake → Hawk

19 Which organism forms the base of the trophic pyramid in the food chain shown above?

A. Hawk B. Snake

C. Mouse D. Maize

20 Why is maize placed at the base of the trophic pyramid?

A. It is the largest organism in the food chain B. It produces its own food using sunlight

C. It eats other organisms D. It lives the longest

21 If 10,000 kcal of energy are available at the maize level, approximately how much energy will be available to the snake, assuming 10% energy transfer between trophic levels?

A. 1,000 kcal B. 100 kcal

C. 10 kcal D. 10,000 kcal

22 Which of the following best explain why energy decreases as it moves up the trophic pyramid?

A. Energy is destroyed at higher levels B. Organisms do not eat enough food

C. Energy is lost as heat through metabolism D. Producers store energy underground

23 A student who avoids littering in rivers demonstrates:

A. Academic achievement B. Environmental responsibility

C. Scientific investigation D. Economic awareness

24 Which belief best supports biodiversity conservation?

A. Nature exists only for human use B. Wildlife should be exploited freely

C. Humans depend on healthy ecosystems D. Conservation limits development

25. A student applies conservation knowledge practically by:

A. Reading about soil erosion B. Writing notes on ecosystems

C. Practicing terracing on farmland D. Discussing biodiversity in class

Thank you very much for your time

Appendix B: Table of specifications (blueprint) for EAT

Ecology Content Areas	Curriculum Learning Objectives	Remembering	Understanding	Applying	Analyzing	Total Items	Weight (%)
Ecosystem Components and Interactions	Identify biotic and abiotic components and explain their interactions	2	2	1	1	6	24%
Food Chains and Energy Flow	Describe food chains/webs and explain energy transfer in ecosystems	1	2	1	1	5	20%
Biodiversity and Conservation	Explain biodiversity importance and conservation methods	1	2	1	1	5	20%
Soil Fertility and Nutrient Cycling	Describe nutrient recycling and indigenous soil management practices	1	1	2	1	5	20%
Environmental Problems and Ecological Balance	Analyze causes and effects of environmental degradation and conservation strategies	1	1	1	1	4	16%
Total		6	8	6	5	25	100%

Appendix C: Biology attitude questioner

I. English version

Introduction

The purpose of this questionnaire is to assess students' attitudes toward ecology and conservation. The findings generated from this instrument will contribute to understanding students' affective responses to ecology instruction and may inform strategies for improving learning outcomes in upper primary and middle school Biology.

All information provided will be treated with strict confidentiality. No individual student will be identified, and responses will be used solely for research purposes.

Instructions

Please read each statement carefully and respond honestly based on your own feelings and experiences.

1. You are not required to write your name on this questionnaire.
2. For each statement, indicate the extent to which you agree or disagree by placing a cross (X) on **one** option only.
3. There is no right or wrong answers; what matters is your honest opinion.
4. Please respond to **all** items.

Section A: Demographic Information

Gender: ☐ Male ☐ Female

Section: ____________

Group: ____________

Code______________

Response Scale

The following five-point Likert scale is used throughout the questionnaire:

Strongly Disagree	1 (SD)
Disagree	2 (DA)
Not Sure	3 (NS)
Agree	4 (AG)
Strongly Agree	5 (SA)

Please indicate your level of agreement for each statement by marking the appropriate number indicated in the column.

ITEMS		SCALE				
		SD	DA	NS	AG	SA
		1	2	3	4	5
1	Ecology is one of my favorite topics.					
2	I am confident that I can perform well in ecology.					
3	Learning ecology through ethno-biology is interesting.					
4	I like ecology more than other Biology topics.					
5	I would like to have ecology lessons more often.					
6	Ecology fascinates me.					
7	Doing ecology-related activities is enjoyable.					
8	I would like to become an ecologist after completing secondary education.					
9	I would be happy if ecology were removed from the school curriculum.					

10	I feel unhappy whenever I miss an ecology lesson.					
11	Ecology is difficult to understand.					
12	When I hear the word “ecology,” I feel happy.					
13	I often have difficulty understanding what I learn in ecology.					
14	Ecology is one of the easiest Biology topics for me.					
15	I like my Biology teacher.					
16	Learning about ecology is important to me.					
17	Understanding ecology improves my quality of life.					
18	It is important to take care of the environment.					
19	Ecology helps make the world a better place to live in.					
20	Working with ecology topics upsets me. †					
21	Ecology helps develop my conceptual thinking skills.					
22	Knowledge of ecology is important for my future career.					
23	Progress in ecology improves the quality of human life.					
24	Ecology is useful for solving everyday life problems.					
25	Ecology helps me understand today’s world better.					

(Adapted from Mukuka, 2019; Abonyi, 1999)

Thank you very much for your time and cooperation.

II. Awgni version

ባዮሎጂ ካንቲው(Attitude) ፁፍ ካሲ (ሊካርት ስኬል) ባርዳር ዩኒቨርሲቲ ሳይንሱስታ ይሳቡ ክንቲው ዲፓርትሜንት ቤን ሶኼታኒ ቤን ክንታንትካው ካንቲው ፁፉ ካሲ

ቱፂ

እን ፁፍ ካሲው አላሚ ክንታንትካ ኢኮሎጂስስታ ማንዲሻስ ፃይኑሳ ካንቴ ቻውሳ ሴቴፍሻኘ ጋማጋምኜኽ። ክንታንትካ ክንቲስ ፃይኑ ካንቲ ቻው ጂትሻኚዳ፣ ሴቴፍኚዳ እስታ ክንቴ ኻልትስ እርዳትስሻዳ ቻኒስቴ ፌቴራው ያኺኒስ ማልኜ ዋሴናንቲ ጉዳዬኽ። እን ንባራ ኩፐፂዴስ ፍልቻንኩ አግስትካ ክንታንትካ ኢኮሎጂው ክንቲስ ፃይኑ ይጋንቴ ዙርፄ እርዳትስሻስ አጌዜ፤ ክቻክቺው ክንቲሻናሱ ባይሎጂው ክንቲው ዋይምካዋ ኬሽሻፅሻስ ካሊፃንኩ ሴልካዋኪላ አቾፄ። ክንታንትካ እንቶጂ ይቱንኩሳ ንባርካዋ ስርኩኒስ እምስትካማ ፅናትስስታ ምርምሪው ቴግባር ይቪቺስ አጌሌጌላንኩ ያኼኒስ እፐሎላ ዙርፄ (ንባሮ) እይኽ ክንታንቲ ሺሽስታቲው ያኺኒክላ ቼሜትሻፃ።

ሜሜሪ

ቻራ ቻራ ጊሌፅፄ ትንካኪስ አንቤብቱንዴስ ፋሌንጋ ኩው እንኩዋኽስትካስታ ዴስካዳ ሜሴሬትስትሻስ ክችክቼ ዙርፄ እይ።

1. እን ፁፍ ካሲዳ ኩሳ ስሞ ፃፊሻ ቢኪስታላኽ።
2. ቻራ ቻራ ዴብቴርት እንት አስሜምሻታውሳ አኺኪ አስሜምቻቲውሳ ልኪቴ (×) ምልኻቶ ቴኬምስትሻስ ዙሪፅ።
3. ክችክቺ አኺኪ ክችክቻ ጋው ዙርፂ እላኽ። ዲብ ኩፂ ኩስ ፄጌራውሳ ካንቴ እይኜኽ።
4. አዴር ውላስጊ ካስካስ ዙርፄ እይ።

   ቤን A. ትክላሊ ንባር

ፆቲ፡ ሻርጂ ☐ ኹና ☐

ሴክሽን፦ _______________

ኬች፦ __________________

ኮድ፦__________________

ዙርፂ ስኬል (ልኪቲ)

ሲፋው አንኩዋ ትኩሚ ዌና ሊካርት ስኬል እን ፁፉ ካሲዳ ዋኽስ ዋኾ ትክምዳ እሽኹዌኽ

ማልኜ አስሜምፓላ (1)

አስሜምፓላ (2)

እርግቲኒ ጋቲኻኽ (3)

አስሜምኜ (4)

ማልኜ አስሜምኜ (5)

ፓራ ፓራ ጌሌፅካስ (ካስካስ) ቢኪስትኹ ቼፉ ስርዳ (×) ምልኻቶ እንኩርሻስ አስሜምኙኽሳ አቾ ምልኻት።

ቼፍ	ካስካ	ስኬል				
		1	2	3	4	5
1	ኢኮሎጂ አን እንካናኩ ክንቲኩ እምካዴስ እፓሊያኽ።					
2	ኢኮሎጂዳ ጉዶ ዋይሜ አግፅሻስ ካላኻ ያኺኒስ እርጊቲኒያኽ።					
3	ኢኮሎጄ ኢትኖ- ባይሎጄ ቴኬምስታማ ክንትሻ ዴስፃውያኽ።					
4	ኢኮሎጄ እሊኩ ባይሎጂኩ እምካዴስ ኽስኹስ አን እንካኔ።					
5	ሚንቾ ጊዝ ኢኮሎጂው ክንቲ ዝኩዋታ አን እንካኔ።					
6	ኢኮሎጂ እያ ዴስፄ።					
7	ኢኮሎጂሊ እምትኙንኩ ቴግባርካዋ አኮሜችሻ ዴስፄ።					
8	ክንቴ ውቴንዴስ ፋሌንጋ ኢኮሎጂው ሞይቲኑ አኽ□ ፋቴ።					

9	ኢኮሎጂ ክንቲ ሻናው ክንቲው ቴርታዴስ ፉኒ አን ዴስቴና አቼ።					
10	አን ኢኮሎጂውሳ ክንቴ አትኹ ቼፉ ዴስቴና ጋቲኻኽ።					
11	ኢኮሎጂ እርዳትስትሻስ ቼጌርዬኽ።					
12	“ኢኮሎጂ” ናውሳ ካሎ እንኮኻኒ አን ዴስቲኔኽ።					
13	ሚቺኒ ጊዝስ አን ኢኮሎጃኻዳ ክንትኹሳ እርዳትስትሻስ ቼጌርስቴ።					
14	ኢኮሎጂ እያስ ማልኜ ሳሴር ያኹኽ ክንቲው እሜኽ።					
15	አን ይው ባይሎጂውሳ ክንፅፃንቴ እንካኔኽ።					
16	ኢኮሎጂ ካንትፅኹሳ ክንትሻ እያስ ፋይፃንቴኽ።					
17	አን ኢኮሎጂ እርዳትስሻስ ይው ይዋቱሳ ፃንኩቶ ኬሽሻዬ።					
18	ዙራሙሬ አንኬባኬብሻ ፋይፃንቴኽ።					
19	ኢኮሎጂ አሌሞ ኬሽኹኽ ዝኩፂ ስፍሬ ዬውሻስ አጌዜ።					
20	ኢኮሎጂው ጉዳይካሊ እንፃኽሽሻ እያ ማቕችዬ።					
21	ኢኮሎጂ ይው አሳብ -ምሻው አሴብሺው ካሌቕታሳ አድርፅሻስ አጌዜ።					
22	ኢኮሎጂው አቕት ይው ፍንሾሱ እንፅኪስ ቴኬማንቴኽ።					
23	ኢኮሎጂስ ኬሽሻሻ አቒ ጄራው ይዎቱ ፃንኩት ኬሽፓታ እርዳቴ።					
24	ኢኮሎጂ እሌት ቺፋ እይዎቱ ችግርካዋ ኽይሻስ ቴኬሜ					
25	ኢኮሎጂ ናኪኔ አሌሞ ኬሽሻኹስ እርዳትስትናታ አጌዜ።					

(Mukuka 2019, ስታ Abony, 1999, ናውዴስ ካፅስትኹ)

ይቱኑ ጊዝዝ ስታ ዬውቱኑ ቲቪቪርኚስ ማልኜ አሜሴጌኔ!

Appendix D: Biology engagement questioner

I -English version

Introduction

The purpose of this questionnaire is to assess students' levels of engagement in ecology and conservation lessons. The information obtained from this instrument will contribute to understanding how instructional approaches—particularly Indigenous Knowledge (IK)–based teaching—influence students' engagement in Biology. The findings of this study may help improve teaching and learning practices in ecology at the upper primary and middle school levels.

All information provided through this questionnaire will be treated with **strict confidentiality**. No individual student will be identified, and responses will be used **solely for academic research purposes**. Participation is voluntary, and there is no right or wrong answers. You are encouraged to respond honestly, as your responses will not affect your academic standing in any way.

Please read each statement carefully and indicate the extent to which you agree or disagree by placing a cross **(x)** in **one box only** that best represents your opinion.

1. Do **not** write your name anywhere on this questionnaire.
2. Respond to **all** items; do not leave any statement unanswered.
3. Select only **one response option** for each statement.
4. There are no correct or incorrect answers; your honest opinion is important.

Section A: Demographic Information

Gender: ☐ Male ☐ Female

Section: ___________________

Group: ___________________

Code___________________

Response Scale

For each statement, use the following scale to indicate your level of agreement:

1 Strongly Disagree (SD)

2 Disagree (DA)

3 Not Sure (NS)

4 Agree (AG)

5 Strongly Agree (SA)

Please place a cross (✗) in the column corresponding to your choice for each statement in the table provided.

Items		Scale				
		SD	DA	NS	AG	SA
		1	2	3	4	5
Behavioral Engagement (Observable participation, effort, persistence, and involvement in learning activities)						
1	It was easy to follow the instructions during ecology lesson.					
2	I understood what is expected from me during ecology lesson.					
3	I pay more attention during ecology lesson.					
4	I actively participate in ecology class discussions.					
5	I make a summary of material learnt in class.					
6	I discuss course content, ideas, and facts with the teacher outside of the classroom.					
7	I talk to my teacher about my progress in the class.					
8	I try to take notes on key points in ecology classroom.					
9	I work hard when we start something new in ecology class.					

10	I often review my class notes.					
	Emotional Engagement(Interest, enjoyment, curiosity, value, and affective reactions to learning)					
11	The ecology lesson felt meaningful for me.					
12	I enjoyed ecology-based activities.					
13	Participating in ecology practical is enjoyable to me.					
14	I do not enjoy reading ecology part from Biology texts. *(negatively worded)*					
15	When we work on something in ecology classroom, I feel interested.					
16	I feel curious about what we are studying when I am in ecology classroom.					
17	I do not want to waste my time on working ecology quiz. *(negatively worded)*					
	Cognitive Engagement (Strategic learning, self-regulation, deep processing, and metacognition)					
18	I am able to apply the concept learnt in relevant situation.					
19	When I am doing work in ecology, I try to relate what I am learning to what I know.					
20	I develop my own examples to help myself understand the concepts in ecology.					
21	Before I begin to study ecology, I think about what I want to get done.					
22	If what I am working on is difficult, I change the way I learn the materials.					
23	I try to connect different topics from course material while studying.					

24	I try to connect what I am learning to things I have learned before.					
25	I combine ideas from various course contents to complete assignments.					

(*Adapted from Pierre, 2022*)

Thank you very much for your time and cooperation

II. Awgni version

ባይሎጂው ሲፍትኂው (Engagement) ፁፉ ካስካ

ባርዳር ዩኒቨርሲቲ ሳይንሱስታ ሂሳቡ ክንቲው ዲፓርትመንት

ቱፂ

እን ፁፍ ካሲው አላሚ ክንታንትካ ኢኮሎጂስስታ ማንዲሻስ ፃይኑሳስታ ፄውኑሳ ሲቲፍኂው አችካዋ ካማጋምኚያኽ። እን ንባራኩፕፂዴስ አግስቱኽ ንባር ክንፅፅኙ ሴልካ አጌር አቅትዳስታ ክንታንትካው ባይሎጂው ሲቲፍኂዳ ቻኒስቶ ፌቴራው ያኪኔ ቼሜትሻፅሻሲያኽ። እን ፅናቱ አግስትካ ክንቲሻናዳ ኢኮሎጂው ክንቲው ክንትሻ ክንፅፅኙ ዴስካዋ ኬሽሻፅሻስ አጌዜ። እንቶጂ እይቱንኩ ውላጊ ንባርካ ስርኩኒስ እምስትካማ ፅናትስስታ ምርምሪው ቴግባር ይቢቺስ እሼንኩዌኽ።

ቹፍ	ካስካ	ስኬል				
		1	2	3	4	5
	ባይሪው ሲቲፍኚ (ክንቲው ቴግባራኻዳ ካንፅስታው ሲቲፍኚ ፣ፅሬቶ፣ፅናት ስታ ሲፍሻኚ)					
1	ኢኮሎጂው ክንቲ ጉዝማ ሜሜርካዋ ሲፍሻ ሳሴር እሺኮ።					
2	ኢኮሎጂው ክንቲ ጉዝማ ይዴስ እንዳር ማንዲስታው ያኪኔ አን እርዳትስታ					
3	ኢኮሎጂው ክንቲ ጉዝማ አን ኽሱኽሻ ትኩቶ እዬ።					
4	ኢኮሎጂው ቤኑ ኩስኂዳ አን ንካትስ (ፅንግስ) ሴቴፍኜ።					
5	ቤናኻዳ ክንትኹ ክንቲስ አን ቴክሌልሻፄ እዬ					
6	ቤንሴጋዳ ክንቲውሳ እሜስታ አሳቦ አን ክንፅፃንቲሊ ኩስሻኜ					
7	ይውሳ ቤናኻሱሳ ኬሽሻኜ ክንትኹስ አን ክንፅፃንቲሊ ዲብስኜ።					
8	ኢኮሌጂው ቤናኻዳ ቹዋ ትኩምካዋ ታክስፄ እሚሻስ ሞኬሬ።					

9	ኢኮሎጂውሳ ቤናኻዳ እስካዌ ዲቦ ጄሜርኑስ ይሳታ እንፃኽስቴ።					
10	ይኩ ቤኑ ታክስትካዋ አን ሚንቾ ጊዞ ጋማጋሜ።					
እንኩዋኽስቱ ሲቲፍኚ (ፋይ፣ዴስቲ፣አቕኙ ፋይ፣ ዋይሚ እስታ ክንቲስ ፃይኑ እንኩዋኽስቱ ዙርፅካ)						
11	ኢኮሎጂው ክንቲ እየስ ኽይ ዝኩኽ ያኻማ እንኩዋኽስቴ።					
12	ኢኮሎጂዳ ስርቱንኩ ልቕልቕትካዋ አን እንካኔ።					
13	ኢኮሎጂው ቲጊቪርኚዳ ሴቴፍሻ እያ ዴስፄ።					
14	ባዮሎጂው ቤንዴስ ኦኮሎጂ አንቤብሻ እያ ዴስፃላ።					
15	ኢኮሎጂው ቤናኻዳ ያኹኽ ዲቭዳ እንፃኽስትናኒ እያስ ፋይ እንኩዋኽስቴ።					
16	ኢኮሎጂው ቤናኻዳ ዝኮስኩስ እንዳራ ፂኒስናውሽናኻ ያኪኔ አቕሻስ ይዳ እንጉ እንኩዋኽሽቴ።					
17	ይውሳ ጊዞ ኢኮሎጂው ካስካዳ ዊድሻስ ፋታላ።					
አቕቱ (ኮግኒቲቭ) ሴቴፍኚ (ስትራቴጂው ክንቲ፣ ኚኧራሳ ቼፍሻሻ፣ኮቴቴርሻ፣ ኻልት ካስስት እስታ ሜታኮግኒሽን)						
18	ድግርቱንኩ አኼንካኻዳ ክንትኹ አሳብ-ምሻሳ አን ቴግባራዋ ፄውሻስ ካሌ።					
19	ኢኮሎጂኻዳ አን እንፅኼ አንፃኽስቱስ ክንትኹሳ አቓያሱሊ ድንግርፅሻስ ሞኬሬ					
20	ኢኮሎጃኻዳ ዝኩንኩ አሳቡ ምሽካዋ እርዳትስትሻስ አን ይኧርትኧሱ ምስልካዋ ቴርሳ።					
21	ኢኮሎጂ ፂኒስ□ ጄሜርሻዴስ ፍና አን እንዳራ ፄው□ ፋታኻ ያኪኔ አሴፔ።					
22	አን ክንታው ዲቭ ቺጊርፂ ያኻኒ አን ዲቭካዋ ክንታውሳ ዳዶ ኪሴ።					
23	አን ፂኒሱስ ሊሊትካ ኮርሱ እምካዋ እምትሻፅሻስ ሞኬሬ።					
24	አን ክንታውሳ እንዴስ ፍና ክንቱክ ዲቭካሊ እምትሻፅሻስ ሞኬሬ።					
25	እይስቱኽሳ አሳይመንቶ ሲሪሻስ ሊሊትካ ኮርሱ እምካዴስ ፊትኙንኩ አሳብካዋ አን ፃምርሻሴ።					

(Pierre, 2022 ዴስ ካፅስቱኽ)

ይቱኑ ጊዝዝ ስታ ፄውቱኑ ቲቪቪርኚስ ማልኼ አሜሴጌኔ

Appendix E: Classroom engagement observation checklist

School:____________________
Date:______________________
Grade:____________________
Section:___________________
Number of students: Male________ Female_________ Total_________
Subject: General Science
Period: ___________
Lesson topic_________________________________
Observer: _________________________________
Observation type: Nonparticipant

The purpose of this classroom observation checklist is to systematically assess students' level of engagement during ecology instruction sessions. Specifically, the checklist is designed to examine students' behavioral, emotional, and cognitive engagement while participating in IK-based and conventional ecology lessons. It enables the researcher to observe the extent to which students actively participate in classroom activities, demonstrate interest and enthusiasm, and apply critical thinking and contextual understanding during the learning process.

Rating scale

1 = Not observed | 2 = slightly observed | 3 = moderately observed | 4 = highly observed

No	Activities	1	2	3	4	Additional description
	Behavioral Engagement (Observable participation and effort)					
1	Students attentively follow instructions during the ecology lesson.					
2	Students actively participate in whole-class and small-group discussions.					
3	Students ask questions to seek clarification or additional information.					
4	Students take notes or record key ideas during the ecology lesson.					

	Emotional Engagement (Interest, enjoyment, and affective involvement)					
5	Students appear to enjoy the ecology lesson and learning activities.					
6	The lesson captures students' interest through meaningful and culturally relevant examples.					
7	Students show enthusiasm (e.g., smiles, verbal excitement, willingness to participate).					
8	Students demonstrate a positive emotional response to IK-based activities.					
	Cognitive Engagement (Deep thinking, strategy use, and meaning-making)					
9	Students develop their own examples to explain ecological concepts.					
10	Students relate ecology concepts to prior knowledge or real-life Indigenous practices.					
11	Students apply learned concepts to problem-solving or discussion tasks.					
12	Students demonstrate thoughtful reasoning by explaining "why" or "how" during activities.					

Appendix F: IK-based instruction FGD guide

I. English version

Thank you for agreeing to participate in this focus group discussion. You have recently completed the study of ecology using an IK–based instructional approach. The purpose of this discussion is to explore your experiences, perceptions, and reflections regarding this teaching strategy, particularly in relation to learning ecology and biodiversity conservation.

Your participation is entirely voluntary. All responses will be treated with strict confidentiality and used solely for academic research purposes. Your identity will not be disclosed, and none of the information you provide will be used for assessment, grading, or any form of evaluation. There is no right or wrong answers; rather, we are interested in your honest opinions and lived experiences. You are encouraged to express your views freely and openly. You may choose not to respond to any question or withdraw from the discussion at any time without any negative consequences.

Theme____________________

No	Activities	Note/ Probing Prompts
1	Please describe your overall experience of learning ecology through the IK–based teaching approach. How would you characterize this method of instruction (e.g., engaging, motivating, or challenging)?	What aspects did you like or dislike most?
2	In your opinion, how well did the ecology lessons connect with your everyday life, community practices, or local environment?	Can you give specific examples?
3	How would you describe the level of difficulty of learning ecology concepts through this IK-based approach compared to previous methods you experienced?	What made the lessons easier or more difficult to understand?

4	During the lessons, you were sometimes asked to consult parents, elders, or other knowledgeable community members. How did these activities influence your understanding of ecology topics?	Did this change how you view learning science?
5	After completing the ecology unit, you took an assessment to evaluate your learning. How do you feel about your performance on this assessment?	Do you think the IK-based approach helped you prepare for the test?
6	Would you recommend the IK-based teaching approach to other teachers or schools? Please explain the reasons for your recommendation or concerns.	What improvements, if any, would you suggest?
7	Is there anything else you would like to share about your experience of learning ecology through the IK-based instructional strategy?	

Thank you very much for your participation and patience. Your input is greatly valued and appreciated.

II. Awgni version

እን ኬቾ ኩስፓዳ **(FGD)** አሴቴፍሻታንኻሳ አይሎ አሜሴጌኔ። ኢኮሌጂውሳ ክንቴ ዙራሙሪው አቕትዳ ስርትኹ ክንትሻ ክንፅፅኹሳ ሴሎ ቲኪምስቲካማ ዊዲካ። እን ኩስኟው አላሚ እን ክንትሻ ክንትፅኹ ሴል እንቶጂዳ ቺፁኽሳ አሳብ ምሻሳ /ካሊቕቶ/ ማሊሻስያኽ። እንቶጂሱ ኩስሻኚ /ዙርሚ/ ማራማርኚስጃ እሊውስ እሺያቲው አኽሻስ ፋቱንታ ሲጌኑላ ኩስፓን። ክችክቺ አኹ ስቴት ናው አሳብ እላቲው አኽሻስ እንቶጂዳ አንኮኽስታውሳ ፋቱንታ ዙርፃን /ኩስፓን/፡: እን ኩስኚ ፍቃድስ ያኽስታው አኽሻሽ እንቶጂ ፋቱንታ ባይሻስ ካሌና።

ቴ.ቼ	ቴግባርካ	ኖት
1	ዙራሙሪው አቕትዳ ስርትኹ ክንትሻ ክንፅፅኹ ሴሎ ቲኪምስቲካማ ኢኮሎጂ ክንቴኒስ አግፂኑሳ ዴሶ አዴር ጌሌፄን። እንሳ ሴሎ ዋትፓይ ካንቲን:: ምሳሊ ሼጊማ ቺጊርፂይ?	ዋሺኔ አኺኔይ እንካንቱን አኹ ፍችቲን
2	እንቱው አሳብስ ኢኮሎጂው ክንቲ እንቱው እሌቱ ዝኪዋኒሊ/ ይወትሊ/ ዋትኚይ ታምትፓ?	ምሳሌ እይሻስ ካሌናማ?
3	ዙራሙሪውሳ አቕቶ ቴኬምስታ ኢኮሎጂ ክንፅፅሻ ምንጊሱ ክንትፅኹ ሴልሊ ልኺትሻፄና ዋትኚይ ጌሌፅስቴ?	እንሳ ክንቴ ሳሴር አኹ እርዳትስትሻስ ቺጊርፄ ፄውኹ ዳርማይ?
4	ኢኮሎጂ ክንቴኑጉዝማ ቹዋ ታብሎ ስታ አሊኩ ኽሳንትካ አቖ ካስቲካማ ቲንታሽቲና። እን ቴግባር እንቶጂ ኢኮሎጂውሳ ክንቴ እርዳትቴንታ ቺፁኽ ቻኒስት ዳርማይ?	እን ሳይንሶ ክንትሻስ ቴኬማማ?
5	ኢኮሎጂውሳ ክንቴ ዊዲንዴስ ፋሌንጋ ፋታኔ ፌቲንስቲካ። እንት አግፂኹ ወይሚ ዋትኚይ?	ዙራሙሪው አቕቶ ስርትኹ ክንፅፅኹሳ ሴሎ ቴኬምስታማ ክንትሻኩሳ ወይሜ ዴሜካ ኔታ አሴብቴማ?
6	እሊው ክንትሻናዳ ያኻ ክንቲው ሴልዳ ክንታንትካ ዙራሙሪው አቕቶ ስርትኹ ክንትሻ ክንፅፅኹሳ ሴሎ ቴኬምስትካማ ዴሳንታ /ክንታንትካ/	ዋታኮውሳ ኩስኜይ ኩስሻፂ

	ሜኬርቴማ /ኩስሻፂማ/?	
7	ዙራሙሪው አቐቶ ስርታማ ክንትሻ ክንፅፅኾላ ዲግኜ ካንትኹሳ ዳርኪ እሊው ዴሜክታታ ዲብስታው /ድኹታው ዲብ ዝኮማ?	

ይቱኑ ጊዝዝ ስታ ዬውቱኑ ቲቪቪርኚስ ማልኜ አሜሴጌኔ!

Appendix G: IK based instructional package sample lesson plan for the experimental group

A

Class: 8C
No. of Students: 43
Subject: General science
Duration: 40 Minutes
Topic: Ecosystem and interactions
Sex: Mixed

Subtopic: Definition and components of ecosystem

Types of biological interactions

Performance objectives: By the end of the lesson the students will be able to

1. Describe the biotic and abiotic components of ecosystem
2. Explain the biological interactions by giving local examples for each interaction type
3. Compare and contrast each biological interactions

Stage/time	**Teacher activity**	**Students activity**
Introduction	The teacher introduces the topic to the students. Begin Asks open-ended questions: What is an ecosystem? Can you explain biological interactions? Encourages students to share any prior knowledge or cultural perspectives about their environment and living things. Creates a respectful atmosphere that validates IK as well as scientific inquiry.	Share observations and experiences about local ecosystems.

Presentation	The teacher takes students to school playground and ask to explain certain living (plants & animals) and nonliving components of an ecosystem in local names and their uses. The teacher provides the opportunity for students to discuss the various indigenous views associated with biological interactions. The teacher notes down the concepts students have acquired culturally with respect biological interactions. The teacher now resolves which ever misconception that was noted without out rightly dismissing their conceptions, rather he resolves it by creating a link between the student's initial ideas and the new concept he has come to introduce. Gradually, he introduces the Western Scientific Concept: note their local and scientific names.	The students are directed to observe and list the living and nonliving components of the ecosystem. The students should identify the uses of each component and biological interactions in the guidance of the teacher. Classify given examples into biotic and abiotic categories. Draw a simple ecosystem diagram showing components from their environment and indigenous practices affecting these components.
Conclusion (summary)	The teacher summarizes the topic and point out key areas in the topic. Encourages students to ask their parents or elders about local IK on food chains and food webs as a take-home activity.	Take notes on the summary. Prepare to discuss IK about food chains and food webs with family or community members for the next lesson.
Evaluation	Use formative assessment through class discussions, quizzes on definitions/concepts, and group presentations on ecosystem components and interactions.	Participate in quizzes and discussions. Write reflections on lessons learned about ecosystem

B

Class: 8C

Subject: General science Duration: 40 Minutes

Topic: Conservation of natural resources No. of Students: 43

Subtopic: Definition and uses of soil

Soil conservation strategies Sex: Mixed

Performance objectives: By the end of the lesson the students will be able to

1. Describe soil key characteristics using indigenous and scientific perspectives
2. Identify different soil types.
3. Explain the uses of soil in nature and for human livelihoods, including traditional and modern practices.
4. Discuss the various soil conservation strategies

Stage/time	Teacher activity	Students activity
Introduction	Initiate a class discussion linking students' prior knowledge and experiences about soil from their local environment. - Prompt with open-ended questions such as: ✓ Can you define soil? ✓ What are the uses of soil in nature? ✓ What indigenous practices do you know that help conserve soil?	Students share observations and local examples of soil conservation strategies and soil uses. Engage actively by relating their personal or community experiences.
Presentation	First the teacher sits students in groups then ✓ Asks them to think about eroded agricultural land in their local area ✓ Give them a chart that shows different soil conservation strategies and let them to discuss associated with their indigenous views and ask them to answer the following questions What can you say about this chart? Which of them are common in your local area? Do you think that these practices reduce soil erosion and improve soil fertility? Explain how? Have you and your parents ever made any contributions towards soil conservation? Discuss. The teacher round in each group and provides the opportunity for students to discuss the various indigenous views associated with soil conservation strategies.	Students create lists of soil uses drawing from their community and textbook content. - Share indigenous soil conservation practices. - Reflect on the importance of soil sustainability for future generations.
Conclusion (summary)	The teacher summarizes the topic and point out key areas in the topic. Through a detailed explanations and illustrations the teacher merges the indigenous conceptions. Gradually he introduces the school science Finally, the teacher let students asking their parents on IK system and practice about water and water conservation for the next period	Take notes on key points. - Ask questions for clarification. - Prepare for home assignment by planning questions for community interview.
Evaluation	Evaluate understanding through question-answer sessions on soil Use quick quizzes integrating indigenous and scientific knowledge.	Respond to oral or written questions. Express understanding through indigenous-scientific integration.

Appendix H: Contents to be taught during six weeks

Week	Topic	Subtopics
1	Ecosystem and interactions	✓ Definition and components of ecosystem ✓ Types of biological interactions ✓ Tropic (feeding) relationship in an ecosystem ✓ Nutrient cycles and energy flow in an ecosystem ✓ Trophic levels and ecological pyramids
2	Ecosystem and interactions Conservation of natural resources	✓ Soil o Soil definition and characteristics o Soil formation o Uses of soil
3	Conservation of natural resources	✓ Soil o Factors affecting soil fertility and Soil erosions o Soil conservation strategies ✓ Water o Uses of water
4	Conservation of natural resources	o Water conservation strategies ✓ Air o Composition of air and its uses o Air pollution and its impacts
5	Conservation of natural resources	✓ Forests o Deforestation and its impacts
6	Conservation of natural resources	✓ Biodiversity o Biodiversity values ✓ Revision

Appendix I: Participant consent form

Appendix I: Participant Consent Form

Consent Statement

I am being invited to participate in a research study conducted for the partial fulfillment of Doctor of education in Biology. I have been fully informed about the purpose, procedures, significance, and potential benefits of the study, both to me as a participant and to the wider educational community. I understand that my participation in this study is entirely voluntary and that I will not receive any financial or material compensation for taking part. I have been given adequate opportunity to ask questions about the study, and all my questions have been answered clearly and satisfactorily. I have been informed that all information collected during the study will be treated with strict confidentiality. My identity will not be disclosed at any stage of the research process, and the data I provide will be used solely for academic research purposes. The findings will be reported in aggregate form, ensuring that no individual participant can be identified. I understand that I have the right to withdraw from the study at any time, without penalty or negative consequences, and without being required to provide a reason for my withdrawal. I confirm that I have been given sufficient time to consider my participation and, where appropriate, to discuss it with family members or others before making my decision. By signing below, I indicate that I freely and knowingly consent to participate in this study.

Name of Participant: [illegible]

Signature of Participant: [illegible]

Date: 14/08/2016

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Appendix J: Permission Letters

በሳይንስ ኮሌጅ
የድህረ-ምረቃ፣ምርምርና
ማህበረሰብ አገልግሎት ም/ዲን
ባህር ዳር ዩኒቨርሲቲ
ባህር ዳር - ኢትዮጵያ

The Graduate, Research & Community
Services Vice Dean, Science College
Bahir Dar University
Bahir Dar - Ethiopia

☎ 251 (588) 209997
website: www.bdu.edu.et ✉ 79 Fax: 251 (582) 220- 20- 25

Ref: PRCSVD/632/2023
Date: February 28, 2023

Ethical Clearance Approval Form

Applicant's Name: Shitaye Kassahun

Research Title	The integration of indigenous knowledge and practice into biology instruction and its effect on students' learning; the case of middle schools in Injibara city
Researcher (s) Name (s)	Shitaye Kassahun

Thank you for submitting your application for ethical clearance, which was considered at the College of Science Research Ethics Committee meeting on 27 February 2023. The committee has reviewed your ethical application, issues pertaining to participants, consent form, debriefing, and relevant questionnaires.

The researcher should keep the confidentiality of the identity of research participants and data that will be obtained from them. Any serious adverse events or significant changes which occur in connection with this study and /or which may alter its ethical consideration must be reported immediately to the committee for a possible ethical amendment.

We are therefore pleased to inform you that the College's Ethical Clearance Committee has approved your study from an ethical point of view.

With kind regards

Tsegaye Kassa (PhD)
The Graduate, Research and Community Services V/Dean
College of Science

CC//
- Dean office
- The Graduate, Research and Community Services V/Dean
- Department of Biology

College of Science

INREPLAYING, PLEASE QUOTE OUR REF. NO
መልሱን ሲጽፉ የኛን ቁጥር ይጥቀሱ

በአማራ ብሔራዊ ክልላዊ መንግስት
በአዊ አስተዳደር ዞን በእንጅባራ ከተማ
አስተዳደር ትምህርት ጽ/ቤት ቁጥር 2

ቁጥር ስትም/2565/14/18

ቀን 16/04/2016

ለ [illegible] ት/ቤት

<u>እንጅባራ</u>

ጉዳዩ፡- <u>ትብብር እንዲደረግላቸው ስለመጠየቅ</u>

በባህርዳር ዩኒቨርሲቲ የባዮሎጂ ትም/ክፍል 3ኛ ዲግሪ መደበኛ ተማሪ የሆኑት አቶ ሽታየ ካሣሁን ለመመረቂያ ፁሑፍ የሚያስፈልጋቸውን መረጃ ለመሰብሰብ በዝግጅት ላይ መሆናቸውን በመግለጽ የትብብር ደብዳቤ እንዲጽፍላቸው ጽ/ቤታችንን በማመልከቻ ጠይቀዋል፡፡

በመሆኑም አቶ ሽታየ ካሳሁን ለጥናታቸው የሚስፈልጋቸውን መረጃ ለመሰብሰብ ወደናንተ ት/ቤት በሚመጡበት ወቅት አስፈላጊውን ትብብር ታደርጉላቸው ዘንድ በትህትና እንጠይቃለን፡፡

"ከሠላምታ ጋር"

[illegible]

የአ/ትም/ዝ/ገ/ባለሙያ

<u>ግልባጭ</u>

- ለአቶ ሽታየ ካሣሁን

[illegible]

ቁጥር [illegible]

ቀን 16/04/2016

ለ [illegible] ት/ቤት

እንጅባራ

ጉዳዩ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ

በባህርዳር ዩኒቨርሲቲ የባዮሎጂ ትም/ክፍል 3ኛ ዲግሪ መደበኛ ተማሪ የሆኑት አቶ ሽታየ ካሣሁን ለመመረቂያ ፁሑፍ የሚያስፈልጋቸውን መረጃ ለመሰብሰብ በዝግጅት ላይ መሆናቸውን በመግለጽ የትብብር ደብዳቤ እንዲጽፍላቸው ጽ/ቤታችንን በማመልከቻ ጠይቀዋል፡፡

በመሆኑም አቶ ሽታየ ካሳሁን ለጥናታቸው የሚስፈልጋቸውን መረጃ ለመሰብሰብ ወደናንተ ት/ቤት በሚመጡበት ወቅት አስፈላጊውን ትብብር ታደርጉላቸው ዘንድ በትህትና እንጠይቃለን፡፡

"ከሠላምታ ጋር"

[illegible]

ግልባጭ

- ለአቶ ሽታየ ካሣሁን