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Effect of Guided Inquiry Based Learning on Grade 12 Students' Achievement, Conceptual Understanding, and Epistemic Belief towards Evolution

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Effect of Guided Inquiry-Based Learning on Grade 12 Students' Achievement, Conceptual Understanding, and Epistemic Belief towards Evolution

By

Lidet Awlachew Agonafre

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science Education in Focused of Biology

Advisor- Mersha Minwuyelet (PhD, Asst Professor)

June - 2026

BAHIR DAR, ETHIOPIA

DECLARATION

I, the undersigned, declare that this thesis work, entitled "Effect of Guided Inquiry-Based Learning on Grade 12 Students' Achievement, Conceptual Understanding and Epistemic Belief towards Evolution" submitted in partial fulfillment of the requirements for a Master of Science 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.

Name of the candidate, Lidet Awlachew, June, 2026, Bahir Dar University

Signature_________________

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DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

APPROVAL OF THESIS FOR DEFENSE

We hereby certify that I have supervised, read, and evaluated this thesis entitled **“**Effect of Guided Inquiry-Based Learning on Grade 12 Students' Achievement, Conceptual Understanding, and Epistemic Belief towards Evolution,**”** prepared under my guidance. I recommended that the Thesis be submitted to an oral defense.

Approval of dissertation proposal for defense

Mersha Minwuyelet (PhD, Asst. Prof.) __________________ June 12, 2026

Adem Ahmed (PhD, Assi. Prof.) __________________ June 12, 2026

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APPROVAL OF THESIS FOR DEFENSE RESULT

As members of the head of examination, we examined the thesis entitled “Effect of Guided Inquiry-Based Learning on Grade 12 Students' Achievement, Conceptual Understanding and Epistemic Belief towards Evolution,” by Lidet Awlachew. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the “Master of Science Education in Biology”.

Board of Examiners

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External Evaluator’s name Signature Date__

____Habtamu Wodaj (PhD, Asst. Prof.) _____ ___________ June 12, 2026

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Million Tadesse (PhD, Asst. Prof.) __ __________ June 12, 2026

Chairperson’s Name Signature Date

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List of Acronyms

CER: Claim Evidence Reasoning

CUT: Conceptual Understanding Test

DBR: Design-Based Research

EBQ: Epistemic Belief Questioner

GIBL: Guided Inquiry-Based Learning

IBL: Inquiry-Based Learning

MC: Multiple Choice

NOS: Nature of Science

ABSTRACT

Evolution is one of the most conceptually challenging and socially contested topics in secondary biology education. Many students enter the classroom with persistent misconceptions and naïve epistemic beliefs that hinder their ability to understand evolutionary concepts scientifically. These difficulties are often reinforced by cultural, religious, and sociocultural influences that shape learners' attitudes toward evolution. This study investigated the impact of Guided Inquiry-Based Learning (GIBL) on Grade 12 students' learning achievement, conceptual understanding, and epistemic beliefs regarding evolution at Fasilo Secondary and Preparatory School in Bahir Dar, Ethiopia. The study employed a mixed-methods approach within a Design-Based Research (DBR) framework and involved 55 students from one intact classroom. Initial classroom observations, diagnostic assessments, and student discussions were conducted to identify learning difficulties and misconceptions that informed the design and refinement of the intervention. Throughout implementation, formative evidence gathered from classroom activities and student responses was used to iteratively refine inquiry tasks and instructional scaffolds in accordance with DBR principles. Data were collected using pre-tests and post-tests, two-tier conceptual understanding tests, epistemic belief questionnaires, classroom observations, and qualitative student reflections. The quantitative findings revealed significant improvements in students' learning achievement, with mean scores increasing from 9.16 (SD = 2.84) to 13.60 (SD = 2.95). Likewise, students' conceptual understanding improved substantially, with mean scores increasing from 3.85 to 7.56 and a normalized gain score of 0.60, indicating a medium conceptual gain. Item-level Wilcoxon Signed-Rank analyses further revealed significant improvements across all five targeted misconception domains ($p < .001$), while the proportion of students exhibiting misconceptions decreased from 40.7% before the intervention to 9.8% afterward. Furthermore, students demonstrated significant improvement in their epistemic beliefs, with mean scores increasing from 26.96 to 32.29, $t(54) = 4.26$, $p < .001$, and a moderate effect size ($d = 0.57$). The intervention produced a large effect on learning achievement (Cohen's $d = 1.16$) and conceptual understanding (Cohen's $d = 1.42$), while a moderate effect was observed for epistemic beliefs (Cohen's d

= 0.57). Qualitative findings corroborated these results by revealing improved scientific reasoning, greater engagement in inquiry activities, and an enhanced ability to distinguish scientific explanations from personal beliefs. Overall, the findings indicate that Guided Inquiry-Based Learning is an effective instructional approach for improving students' achievement, promoting conceptual change, reducing misconceptions, and fostering more sophisticated epistemic beliefs about evolution.

Keywords: Conceptual understanding, Epistemic belief, Evolution, Guided-inquiry-based learning

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Education has been conceptualized in various ways among different scholars, reflecting a theoretical orientation, operational focus, and decision-making perspectives (Malik., 2018). In a broad view, Education is a widely recognized transformative social process that equips learners with the knowledge, skills, and attitudes necessary to navigate an increasingly complex and dynamic world. Contemporary educational paradigms emphasize learner-centered pedagogies that promote critical thinking, problem-solving, and the construction of meaning rather than the passive reception of information (Tang, 2023). However, recently, education in general and instruction in particular face challenges in implementing quality education. This instructional problem has been caused by teachers' teaching methods, the nature of the curriculum, and students' participation in the classroom (Assefa Kibret et al., 2025; Million Tadesse et al., 2025)

To enhance instructional quality and improve students' performance, different strategies have been implemented. Among these approaches, guided inquiry-based learning (GIBL) encourages students to question, explore, and explain. GIBL has been widely recognized as an effective instructional method capable of advancing deep and meaningful learning (Ismail, 2006). Moreover, GIBL has a great role in science instruction because it enhances students' engagement and promotes conceptual learning. In the Ethiopian context, recent evidence indicates that guided inquiry-based learning can enhance students' engagement across cognitive, behavioral, and social dimensions in biology classrooms (Dereje Negerie et al., 2026). Science education, which emphasizes empirical evidence and scientific reasoning, strongly supports inquiry-based pedagogies because they help students understand how scientific knowledge is generated, evaluated, and validated (Lederman et al., 2019). Among biological domains, evolution is considered a foundational concept; however, it remains difficult for many learners because of its abstract nature, counterintuitive mechanisms, and influence from cultural and religious backgrounds (Mead et al., 2019).

Science education, with its focus on developing empirical evidence, strongly supports guided inquiry-based learning pedagogies (Matti Hiltunen, 2021). It not only intends to transmit scientific knowledge but also aims to cultivate an understanding of the nature of science and how scientific knowledge is conceptualized and validated (Lederman et al., 2019). Biology education is vital, and among its theoretical domains, evolution is both foundational and challenging. It serves as the unifying theory of biology, explaining biodiversity, adaptation, and genetic change (Cooper et al. 2019). Despite its significance, students globally face difficulties with understanding evolutionary principles due to their abstract nature, religious background, and cultural influences (Mead et al., 2017; Valdesolo et al., 2017). Teaching evolutionary concepts is challenging due to misconceptions, students' backgrounds, and other related factors.

A misconception is a perception of phenomena that is not consistent with the scientific explanation. It is also called concept misinterpretation (Modell et al., 2005). Misconceptions remain one of the most persistent challenges in biology education, particularly in foundational topics such as evolution. Students often enter classrooms with pre-existing thoughts grown from cultural beliefs and incomplete previous instruction (Kampourakis, 2020).

The causes of misconceptions can be summarized into five factors: student, teacher, textbook, context, and teaching method (Zewdu Gebrekidan, 2010). School is a place where students are introduced to core evolutionary concepts, and these ideas can shape or even obstruct their understanding of scientific concepts. These misinterpretations can create long-term conceptual gaps in subsequent grades and in practical perspectives such as ecological and environmental science. In this regard, an informed education on the subject will be crucial to avoid misunderstanding among students. Student misconceptions about evolution persist as one of the most determined challenges in preparatory school (Suleiman et al., 2024). Biology students often lead to misunderstandings about the evolution of life. Identifying and accounting for these misconceptions leads to more efficient teaching and a lasting memorization of well-known scientific concepts through conceptual change (Coley & Tanner, 2012).

Misconceptions about evolution, such as the perception that single individuals evolve rather than populations, or that evolutionary change is determined by purpose or prerequisite, are remarkably persistent and often resistant to conventional lecture-based instruction (Anderson et al., 2002). Combining this issue with students' epistemic beliefs, their views about the nature, justification, and certainty of knowledge. Students with naive epistemic beliefs tend to view scientific knowledge as fixed and authority-driven, making them more susceptible to misconceptions and less accepting of evolution as a scientific explanation (Sinatra et al., 2003). Conversely, students with more sophisticated epistemic beliefs exhibit greater flexibility in evidence-based reasoning (Kampa et al., 2016). Therefore, evolution instruction must support not only conceptual understanding but also the development of epistemic beliefs.

This study is grounded in constructivist learning theory and conceptual change theory. Constructivism views learning as an active process where learners construct knowledge based on prior experiences, while conceptual change theory explains how students replace alternative conceptions with scientifically accepted explanations when they encounter evidence that challenges their existing ideas.

A Design-Based research (DBR) approach, which incorporates iterative problem-solving, real-life tasks, and constant teacher contemplation, was implemented in this study. It stipulates an ordered yet amenable framework for delivering misconceptions. Addressing students' misconceptions is a central challenge in science education. Methodologies that encourage learners to question are particularly effective, as they enable students to test or refute ideas against empirical evidence. When students are encouraged to investigate, gather information, and reflect on their point of view, there is a huge gap between their prior beliefs and scientific explanations. This iterative process of exploring and revising understanding supports meaningful conceptual improvement. To achieve this, the GIBL intervention was delivered. Research explained that guided inquiry opportunities support teachers to disclose learners' misconceptions and direct them toward scientifically valid concepts (Anderson & Shattuck, 2012b). Moreover, students' epistemic beliefs in relation to scientific thoughts were assessed by a standard tool.

Epistemic beliefs refer to students' attitudes about the nature of knowledge and how it is constructed, validated, and justified. These beliefs mold how students interpret scientific information, evaluate evidence, and engage with inquiry-based tasks. When students hold naive epistemic beliefs, such as perceiving knowledge as fixed and simple, they struggle to build deeper scientific understanding. As a result, this limits their ability to participate in inquiry, solve problems, and connect concepts. Consequently, these limitations lead to persistent learning difficulties and lower achievement in science (Hakan & Münire, 2012).

The students' achievement scores and performance level are classified as: low, medium, and high achievers (Everett, 1971). According to the Education and Training Policy of Ethiopia, the report on Grade 12 Students' achievement by content domain in percent mean score is 47.49% (Zewdu Gebrekidan, 2010). Based on this evidence, preparatory school students remain at only a low level of achievement, indicating persistent learning difficulties. Furthermore, there is limited evidence regarding the application of GIBL for improving conceptual understanding and epistemic beliefs within the context of evolution education in Ethiopian secondary schools (Ageze Mekonnen et al., 2023).

Despite the importance of evolution in Biology education, students continue to struggle to fully understand and retain due to persistent misconceptions and teacher-centered teaching methods focused only on memorization over active student engagement (Gregory, 2009). While conceptual change theories emphasize the role of active learning for encouraging conceptual understanding, previous studies have mostly focused on misconceptions and academic achievement, giving limited attention to students' epistemic beliefs (Chengere et al., 2025). Additionally, research examining the combined effect of guided-inquiry-based learning on both conceptual understanding of evolution and epistemic beliefs among secondary school students remains limited, particularly in the Ethiopian context (Ziadie & Andrews, 2018). Therefore, this study aimed to investigate the impact of GIBL on students' conceptual understanding and epistemic beliefs of the evolution concept of biology in secondary school students.

1.2. Statement of the problem

Evolution is one of the central topics in biology, yet it is commonly challenging for secondary students to understand because its concepts are abstract, counterintuitive, and frequently disagree with students' prior experiences. These challenges often lead to persistent misconceptions about natural selection, genetic variation, and the mechanisms that produce biological change in secondary school students' conceptual understanding (Gregory, 2009). Both students and teachers frequently hold misconceptions, and these concepts are resistant when the instruction method mainly focuses on memorization rather than evidence-based reasoning (Melaku et al., 2025). Such misconceptions arise from students' instinctive reasoning, teachers' limited preparation, and textbook oversimplifications, and they strongly influence how students interpret biological concepts across consecutive grades (Yates & Marek, 2014). This means that even after instruction, Grade 12 students may not truly understand the evolution conceptually, which weakens science learning at the secondary level (Yasri, 2014).

These difficulties are further assisted by students' epistemic beliefs. These beliefs about how knowledge is constructed and justified affect how they engage with evidence, uncertainty, and scientific explanation (Baytelman & Loizou, 2023). Learners who perceive scientific knowledge as predetermined and non-empirical often struggle to evaluate evidence and modify their misconceptions. Cultural and societal influences, including religious beliefs, shape the learners' willingness to accept those evolutionary explanations (Cho et al., 2011). Classroom observations from the target school reveal that evolution is mainly taught through lecture, textbook summaries, and recall-based assessments. In lecture-based learning, Students rarely participate in inquiry, data analysis, or investigative tasks that could help them confront misconceptions (Khasawneh, 2016). Teachers, aware of these sensitivities, may limit discussion or simplify the content, which reduces opportunities for critical reflection and inquiry. In evolution, where learners must accept evidence-based explanations and evaluate competing ideas, weak epistemic beliefs may block meaningful learning even when content is taught well (Schiefer et al., 2022).

According to the Education Sector Development Programme reports, only about 47.49% score on the national examination for evolution-related questions, placing them at a low achievement level, and indicating significant learning difficulties in core scientific content about evolution (MoE, 2022; Zewdu Gebrekidan, 2010). This implies that many secondary and preparatory school students are not meeting the expected competency and proficiency standards and still experience significant learning difficulties. This situation emphasizes the need for instructional approaches that directly challenge misconceptions and strengthen students' evidence-based reasoning and cognitive processing because it supports students with questions, evidence use, and conceptual framing while still keeping them actively involved in discovery (Johnston et al., 2022). Moreover, existing studies show that guided inquiry can improve science learning, but fewer studies connect guided inquiry, conceptual understanding, and epistemic beliefs (Lawson & Weser, 1990; Schiefer et al., 2022). In the Ethiopian context, evolution is mainly taught through the conventional lecture method. Students rarely participate in inquiry, data analysis, or investigative tasks that could help them challenge those misconceptions (Yidnekachew Awraris et al., 2024). Therefore, understanding the basic causes of these difficulties and designing instructional tools to resolve these learning difficulties is very critical. This study aims to investigate these challenges by examining students' conceptual understanding and epistemic beliefs toward evolution, and the impact of guided inquiry-based learning on the development of students' achievement, conceptual understanding, and epistemic beliefs about Evolution, making the research significant.

1.3. Research questions

1. How does GIBL influence the learning achievements of Grade 12 students on the topic of Evolution?
2. What effect does Guided Inquiry-Based Learning (GIBL) have on students' conceptual understanding of evolution and the reduction of common evolutionary misconceptions?
3. How does exposure to GIBL influence students' epistemic beliefs about Evolution and scientific knowledge?

4. What instructional activities and scaffolding strategies are identified and refined through the DBR process to reduce students' misconceptions by the implementation of Guided Inquiry-Based Learning in teaching evolution?

1.4. Research objectives

1.4.1. General objective

- To investigate the effects of GIBL in the development of students' learning achievement, conceptual understanding, and epistemic beliefs about Evolution, in Bahir Dar City Fasilo Secondary School, Ethiopia.

1.4.2 Specific objective

1. To determine the effects of GIBL on students' learning achievements about the concept of Evolution.

2. To assess changes in students' conceptual understanding of Evolution and measure the reduction of specific misconceptions following the GIBL intervention.

3. To explore changes in students' epistemic beliefs towards Evolution following the GIBL intervention.

4. To identify and refine the instructional activities and scaffolding strategies that reduce students' misconceptions by the implementation of Guided Inquiry-Based Learning in evolution instruction.

1.5. Significance of the study

This study is significant because it will examine how GIBL can improve Grade 12 students' conceptual understanding and epistemic beliefs about evolution, a topic where students commonly struggle. By evaluating the effect of GIBL before and after intervention, the study provides evidence on an instructional approach that supports conceptual change and scientific reasoning by helping students actively build knowledge through structured questioning, evidence use, and reflection rather than passive reception. In evolution teaching, this matters because students often enter class with misconceptions that are not corrected by lecture alone.

By implementing GIBL in the classroom, the study delivers solid confirmation on how the intervention shapes students' learning outcomes that directly support the study objectives. The results provided encouraging instructional tools for understanding how guided inquiry can be used to correct misconceptions and develop students' evidence-based reasoning. Moreover, the study helps curriculum developers and policy makers to give emphasis to DBR and GIBL, and may be used as a springboard for other researchers to use DBR and GIBL as a research method to solve the problem practically. Overall, the study is significant because it offers practical, research-based guidance for improving evolution teaching and learning, addressing a well-known area of difficulty for Grade 12 students.

1.6. Scope of the study

This study emphasizes the Grade 12 evolution content approved in the Ethiopian biology curriculum. It is conducted at Fasilo Secondary and Preparatory School and includes Grade 12 biology students during the regular academic period in which evolution is taught. Methodologically, the study employs a Design-Based Research (DBR) approach, involving iterative cycles of designing, implementing, evaluating, and refining. Within this framework, the Guided Inquiry-Based Learning (GIBL) instructional method was delivered to investigate the effect of the intervention on the reduction of students' misconceptions through the improvement of students' achievement, conceptual understanding, and epistemic belief. The study is limited to examining students' conceptual understanding of evolution and their epistemic beliefs about scientific knowledge within this specific instructional context.

1.7 Limitations of the study

Several considerations should be acknowledged when interpreting the findings of this study. In this study, a single group design without a control or comparison group, even if the pre-test/post-test comparison shows meaningful change over time, though it is difficult to say with certainty that GIBL alone caused those improvements, factors like student maturation or outside learning experiences could have played a role as well. Beyond this, the sample consisted of 55 Grade 12 students from a single school in Bahir Dar, Ethiopia, so the result was what happened in this particular classroom rather than what might happen in every setting, and it is difficult to generalize the result for the whole population.

CHAPTER 2: LITERATURE REVIEW

2.1. Conceptualizing Education and Inquiry-Based Learning

Education has been theorized in multiple ways, denoting philosophical, sociological, and pedagogical perspectives. Malik (2018) claims that education represents both a theoretical and operational system in which decisions are guided by clearly defined instructional purposes. Modern educational paradigms have progressively moved from transmissive teaching models to learner-centered frameworks. These frameworks emphasize active engagement, critical thinking, and the co-construction of meaning (Maffei et al., 2022).

Within this paradigm shift, Guided-Inquiry-Based Learning (IBL) has emerged as an effective pedagogical model grounded in constructivist learning theory. IBL claims learners as investigators who generate questions, explore ideas, gather evidence, and construct explanations (Ismail, 2006). Research consistency determines that inquiry-oriented instruction enhances conceptual perception, logical reasoning, and long-term memorization compared to conventional lecture-focused approaches (Lederman et al., 2019). The effectiveness of inquiry-based learning depends on the level of guidance provided to learners. While unguided inquiry may create excessive cognitive demands for students with limited prior knowledge, guided inquiry provides structured questioning, scaffolding, and feedback that support knowledge construction (Kirschner et al., 2006; Hmelo-Silver et al., 2007). Therefore, GIBL is particularly suitable for complex biological topics because it balances student autonomy with teacher support. Through these processes, GIBL can improve students' learning achievement by promoting active participation, enhancing conceptual understanding by challenging alternative conceptions, and supporting epistemic development by exposing students to evidence-based scientific reasoning.

Science education particularly aligns well with Inquiry-Based approaches since scientific knowledge is, by nature, constructed through evidence and research. It aims not only to reflect scientific facts but to cultivate an understanding of the nature of science (NOS), how scientific claims are developed, tested, and validated (Lederman et al., 2019). This foundational focus on epistemic awareness makes IBL especially relevant to topics often dogged by misconceptions, such as evolution.

2.2. Evolution in Biology Education

Evolution is universally well known as the core unifying theory of biological sciences, explaining patterns of biodiversity, adaptation, natural selection, and genetic change (Cooper et al., 2019). Despite its centrality, evolution remains one of the most conceptually difficult topics for secondary school students worldwide (Johnston et al., 2022). Challenges arise due to the abstract nature of evolutionary processes, the long timescales involved, and conflicts with pre-existing cultural and religious beliefs (Valdesolo et al., 2017). Studies show that even after formal instruction, students often maintain inaccurate or incomplete conceptions. Such as: individuals evolve, rather than populations; evolutionary change occurs because organisms need to adapt, and a purpose drives natural selection (Anderson & Shattuck, 2012b). Such misconceptions persist across educational levels and cultural contexts, underscoring the need for pedagogical strategies that confront these ideas explicitly. However, many previous evolution education studies have mainly focused on identifying misconceptions rather than examining classroom interventions that effectively transform these misconceptions. This creates a need for instructional approaches that actively involve students in evaluating evidence and reconstructing their understanding.

2.3. Misconceptions in science and biology education

Misconception is a scientifically inaccurate interpretation of natural phenomena, and represents a major barrier to meaningful learning (Modell et al., 2005). In biology, misconceptions are particularly resilient because they frequently originate from intuitive reasoning, everyday experiences, or culturally reinforced narratives (Bertka et al., 2018).

According to Zewdu Gebrekidan (2010), the sources of misconceptions are categorized into five major factors. These include the students themselves, the teachers' limited content knowledge, ineffective explanations, and oversimplification of the textbook. The socio-cultural and religious influence, and the instructional tools used. In evolutionary biology, these misconceptions create conceptual barriers that can impede students' understanding of broader scientific ideas, including ecology, genetics, and environmental science. Literature also emphasizes the importance of conceptual change and the process by which learners' pre-existing frameworks are challenged and reconstructed to ensure meaning and understanding (Coley &Tanner, 2012). Although conceptual change approaches have been successful in addressing misconceptions, some studies indicate that misconceptions can remain persistent because students' explanations are influenced by prior experiences, cultural beliefs, and the instructional environment. Therefore, strategies that create continuous opportunities for investigation, discussion, and reflection are necessary to achieve lasting conceptual change.

2.4. Epistemic beliefs and their role in evolutionary learning

Epistemic beliefs are students' assumptions about the nature, structure, and justification of knowledge, play a critical role in how learners interpret scientific information. Students with naïve epistemic beliefs frequently see knowledge as fixed rather than evolving, simple rather than complex, and handed down by authority figures rather than constructed through evidence (Sinatra et al., 2003). Such beliefs limit students' capacity to critically evaluate scientific claims or revise misconceptions, making them more resistant to accepting evolution. By contrast, sophisticated epistemic beliefs support evidence-based reasoning, openness to conceptual change, and deeper scientific engagement (Hakan & Münire, 2012; Kampa et al., 2016). In contexts where evolution is culturally or religiously sensitive, epistemic beliefs become particularly consequential. They shape students' willingness to reconcile scientific explanations with existing belief systems and to adopt scientific habits of mind such as skepticism, evaluation of evidence, and uncertainty tolerance. Inquiry-based environments are particularly important for developing advanced epistemic beliefs because students experience science as a process of questioning, evidence evaluation, and revision rather than a collection of fixed facts. However, compared with achievement and conceptual understanding, fewer studies have investigated the relationship between inquiry-based learning and epistemic beliefs in secondary biology education.

2.5. Design-Based Research (DBR) as a Framework for Addressing Misconceptions and Epistemic Belief

Design-Based Research (DBR) offers a systematic and iterative framework for instructional innovation. DBI emphasizes classroom problem solving, continuous refinement, and string alignment between learning activities and conceptual goals (Anderson and Shattuck, 2012a). Previous studies investigating inquiry-based learning have commonly employed experimental and quasi-experimental designs to compare pre-test and post-test outcomes. These designs provide evidence about effectiveness but often provide limited information about how instructional activities are developed, adjusted, and improved within real classroom contexts. Through repeated cycles of analysis, design, implementation, evaluation, and revision, DBR allows researchers to identify context-specific solutions while contributing to educational theory and practice (Anderson & Shattuck, 2012). DBR addresses this limitation by combining intervention testing with iterative refinement of instructional practices. As a pedagogical approach, DBR supports: identification of learners' existing misconceptions, engagement in evidence-based tasks that challenge incorrect beliefs, scaffolding that guides students through scientific inquiry processes, and reflection and reconstruction of understanding based on empirical evidence. Literature indicates that DBR can effectively strengthen inquiry skills, deepen understanding of complex scientific ideas, and encourage epistemically better alignment to student needs, making it ideal for topics such as evolution that need conceptual change.

Epistemological beliefs about science constitute an important component of individuals' conceptual ecology; consequently, researchers such as Fysh and Lucas (1998) demonstrated that epistemic beliefs significantly shape their positions on various scientific issues. When learners view knowledge as absolute, authority-driven, or grounded in non-empirical sources, they are more likely to reject or reinterpret scientific explanations that conflict with these views. In contrast, students who perceive scientific knowledge as evidence-based, tentative, and subject to revision are more inclined to engage with and accept scientifically grounded explanations. Design-Based Research addresses these epistemic beliefs by situating learners in authentic problem-solving contexts where knowledge is generated, tested, and refined through evidence-based design cycles. These epistemological orientations strongly influence how learners interpret evidence, evaluate competing claims, and respond to controversial scientific topics, such as evolution.

2.6. Students' Achievement Levels and the Ethiopian Context

According to reports by the National Agency for Examinations, persistent learning challenges in science continue to affect science education in Ethiopia. The average Grade 12 students' performance in biology remains below basic proficiency (Zewdu Gebrekidan, 2010). In Ethiopia, science teaching has been dominated by teacher-centered approaches, which limit students' opportunities for investigation, scientific discussion, and evidence-based reasoning. Recent studies have reported that inquiry-based approaches improve students' engagement and science process skills; however, many studies focus on general science outcomes rather than specific biological concepts such as evolution. Furthermore, existing Ethiopian studies have mostly used survey and quasi-experimental designs, with limited application of Design-Based Research for developing and refining context-specific instructional interventions (Elaina Khasawneh, 2016). This suggests that existing instructional methods may not adequately address students' conceptual and epistemic needs, particularly in abstract domains like evolution. Given these challenges, research that explores misconceptions, epistemic beliefs, and inquiry-based pedagogy is timely and essential for informing more effective instructional design at the preparatory level. Interacting with DBI with evolution instruction has the potential to enhance conceptual understanding, promote epistemic development, and contribute to improved achievement outcomes. Therefore, this study employs a DBR framework to develop and evaluate a GIBL intervention aimed at improving students' achievement, conceptual understanding, and epistemic beliefs toward evolution.

2.7. Role of Guided Inquiry-Based Learning in Students' Learning Outcomes, Conceptual Understanding, and Epistemic Belief

Guided Inquiry-Based Learning influences students' achievement by increasing active participation, problem-solving ability, and meaningful engagement with scientific concepts. Unlike teacher-centered instruction, GIBL provides opportunities for learners to investigate evidence, discuss explanations, and apply concepts, which promotes deeper understanding and improved academic performance (Ismail, 2006).

In relation to conceptual understanding, GIBL supports conceptual change by exposing students' alternative conceptions and allowing them to test their explanations against scientific evidence. This process helps learners replace misconceptions with scientifically accepted explanations (Kirschner et al., 2006).

Furthermore, GIBL contributes to the development of epistemic beliefs by allowing students to experience science as a process of questioning, evidence evaluation, and knowledge refinement rather than a collection of fixed facts (Anderson & Shattuck, 2012).

2.8. Theoretical Framework

The conceptual framework of this study, grounded in a Design-Based Research (DBR) approach, is built on three interconnected theoretical pillars. Constructivist learning theory, rooted in Vygotsky's view that knowledge is actively constructed through social interaction and guided instruction, provides the epistemological foundation for engaging students as active participants in their own learning (Moll, 1990; Vygotsky, 1978). Conceptual change theory, as proposed by Posner et al. (1982) and further elaborated by Duit and Treagust (2003), explains why students' persistent misconceptions about evolution often resist conventional instruction and identifies the conditions necessary for restructuring those alternative conceptions into scientifically accepted understandings. In addition, personal epistemology theory emphasizes that students' beliefs about the nature of knowledge and how they interpret evidence, uncertainty, and scientific explanations (Hofer & Pintrich, 1997). These theoretical perspectives converge within the pedagogical mechanism of GIBL, which provides structured inquiry experiences that challenge misconceptions while simultaneously encouraging the development of more advanced epistemic beliefs (Banchi & Bell, 2008; Nicol, 2021). Within the DBR framework, GIBL was implemented to address contextual challenges in the Ethiopian secondary school setting, including limited approaches, difficulties associated with teaching evolution, and the prevalence of misconceptions among students. Consequently, the intervention was expected to enhance students' conceptual understanding of evolution and promote more informed epistemic beliefs regarding scientific knowledge (Gregory, 2009; Scott et al., 2020; Yates & Marek, 2014).

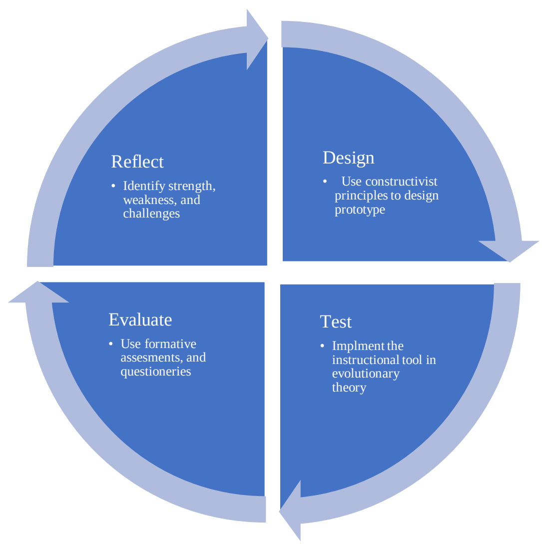

Figure 1: The four stages of Design-Based Research experienced in iterative cycles (Scott et al., 2020)

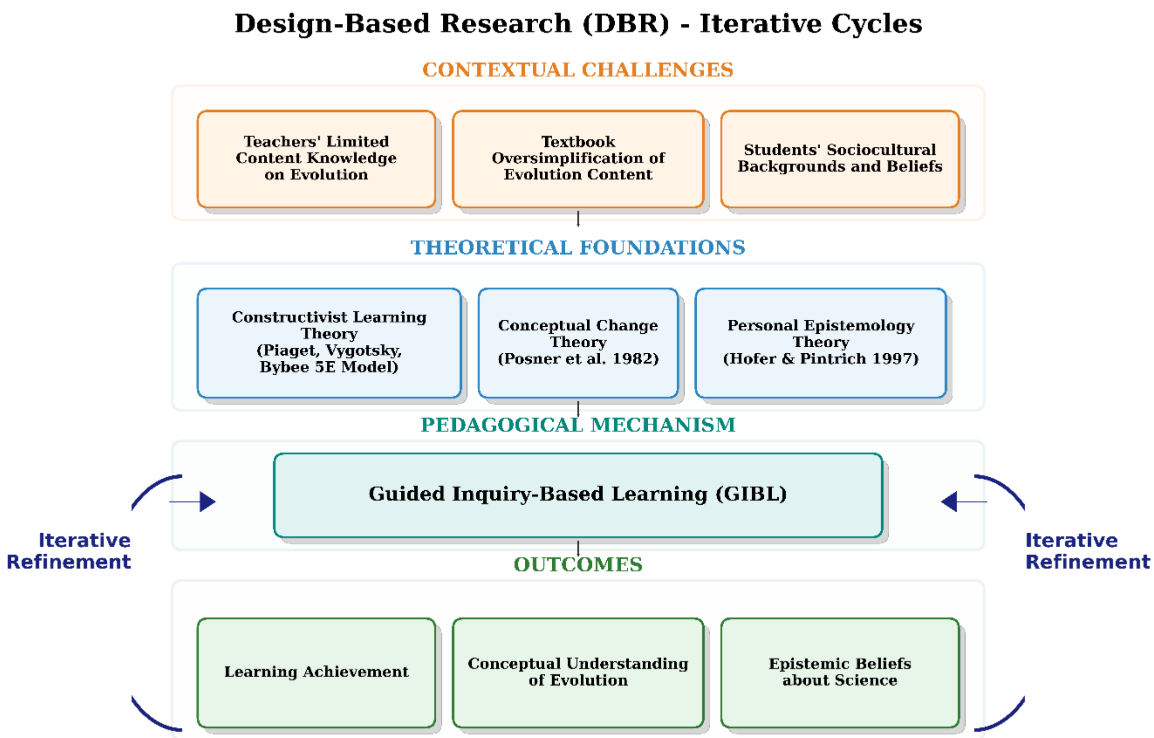

Figure 2: Conceptual Framework that shows the variable stakeholders and intervention for assessing students' misconceptions.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Paradigm

This study is grounded in the philosophical paradigm of pragmatism. Pragmatism was chosen because it rejects the notion that research must adhere exclusively to either a positivist or interpretivist worldview; instead, it embraces the use of whatever methodological approaches best address the research problem (Creswell & Creswell, 2018). Since this study aims to measure changes in students' learning achievement, conceptual understanding and epistemic beliefs quantitatively and to understand the processes and mechanisms underlying those changes qualitatively, pragmatism provides a coherent and flexible philosophical foundation. As Morgan (2007) argues, pragmatism shifts the focus from abstract epistemological debates to the practical consequences of research and the question of what works.

3.2 Research Approach

Consistent with the pragmatist paradigm, this study adopts a mixed-methods research approach that integrates both quantitative and qualitative data collection and analysis. The mixed-methods approach was chosen because no single method is sufficient to address the full complexity of the research objectives. Quantitative data gathered through pre- and post-tests and questionnaires enable the researcher to measure the magnitude of changes in students' learning achievement, conceptual understanding and their epistemic beliefs across DBR cycles. Qualitative data gathered through semi-structured interviews, classroom observations, student worksheets, and teacher reflection notes allow the researcher to explore how and why those changes occur, as well as to identify instructional challenges, student reasoning patterns, and areas needing revision.

This combination ensures that the study provides what Barab (2014, p. 158) calls baseline evidence focusing on "mechanism and process," characterizing the nature of student thinking. The integration of both data types at multiple stages of the research strengthens the internal validity of the findings and enriches the interpretive depth of the study.

3.3 Research Design

This study employs a Design-Based Research (DBR) design. Unlike other experimental designs that aim to test pre-established hypotheses under controlled conditions, DBR is iterative and collaborative: it proceeds through multiple cycles of design, implementation, data collection, analysis, and redesign in order to produce both improved instructional tools and theoretical insights about learning (Plomp, 2013) (Anderson & Shattuck, 2012).

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DBR was selected for this study because it is well-suited to addressing the dual goals of improving classroom practice and generating theoretical understanding. Specifically, DBR enables the researcher to design Guided Inquiry-Based Learning (GIBL) activities for teaching evolution, implement them in an actual Grade 12 classroom, examine how students respond, and revise the instructional design on the basis of evidence gathered in each cycle. This iterative process ensures that the intervention is continuously refined to address diagnosed student misconceptions about evolution and to improve both conceptual understanding and epistemic beliefs.

Guided Inquiry-Based Learning (GIBL) was selected as the instructional approach underpinning the DBR cycles because it actively engages students in building knowledge through structured inquiry, encouraging them to ask questions, gather evidence, and formulate conclusions under the guidance of the teacher (Pedaste et al., 2015). GIBL is thus aligned with both the constructivist learning objectives of the study and the misconception-targeting function of DBR. Together, DBR and GIBL form a mutually reinforcing research and pedagogical framework that is both theoretically grounded and practically responsive.

3.4 Study Area

The study was conducted at Fasilo Secondary and Preparatory School, located in Bahir Dar city, the capital of the Amhara Regional State, Ethiopia. The city lies at an altitude of approximately 1,800 meters above sea level, at coordinates 11°36′N and 37°23′E. Bahir Dar is one of the major urban centers in Ethiopia and hosts numerous secondary schools serving a diverse student population from both urban and peri-urban backgrounds.

3.5 Study Population, Study Sample, and Sampling Techniques

3.5.1 Study Population and Target Population

The study population consists of all government secondary schools in the Bahir Dar City Administration. The target population is all Grade 12 biology students enrolled in these schools during the 2026 academic year. Grade 12 biology students were specifically targeted because the Ethiopian secondary school curriculum places the topic of evolution at the Grade 12 level.

3.5.2 Sample School and Sampling Technique

Fasilo Secondary and Preparatory School was selected as the study site using purposive sampling. Purposive sampling is a non-probability sampling technique in which the researcher deliberately selects a site or participants that are information-rich and most capable of providing meaningful, relevant data in relation to the research objectives (Creswell & Creswell, 2018). This technique was chosen over random sampling because the DBR design requires a stable, cooperative, and contextually appropriate school environment that can sustain multiple iterative cycles of intervention, observation, and revision, conditions that cannot be guaranteed through random selection.

3.5.3 Sample Class, Sample Size, and Class Selection

One intact Grade 12 biology classroom was purposively selected from among the available Grade 12 biology sections at Fasilo Secondary School. Intact classroom sampling, that is, selecting an existing, naturally formed classroom group rather than randomly assigning individual students, is both a practical and methodological necessity in DBR. Because DBR requires continuous, sustained classroom access over multiple intervention cycles, disrupting the natural composition of classrooms through random assignment would be ethically inappropriate and logistically impractical. Using an intact class also ensures ecological validity, as the intervention takes place under authentic classroom conditions (Barab, 2014).

The selected class comprised 55 students (25 female and 30 male). The class was chosen in consultation with the school administration on the basis of teacher availability, timetable compatibility, and the absence of any concurrent examination or major curricular disruption during the research period. This single intact class served as the study sample across all DBR cycles in one semester interval for three consecutive weeks, divided into 6 learning sessions.

Fasilo Secondary School was selected as the study site because it provides a contextually appropriate setting for implementing the Guided Inquiry-Based Learning intervention. The school is a well-established government secondary school in Bahir Dar that serves a diverse student population broadly representative of Grade 12 learners in the study area. The selection was based on three main considerations: first, the willingness of the school administration and biology teachers to collaborate in educational research and provide sustained access to classrooms throughout the DBR cycles; second, preliminary observations and discussions with biology teachers confirmed that evolution is among the most conceptually challenging topics for Grade 12 students, making the school an appropriate context where the intervention was needed; and third, the accessibility and proximity of the school to the researcher ensured practical feasibility and ethical suitability for repeated classroom visits over an extended research period. Therefore, the school was chosen not merely for convenience but because it provided a meaningful and relevant environment for investigating the effectiveness of GIBL in addressing students' learning difficulties in evolution.

3.5.4 Limitations of the Sampling Approach

It is important to acknowledge that purposive sampling and the use of a single intact classroom impose limitations on the generalizability of the findings. Because the sample is neither randomly selected nor statistically representative of all Grade 12 biology students in Bahir Dar or Ethiopia, the quantitative findings cannot be statistically generalized to the broader population. However, as is consistent with the epistemological orientation of DBR and mixed-methods research, the goal of this study is not statistical generalizability but analytical transferability, that is, producing detailed, theoretically grounded insights about instructional design for teaching evolution that other practitioners and researchers can critically assess and apply to comparable contexts (Lincoln & Guba, 1985; Creswell & Creswell, 2018). The depth, transparency, and iterative rigor of the DBR process serve as the primary basis for trustworthiness and credibility in this study.

3.6 Data Collection Tools and Procedures

Data were collected using multiple complementary tools aligned with the mixed-methods design. A Conceptual Knowledge Test, Conceptual Understanding Test (CUT), and an Epistemic Belief Questionnaire (EBQ) were administered before and after each DBR cycle to measure changes in students' learning achievement, understanding of evolution, and their epistemic beliefs, respectively. Semi-structured interviews were conducted with selected students and biology teachers to gather in-depth qualitative insights into students' reasoning processes and teachers' instructional experiences. During each implementation cycle, classroom observations, student worksheets, and inquiry sheets were collected to assess students' inquiry behaviors, reasoning abilities, and challenges encountered during GIBL activities. Teacher reflection notes were also documented after each cycle to record instructional challenges and areas requiring further refinement.

All data sources were used collectively to evaluate the effectiveness of the instructional tools and to inform revisions for subsequent DBR phases. The triangulation of multiple data sources strengthens the internal validity of the findings and ensures that both the quantitative outcomes and the qualitative processes of learning are adequately captured and interpreted.

3.7. Result coding for collected tools

For analysis of the learning achievement, 20 conceptual understanding knowledge test in multiple choice question form were employed and also coded as 1 for Correct answer and 0 for incorrect answer. While 5 two tier multiple choice diagnostic test were used to analyze students’ conceptual understanding which were coded as 2 for both correct answer and correct reasoning, 1 for either correct answer or correct reasoning and 0 for both incorrect answer and incorrect reasoning. For analysis of the epistemic belief questioner results gained from both pre-test and post-test was tested by 10 Liker scale question which are coded as Strongly Disagree = 1, Disagree = 2, Neutral =3, Agree = 4 and Strongly Agree = 5

3.8. Categorization of Research Instruments Based on Evolution Content Areas

The research instruments were categorized based on the major conceptual domains of Evolution addressed in the Ethiopian Grade 12 Biology curriculum and evolution education literature. The categorization was conducted to ensure content validity and balanced representation of evolutionary concepts.

Table 1: Content Categorization of Conceptual Knowledge Test Items

Content Domain	Subtopic	Item Numbers	Number of Items
Variation and Heredity	Population variation, inherited traits, and mutation	Q1, Q2, Q8, Q16, Q19	5
Natural Selection and Adaptation	Adaptation, fitness, environmental selection, survival	Q3, Q4, Q5, Q6, Q7, Q11, Q12	7
Mechanisms of Evolution	Genetic drift, gene flow	Q17, Q18, Q20	3
Speciation and Evolutionary Relationships	Reproductive isolation, homologous structures, common ancestry	Q9, Q13, Q15	3
Scientific Nature of Evolution	Scientific explanation of evolution, selection patterns	Q10, Q14	2
Total		Q1–Q20	20

The Conceptual Knowledge Test covered five major domains of evolutionary biology. The largest proportion of items focused on natural selection and adaptation because these concepts are central to understanding evolutionary processes and are commonly associated with student misconceptions. The greatest improvement was observed in the domain of Natural Selection and Adaptation, where students' correct response rate increased from 39.0% during the pre-test to 70.6% during the post-test, representing a 31.7% improvement (Table 1).

Table 2: Categorization of Epistemic Belief Questionnaire Item

Epistemic Dimension	Description	Item Numbers	Number of Items
Source of Scientific Knowledge	Beliefs about authority and experts as sources of knowledge	1, 3	2
Certainty of Scientific Knowledge	Beliefs about whether scientific knowledge is fixed or changing	4, 8	2
Development of Scientific Knowledge	Beliefs about scientific investigation and research	2, 5, 7, 9	4
Justification of Scientific Knowledge	Beliefs regarding evidence and justification of scientific claims	6, 10	2
Total		1–10	10

Reverse-Coded Items

The following items were reverse-coded before statistical analysis because agreement reflected naïve epistemic beliefs:

- Item 1
- Item 3
- Item 4
- Item 10

The Epistemic Belief Questionnaire assessed students' beliefs regarding the nature, development, and justification of scientific knowledge in Evolution. Higher scores after reverse coding represented more advanced epistemic beliefs (Table 2).

3.9. Intervention

3.9.1. Identification of learning difficulties

The first step of the Design-Based Research (DBR) process involves identifying and analyzing learning difficulties in the target context (Reeves, 2006; Anderson & Shattuck, 2012). To this end, existing literature was analyzed to identify misconceptions commonly held by higher secondary school students about evolution. This approach is consistent with established DBR methodology, which emphasizes grounding the design process in a thorough understanding of the learning problem before any instructional solution is developed (McKenney & Reeves, 2012). Given that evolution is one of the most conceptually challenging and misconception-laden topics in secondary biology education (Nehm & Schonfeld, 2008; Gregory, 2009), a systematic literature review was the appropriate starting point for identifying the specific alternative conceptions prevalent at this level.

The identified misconceptions were then used to construct a two-tier multiple-choice (MC) diagnostic questionnaire, which was administered to the sampled students to (i) assess the state of their conceptual knowledge, (ii) identify the most prevalent misconceptions, and (iii) explore the type and origins of those misconceptions. The two-tier MC format was deliberately chosen over single-tier instruments because it provides a richer diagnostic picture: the first tier determines whether a student holds a misconception, while the second tier captures the reasoning behind their answer, thereby revealing the cognitive basis of the error rather than merely flagging its presence (Treagust, 1988; Caleon & Subramaniam, 2010). This dual-layer structure is particularly valuable in misconception research, where understanding the source and nature of a flawed conception is as important as detecting its existence (Tan et al., 2005).

Following the diagnostic phase, instructional methods for addressing the identified misconceptions were selected from the literature. This selection was not arbitrary; it was guided by the origin and type of each misconception, as well as the specific abilities, competencies, and learning needs of the sampled students. This approach aligns with conceptual change theory, which holds that effective instruction must be tailored to the particular nature of the misconception being targeted, distinguishing, for instance, between misconceptions rooted in everyday language, cultural beliefs, or faulty mental models since each type requires a different pedagogical response (Posner et al., 1982; Chi, 2008; Vosniadou, 2013). The selected methods were subsequently discussed and evaluated in a brainstorming session with experienced biology teachers. Involving practitioners at this stage reflects the collaborative and iterative character of DBR, in which teacher expertise is treated not as peripheral but as a core input into the design process (Barab & Squire, 2004). Their feedback served both to validate the appropriateness of the chosen strategies and to ensure their practical feasibility within the school context.

3.9.2. Design-Based Research, Phase 1: Designing Instructional Tools

The first phase of design-based research involves developing instructional tools that address both the theoretical and practical concerns of the learning problem (Edelson, 2009). Accordingly, GIBL-based instructional tools were designed to address documented misconceptions in the notion of evolution and to support more diversified epistemic beliefs. To achieve this, the design incorporates guided inquiry sheets, evidence-based debates, step-wise scaffolding questions, and prompts that require students to justify claims with evidence. These instructional tools were supported with constructivist learning theory and guided by the Grade 12 Biology curriculum. Furthermore, the designed materials were prepared to create observable inquiry practices that can be systematically evaluated.

Based on the discussion during the ideate stage, the method was selected to clear the identified misconceptions and used to produce three prototyped lesson plans. In this study, the selected method to clear the most prevalent misconception on evolution was 'Guided Inquiry-Based Learning (GIBL)' as the primary instructional strategy. This includes prototypes such as guided inquiry worksheets, scaffolding questions, claim evidence reasoning (CER) prompts, structured debates using evolutionary data, and stepwise activities that confront common misconceptions.

3.9.3. Phase 2: Testing the Instructional Tools

In the second phase of design-based research, the instructional tools were tested by implementing them in the selected classroom. According to Cobb et al. (2003), the instructional tools were placed “in harm’s way.” This means that the tools were exposed to real classroom conditions, including diverse students, time constraints, and contextual challenges, so that their strengths and weaknesses can be carefully examined. By doing so, researchers and instructors can closely observe how learning actually unfolds and identify which aspects of the design work as intended and which do not. As Hoadley (2004) notes, actual classroom environments often differ substantially from the controlled assumptions made during the design stage. Therefore, this phase allows the researcher to gather rich evidence about how the instructional tools function in practice, providing a basis for informed revision and improvement in subsequent design cycles.

3.9.4. Phase 3. Evaluating the Instructional Tools

The third phase of the intervention cycle involves evaluating the effectiveness of the instructional tools using the results of student learning (Anderson & Shattuck, 2012a). This was conducted by using the results of students (like home take exams, class activities, and reflections), attitudinal gains measured with participation rates in activities, classroom discourse practices, formative assessments, and exam data (Robert, 2006). While these evaluation methods showed how students respond to the intervention, reliability and validity addressed a different concern. Reliability refers to the consistency of the measurement process, whereas validity refers to whether the tools and assessments truly measure what they are intended to measure.

After evaluating the outcomes, the process was reassessed to identify challenges and areas for improvement. These insights were then used to refine the instructional design and feed into the next iteration of the DBR cycle. This was conducted by using the results of students (like home take exams, class activities, and reflections), and attitudinal gains were measured with participation rates in activities, classroom discourse practices, formative assessments, or exam data (Robert, 2006).

3.9.5. Reflecting on the Instructional Tools and Their Implementation

The final phase of the design-based research cycle involves a reflective data analysis that focuses on the epistemic commitments of the methodology: how the theory emphasized the research advanced by the research effectiveness (theoretical outcomes)? Did the instructional tools support student learning about how to solve learning difficulties and problems (practical outcome)? What were the main features of the design solution that support student learning (design principles) (Scott et al., 2020)?

3.9.6. Redesign and Refine the Intervention

The final epistemic commitment of design-based research is its emphasis on iterative refinement based on evidence gathered during implementation. Rather than evaluating an instructional intervention only at the end of the study, DBR involves continuously modifying and improving instructional strategies in response to students' learning needs and observed challenges. During the implementation of Guided Inquiry-Based Learning (GIBL), formative evidence obtained from classroom observations, student discussions, worksheets, and assessment results revealed persistent difficulties related to natural selection, common ancestry, and the relationship between scientific explanations and religious beliefs. In response, additional scaffolding strategies were incorporated, including more structured inquiry questions, misconception-focused discussions, collaborative argumentation activities, and explicit clarification of the distinction between scientific and religious ways of knowing. Furthermore, inquiry tasks and learning materials were revised to provide clearer guidance and stronger conceptual support for difficult evolutionary concepts. These iterative refinements enhanced the effectiveness of the GIBL intervention and helped address learning gaps that were not fully resolved during the initial implementation cycle. By viewing educational inquiry as formative research, design-based research acknowledges the complexity of classroom learning environments and recognizes that instructional tools must be continuously adapted to meet students' evolving needs (Allan Collins, Diana Joseph, 2009).

3.10. Data analysis

The data collected from the study were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25. Initially, descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize students' achievement, conceptual understanding, and epistemic belief scores before and after the GIBL intervention. Subsequently, paired-sample t-test scores. The paired-sample t-test is believed to be suitable because the same group of students was evaluated before and after the intervention. In addition, Choen's d effect size was calculated to assess the magnitude of the observed changes and to evaluate the practical significance of the intervention. Furthermore, frequencies and percentages were used to analyze students' responses to the two-tier conceptual understanding test, thereby enabling the identification of changes in scientific reasoning and misconceptions related to evolution. Finally, the classroom observation and interview data collected throughout the implementation phase were recoded, transcribed, and thematically analyzed to identify relevant statements to provide confirming evidence regarding students' conceptual development, engagement, participation, and scientific reasoning during the GIBL activities. This provides a more complete and nuanced understanding of the investigation

3.11. Reliability test

The reliability of scores obtained from the evolution conceptual understanding test was established using the test-retest reliability method. The test was piloted with students from a comparable biology class who would not participate in the main study. The Pearson product-moment correlation coefficient was computed to examine the consistency of scores across the two testing occasions. A high correlation coefficient $r = 0.82$ indicates that the instrument yields stable and reliable scores over time.

3.11.1. Reliability Analysis of Instruments

Reliability analysis was conducted to determine the internal consistency of the instruments used in the study, namely the Conceptual Knowledge Test (CKT), Epistemic Beliefs Questionnaire (EBQ), and Conceptual Understanding Test (CUT).

Table 3: Reliability Statistics of Research Instruments

Instrument	Number of Items	Reliability Method	Cronbach's Alpha	Interpretation
Conceptual Knowledge Test (CKT)	20	Cronbach Alpha	0.78	Acceptable
Epistemic Belief Questionnaire (EBQ)	10	Cronbach Alpha	0.82	Good
Conceptual Understanding Test (CUT)	5 Two-tier items	Cronbach Alpha	0.74	Acceptable

The reliability analysis indicated that all instruments demonstrated acceptable internal consistency. The Epistemic Belief Questionnaire showed good reliability ($\alpha = 0.82$), while the Conceptual Knowledge Test and Conceptual Understanding Test showed acceptable reliability coefficients of 0.78 and 0.74, respectively. Therefore, the instruments were considered suitable for data collection and further statistical analysis (Table 3).

To assess the internal consistency of the instrument, Cronbach's alpha was calculated for the 10-item scale. The scale demonstrated acceptable internal consistency reliability, alpha = 0.721, indicating that the items reliably measure the targeted construct.

Reliability Statistics	
Cronbach's Alpha = 0.721	No of Items = 10

3.12. Ethical Issues

Ethical principles were carefully maintained throughout the study. Before data collection, a formal permission letter was obtained from Bahir Dar University College of Education and Behavioral Science, School of Teachers Education, and the administration of the target school. Informed consent was secured from all participants, and they were clearly informed about the purpose of the study, procedures involved, and they were assured that all information collected would be treated with strict confidentiality and anonymity. Participants have had the right to voluntarily participate or withdraw at any time.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 RESULTS

Introduction

This chapter presents the empirical findings of the study and their implications in relation to the primary research questions. Specifically, it details the impact of Guided Inquiry-Based Learning (GIBL) on students' academic achievement regarding the concept of evolution. Furthermore, the chapter assesses changes in students' conceptual understanding and epistemic beliefs towards evolution before and after the GIBL intervention. Finally, these quantitative outcomes are supplemented by the interpretation of qualitative data gathered through structured classroom observations.

A total of 55 students, 30 male and 25 female, participated in the study. The participants ranged in age from 17 to 20 years.

4.1.1. Normality check

Table 4: Shapiro-Wilk Test of Normality for Difference Scores

Variable	Shapiro–Wilk Statistic	df	Sig. (p)	Decision
Learning Achievement	0.989	55	0.883	Normal
Conceptual Understanding	0.950	55	0.024	Not Normal
Epistemic Belief	0.988	55	0.837	Normal

The Shapiro–Wilk test was conducted to assess the normality of the difference scores between pre-test and post-test results. The findings indicated that the difference scores for learning achievement ($W = 0.989$, $p = 0.883$) and epistemic belief ($W = 0.988$, $p = 0.837$) were normally distributed (Table 5). However, the conceptual understanding difference scores showed significant deviations from normality ($W = 0.950$, $p = 0.024$). Despite this, because the study included 55 students and the paired-samples t-test is relatively robust to violations of normality, the analysis proceeded using non-parametric statistics. Therefore, the Wilcoxon Signed-Rank Test was employed to analyze changes in students' conceptual understanding. The results of this analysis are presented in the conceptual understanding results section.

4.1.2 Impact of GIBL on students' learning achievements about the concept of Evolution

Table 5: Descriptive Statistics of Students' Learning Achievement Scores

Test	N	Mean	SD	SE	Minimum	Maximum
Pre-test	55	9.16	2.84	0.38	3	15
Post-test	55	13.60	2.95	0.40	7	19

The descriptive statistics revealed an increase in students' mean achievement scores following the implementation of GIBL. The post-test mean score (M = 13.60) was considerably higher than the pre-test mean score (M = 9.16), suggesting improvement in students' achievement regarding evolutionary concepts (Table 5).

Table 6: Paired Sample t-Test for Learning Achievement

Variable	Mean Difference	t	df	p-value	Cohen's d
Achievement Pre-test vs Post-test	4.44	8.64	54	< .001	1.16

The paired-samples t-test revealed a statistically significant difference between pre-test and post-test achievement scores, $t(54) = 8.64$, $p < .001$. The result indicates that Guided Inquiry-Based Learning significantly improved students' achievement in Evolution. Furthermore, the effect size (Cohen's d = 1.16) indicated a large practical effect of the intervention (Table 6).

Table 7: Students' response rate to each content domain

Content Domain	Test type	Number of Items	Out of the 55 students, correct respondents (mean)	%
Variation and Heredity	Pretest	5	29.2	53.1
	Post test	5	39.2	71.3
Natural Selection and Adaptation	Pretest	7	21.4	39
	Post test	7	38.9	70.6
Mechanisms of Evolution	Pretest	3	26	47.3
	Post test	3	33.7	61.2
Speciation and Evolutionary Relationships	Pretest	3	26.7	48.5
	Post test	3	36	65.5
Scientific Nature of Evolution	Pretest	2	25	45.5
	Post test	2	35.5	65.5
Total	Pretest	20	504	45.8
	Post test	20	748	68.0

Table 7 presents students' performance across the five content domains of evolutionary biology before and after the Guided Inquiry-Based Learning (GIBL) intervention. Prior to the intervention, students demonstrated the highest level of understanding in the Variation and Heredity domain, achieving 146 correct responses out of 275 possible responses (53.1%). This relatively higher performance may be attributed to students' prior exposure to genetics, inheritance, and variation concepts in earlier biology courses, making these concepts more familiar and easier to comprehend. In contrast, the lowest performance was observed in the Natural Selection and Adaptation domain, with only 150 correct responses out of 385 possible responses (39.0%). This finding suggests that students entered the intervention with substantial misconceptions regarding adaptation and natural selection, which are widely recognized as among the most difficult concepts in evolutionary biology. Many students tend to believe that organisms intentionally change because they need to survive or that adaptation occurs as a purposeful response to environmental demands rather than through differential survival and reproduction.

Following the GIBL intervention, students' performance improved considerably across all content domains. The highest post-test performance remained in the Variation and Heredity domain (71.3%), while the greatest improvement occurred in Natural Selection and Adaptation, which increased from 39.0% to 70.6%, representing a gain of 31.6 percentage points. This substantial improvement suggests that the inquiry-based activities, evidence-centered discussions, and guided investigations effectively challenged students' misconceptions and promoted a more scientifically accurate understanding of evolutionary processes. Although all domains showed notable gains, Mechanisms of Evolution remained the lowest-performing domain in the post-test (61.2%). Concepts such as genetic drift and gene flow require abstract population-level reasoning and probabilistic thinking, making them inherently more difficult for students to understand than more concrete concepts related to heredity and variation (Table 6).

Overall, the findings indicate that students initially possessed uneven understanding across the different domains of evolutionary biology, with particularly weak understanding of natural selection and adaptation. However, the substantial gains observed after the intervention demonstrate that GIBL was effective in improving students' understanding across all content areas, especially those traditionally associated with persistent misconceptions and conceptual difficulties.

4.1.3. Students' Conceptual Understanding of Evolutionary Concepts

Table 8: Descriptive Statistics of Conceptual Understanding Scores

Test	N	Mean	SD	Minimum	Maximum
Pre-test	55	3.85	1.42	1	7
Post-test	55	7.56	1.71	3	10

The mean conceptual understanding score increased substantially from the pre-test (M = 3.85) to the post-test (M = 7.56). This finding suggests that students developed improved scientific understanding of evolutionary concepts after exposure to GIBL (Table 8).

Table 9: Wilcoxon Signed-Rank Test Results for two-tier question

Question	Pre M (SD)	Pre Mdn	Post M (SD)	Post Mdn	W	Z	p	r	+	−	Ties
Q1	0.75 (0.58)	1.0	1.55 (0.63)	2.0	66.0	5.109	< .001	.689	38	4	13
Q2	0.76 (0.74)	1.0	1.45 (0.66)	2.0	150.0	3.910	< .001	.527	34	8	13
Q3	0.71 (0.71)	1.0	1.49 (0.66)	2.0	85.0	4.533	< .001	.611	35	5	15
Q4	0.73 (0.76)	1.0	1.51 (0.60)	2.0	90.5	4.589	< .001	.619	36	5	14
Q5	0.91 (0.65)	1.0	1.56 (0.57)	2.0	87.0	4.335	< .001	.584	32	6	17

Table 9 presents the results of the Wilcoxon Signed-Rank Test comparing students' pre-test and post-test performance on the five two-tier conceptual understanding questions designed to diagnose common misconceptions about evolution.

Overall, the results indicate a statistically significant improvement in students' conceptual understanding across all five misconception domains following the GIBL intervention. For each question, the post-test median score increased from 1.0 to 2.0, suggesting that students were more likely to provide both the correct answer and correct scientific reasoning after participating in the intervention.

Specifically, for Question 1, students' mean score increased from 0.75 (SD = 0.58) in the pre-test to 1.55 (SD = 0.63) in the post-test. The Wilcoxon Signed-Rank Test revealed a statistically significant difference ($Z = 5.109$, $p < .001$), with a large effect size ($r = .689$). Furthermore, 38 students showed improvement, only 4 showed a decline, and 13 remained unchanged, indicating substantial conceptual change regarding natural selection.

For Question 2, the mean score increased from 0.76 to 1.45, and the difference was statistically significant ($Z = 3.910$, $p < .001$, $r = .527$). A total of 34 students improved, while only 8 showed lower scores and 13 remained unchanged. This suggests that students developed a better understanding of speciation and reproductive isolation after the intervention.

Similarly, Question 3 showed a significant increase from 0.71 to 1.49 ($Z = 4.533$, $p < .001$, $r = .611$), with 35 students improving and only 5 declining. This result indicates a reduction in misconceptions regarding the nature of scientific theories and scientific explanations.

For Question 4, students' scores increased from 0.73 to 1.51, yielding a significant result ($Z = 4.589$, $p < .001$, $r = .619$). The finding that 36 students improved compared to only 5 who declined suggests that misconceptions related to human evolution and common ancestry were substantially reduced.

Finally, Question 5 demonstrated a significant increase from 0.91 to 1.56 ($Z = 4.335$, $p < .001$, $r = .584$). Although students initially performed relatively better on this item than on the other questions, 32 students still showed improvement following the intervention, indicating enhanced understanding of common ancestry and evidence for evolutionary relationships.

4.1.4 Analysis of Students' Responses in Two-Tier Questions

The two-tier conceptual understanding test was used to assess students' scientific reasoning and misconceptions regarding Evolution.

Table 10: Distribution of Students' Responses in Two-Tier Questions

Item	Test	Both Correct Answer and Correct Reasoning n (%)	Either Correct Answer or Correct Reasoning n (%)	Both Incorrect Answer and Incorrect Reasoning n (%)
CUT1	Pre-test	4 (7.3%)	33 (60.0%)	18 (32.7%)
CUT1	Post-test	34 (61.8%)	17 (30.9%)	4 (7.3%)
CUT2	Pre-test	10 (18.2%)	22 (40.0%)	23 (41.8%)
CUT2	Post-test	30 (54.5%)	20 (36.4%)	5 (9.1%)
CUT3	Pre-test	8 (14.5%)	23 (41.8%)	24 (43.6%)
CUT3	Post-test	32 (58.2%)	18 (32.7%)	5 (9.1%)

CUT4	Pre-test	11 (20.0%)	28 (50.9%)	16 (29.1%)
CUT4	Post-test	37 (67.3%)	15 (27.3%)	3 (5.5%)
CUT5	Pre-test	9 (16.4%)	32 (58.2%)	14 (25.5%)
CUT5	Post-test	33 (60.0%)	20 (36.4%)	2 (3.6%)

CUT (Conceptual understanding test)

The findings revealed substantial improvement in students' scientific reasoning and conceptual explanations after the GIBL intervention. Before the intervention, many students demonstrated misconception-based reasoning by selecting incorrect answers together with incorrect explanations. However, after exposure to GIBL, the proportion of students selecting both correct answers and correct reasoning increased considerably across all conceptual areas.

For example, in CUT1, only 7.3% of students selected both the correct answer and reasoning during the pre-test, whereas this increased to 61.8% during the post-test. Similarly, in CUT4, which assessed understanding of human evolution and common ancestry, scientifically accurate responses increased from 20.0% to 67.3%.

The results indicate that Guided Inquiry-Based Learning promoted conceptual change and improved students' scientific reasoning regarding Evolution (Table 10).

4.1.5 Categorization of Conceptual Understanding Test (CUT)

Table 11: Categorization of Two-Tier Conceptual Understanding Items

Item	Main Concept Area	Misconception Targeted	Scientific Concept Measured	Pre-test Response Rate (Both Correct / Partial / Incorrect)	Post-test Response Rate (Both Correct / Partial / Incorrect)
CUT1	Natural Selection	Need-based evolution and inheritance of	Selection acts on existing	7.3% / 60.0% / 32.7%	61.8% / 30.9% / 7.3%

		acquired traits	variation		
CUT2	Speciation	Misunderstanding reproductive isolation	Allopatric speciation and gene flow	18.2% / 40.0% / 41.8%	54.5% / 36.4% / 9.1%
CUT3	Nature of Scientific Theory	"Theory means guess" misconception	Scientific theory as an evidence-based explanation	14.5% / 41.8% / 43.6%	58.2% / 32.7% / 9.1%
CUT4	Human Evolution	Humans evolved directly from chimpanzees	Common ancestry and divergence	18.2% / 36.4% / 45.5%	56.4% / 38.2% / 5.5%
CUT5	Common Ancestry	Linear and goal-directed evolution	Shared ancestry supported by evidence	16.4% / 58.2% / 25.5%	60.0% / 36.4% / 3.6%

The two-tier conceptual understanding instrument specifically targeted common misconceptions in Evolution education. The test was designed to evaluate both students' selected answers and the scientific reasoning underlying their responses.

Pre-instruction, most students lacked full conceptual understanding across all five items, with incorrect rates ranging from 25.5% (CUT5) to 45.5% (CUT4). Post-instruction, full understanding rates jumped dramatically from below 20% to above 54% in every domain, while incorrect responses nearly disappeared (under 10% for all items). CUT1 (Natural Selection) showed the most remarkable shift, moving from just 7.3% to 61.8% full understanding, while CUT4 (Human Evolution) entered instruction as the most widely misunderstood concept. Overall, the two-tier instrument effectively captured not only whether students knew the right answer but also whether their reasoning was scientifically grounded, and the post-test results confirm that the instruction successfully addressed all five targeted misconceptions (Table 11).

4.16. Normalized Gain Analysis of Conceptual Understanding

Normalized gain analysis was conducted to determine the magnitude of conceptual improvement.

Formula

g = (post-test score − pre-test score) / (Maximum score − pre-test score)

Using the mean pre-test score of 9.16, the mean post-test score of 13.60, and the maximum attainable score of 20, the normalized gain was calculated as follows:

$g = (13.60 - 9.16) / (20 - 9.16) = 0.41$

The normalized gain of 0.41 falls within the medium-gain category according to Hake's classification. This result indicates that the Guided Inquiry-Based Learning intervention produced a meaningful improvement in students' achievement in evolutionary biology concepts.

Table 12. Normalized Gain of Conceptual Understanding

Variable	Mean Gain (g)	Interpretation
Conceptual Understanding	0.60	Medium Gain

The normalized gain score of 0.60 indicates a medium conceptual gain according to Hake’s classification. This suggests that Guided Inquiry-Based Learning was effective in promoting misconception reduction analysis (Table 12).

2.4 Misconception Reduction Analysis

The two-tier diagnostic test was used to identify common misconceptions related to Evolution before and after the intervention.

Table 13: Reduction of Common Evolution Misconceptions

Item Number	Concept Area	Misconception Identified	Pre-test Incorrect n (%)	Post-test Incorrect n (%)	Improvement
CUT1	Natural Selection	Organisms evolve because they need traits	43 (78.2%)	16 (29.1%)	49.1% reduction
CUT2	Speciation	Species change intentionally or instantly	38 (69.1%)	14 (25.5%)	43.6% reduction
CUT3	Nature of Scientific Theory	"Theory" means a guess or opinion	38 (69.1%)	13 (23.6%)	45.5% reduction
CUT4	Human Evolution	Humans evolved directly from chimpanzees	36 (65.5%)	10 (18.2%)	47.3% reduction
CUT5	Common Ancestry and Geological Time	Evolution is goal-directed or instantaneous	35 (63.6%)	11 (20.0%)	43.6% reduction

The findings indicate a considerable reduction in major misconceptions after the GIBL intervention. The greatest improvement was observed in misconceptions related to human evolution and the scientific meaning of theory. This suggests that inquiry-based learning promoted conceptual restructuring and scientific reasoning (Table 13).

4.1.7 Observation-Based Evidence of Students' Conceptual Understanding

Classroom observations conducted throughout the intervention provided compelling evidence of students' progressive conception development in evolutionary biology. Initially, students exhibited persistent misconceptions, believing that organisms evolve out of necessity, that evolutionary change occurs instantaneously, and that humans descended directly from modern chimpanzees while relying heavily on rote memorization rather than scientific reasoning. As the GIBL activities advanced, however, a marked shift in cognitive engagement became evident. Students transitioned from passive recall to actively constructing evidence-based explanations, justifying claims through scientific reasoning, and drawing meaningful connections between evolutionary concepts and real-world examples and analogies. Notably, their command of core concepts, including natural selection, common ancestry, adaptation, and speciation, grew increasingly articulate and confident. Beyond content knowledge, observations consistently documented heightened curiosity, collaborative discourse, questioning behavior, and reflective thinking, all of which are hallmarks of deeper conceptual understanding, and day by day, eager to know more and open to accepting what scientific theories really mean. Additionally, onetime one student asks about a tree that produce only seeds at its last energy she wants to know how this behavior help the tree, we discussed this to the whole class that it is one of its survival method to continue its kind, as a result this is a sign that students are starting to notice their environment and also ask question which is a key point in learning science. Collectively, these qualitative observations strongly corroborate the quantitative findings, affirming that GIBL served as an effective pedagogical approach in improving students' understanding of evolution.

4.1.8 Qualitative evidence supporting conceptual understanding

When students were informally interviewed following GIBL activities, their responses showed that the misconceptions they held regarding evolutionary concepts were traced back to their religious convictions and cultural beliefs rather than purely cognitive misunderstandings.

Student 1: "*At first, I was very uncomfortable about the topic of evolution because in my religion, we believe that the one and only almighty God created all living and non-living things as they are. I thought learning evolution and accepting the concepts and evolutionary theories meant rejecting my faith. But after our classroom discussions, our teacher helped us to understand that evolution is a scientific explanation, not a replacement for our beliefs. I still have my faith, but I now understand what scientists mean when they talk about evolution and its importance*."

Student 2: "*I asked my teacher if humans came from primates, why do monkeys still exist today? I thought this completely disproved evolution. But through these past weeks, I learned that humans did not evolve from today's monkeys. Rather, human and modern primates share a common ancestor that branched into different lineages long ago. That explanation made more sense to me scientifically, even though I personally still believe in creation*."

Student 3: "*Our cultural and religious teaching says that God created creatures perfectly and completely. So, I questioned how evolution could be real if everything was already made perfect. Through these learning sections and classroom activities, I came to understand that evolution does not mean creatures are imperfect; it is a scientific description of how traits in populations shift over generations in response to environmental pressures. I learned to separate what science explains from what my religion teaches*."

4.1.9. Students' Epistemic Belief towards Evolution

Out of the 10 items evaluated, 9 items yielded mean scores above the neutral midpoint of 3.00, indicating a generally positive perception or high performance across the majority of the assessed areas.

3.1 Descriptive Statistics of Students' Epistemic Beliefs

Table 14: Descriptive Statistics of Epistemic Belief Scores

Test	N	Mean	SD	Minimum	Maximum
Pre-test	55	26.96	4.21	18	36
Post-test	55	32.29	4.53	22	43

The descriptive statistics show an increase in students' epistemic belief scores after the intervention. This implies that students developed a more advanced attitude regarding the nature of scientific knowledge and Evolution.

A paired-samples t-test was conducted to determine whether changes in students' epistemic beliefs were statistically significant (Table 14).

Table 15: Paired Sample t-Test for Epistemic Beliefs

Variable	Mean Difference	t	df	p-value	Cohen’s d
Epistemic Belief Pre-test vs Post-test	5.33	4.26	54	< .001	0.57

A paired-sample t-test was conducted to examine the effect of GIBL on students’ epistemic beliefs concerning Evolution and scientific knowledge. The analysis showed a statistically significant improvement in students’ epistemic beliefs scores after the intervention, $t(54) = 4.26$, $p < 0.001$. The mean difference between pre-test and post-test scores was 5.33, indicating that students developed more advanced epistemic beliefs following exposure to GIBL. Furthermore, the effect size was moderate (Choens’ $d = 0.57$), suggesting that the intervention had a meaningful practical impact, with approximately 66% of students demonstrating improvement in their understanding of the nature and development of scientific knowledge (Table 15).

4.1.10. Qualitative evidence supporting epistemic beliefs

Analysis of students’ reflections revealed important changes in how they viewed scientific knowledge and the nature of scientific explanations.

Student 4: “*I argued in class that natural selection is just based on luck and chance, so it cannot be a real scientific explanation for the diversity of life. But after classroom discussions and home take assignments, I discovered that natural selection is not purely random variation that exists in populations, and the environment consistently favors certain traits over others. It is a non-random process acting on random variation. That distinction was new and important for me*.”

Student 5: “*I believed that evolution was part of a bigger atheist agenda that started with the Big Bang theory that scientists were trying to explain everything without God, from the origin of the universe to the origin of humans. In my previous knowledge, accepting any of these theories means denying that God created the universe and everything in it. So, I rejected all of it together. But through our discussions, I raised this question, and I began to understand that the Big Bang theory belongs to physics and cosmology, while evolution belongs to biology; they are separate scientific explanations* *addressing completely different questions. More importantly, our teacher clarified that science explains the how and when of natural phenomena, while religion addresses the why and who. Science does not claim to answer questions of purpose or creation in a spiritual sense. I still hold my religious belief sincerely, but I now understand that developing scientific literacy and keeping personal belief is a very important distinction I had never been taught before*."

4.2. DISCUSSION

The present study investigated the effect of Guided Inquiry-Based Learning (GIBL) on Grade 12 students' learning achievement, conceptual understanding, misconception reduction, and epistemic beliefs about evolution. The findings imply statistically significant improvements across all measured outcomes following the GIBL intervention. The discussion below examines each major finding in light of relevant empirical and theoretical literature.

1. Effect of GIBL on Students' Learning Achievement

The results of the paired-samples t-test prove a statistically significant improvement in students' learning achievement following the GIBL intervention, with mean scores increasing from 9.16 (pre-test) to 13.6 (post-test), giving a huge effect size (Cohen's d = 1.16). This finding is consistent with a substantial body of research affirming the effectiveness of inquiry-based approaches in improving students' academic achievement in science subjects.

A meta-analysis on inquiry-based learning and academic success implies that the constructivist learning approach, within which guided inquiry is established consistently, yields large effect sizes at the high school level (Heindl, 2019; Kaçar et al., 2021; Öztürk et al., 2022). Similarly, Chengere et al. (2025) found that the Guided Inquiry-Based Laboratory Experiment Instructional (GIBLEI) approach scored a significant improvement in post-test scores among tenth-grade biology students' participation in experiments, which advances self-confidence and enhances comprehension beyond conventional instructional methods (Chengere et al., 2025, p. 4).

The large effect size (Cohen's $d = 1.16$) observed in this study further confirms findings from inquiry-based learning research. Cohen (1988) defined a large effect as $d \geq 0.80$, and empirical work in biology education has determined that active, inquiry-oriented interventions regularly produce a large effect size when compared to passive or teacher-centered instruction (Gottesman & Hoskins, 2013). Panoy et al. (2022) similarly reported significantly higher conceptual knowledge gains among students exposed to inquiry-based instruction compared to those taught via conventional methods, concluding that "increased participation facilitated by inquiry-based learning contributed to better academic performance" (Panoy et al., 2022, p. 3).

In the context of the present study, the achievement gains are particularly meaningful given the conceptual complexity of the evolutionary content addressed. Within the GIBL sessions, students were guided through inquiry activities specifically targeting core evolutionary concepts, including natural selection, adaptation, common ancestry, variation, and mechanisms of evolutionary change. For instance, students examined fossil evidence and comparative anatomy data to construct arguments for common descent, engaged in structured investigations exploring how environmental pressures drive differential survival and reproduction, and analyzed case studies such as antibiotic resistance and industrial melanism to reason about natural selection in observable, real-world contexts. Students also participated in evidence-based debates around the mechanisms of evolutionary change, requiring them to distinguish between Lamarckian misconceptions and Darwinian explanations, a process that directly targeted the conceptual errors identified during the pre-intervention diagnostic phase. These inquiry experiences compelled students to move beyond rote memorization of evolutionary definitions toward genuine conceptual reasoning, which is reflected in the substantial pre-to-post achievement gains observed.

The theoretical basis for these findings lies in constructivist learning theory, particularly the work of Piaget (1970) and Vygotsky (1978), which speculates that meaningful learning occurs when learners actively construct knowledge through interaction with their environment. Guided inquiry operationalizes this principle by engaging students in structured investigation while providing scaffolding teacher support, a balance that maximizes both cognitive engagement and knowledge consolidation (Hofstein & Lunetta, 2004). The present results thus provide additional empirical support for constructivist theory as the theoretical foundation of effective science instruction in the secondary school context.

2. Effect of GIBL on Students' Conceptual Understanding

The analysis revealed a statistically significant improvement in students' conceptual understanding following the GIBL intervention. Consistent with the non-normal distribution of the conceptual understanding difference scores, a Wilcoxon Signed-Rank Test was employed and indicated significant improvement across all five conceptual domains assessed by the two-tier diagnostic instrument ($p < .001$). Furthermore, students' overall conceptual understanding scores increased from a pre-test mean of 3.85 to a post-test mean of 7.56. The normalized gain score of 0.60 indicated a medium conceptual gain according to Hake's (1998) classification, suggesting that GIBL was effective in promoting meaningful conceptual change and reducing misconceptions related to evolution.

The item-level Wilcoxon analyses further demonstrated that conceptual improvement occurred across all targeted misconception domains. Significant gains were observed in students' understanding of natural selection, speciation, the nature of scientific theories, human evolution, and common ancestry ($p < .001$ for all items). The large effect sizes observed across the five questions suggest that the intervention not only improved students' ability to identify correct answers but also strengthened the scientific reasoning underlying those answers. This finding provides strong evidence that GIBL promoted genuine conceptual restructuring rather than simple memorization of evolutionary concepts.

Hake (1998), in a landmark study comparing 62 introductory physics courses encompassing over 6,500 students, defined normalized gain as "a rough measure of the effectiveness of a course in promoting conceptual understanding" and classified gains of 0.30-0.70 as medium and gains above 0.70 as high. The present normalized gain of 0.60 is situated at the upper boundary of the medium gain category, suggesting that GIBL was effective in producing meaningful conceptual change. This result is comparable with previous studies. Pamela et al. (2022) reported a high Hake gain of 0.82 using open inquiry learning, while studies employing guided inquiry, which provides more scaffolding, typically yield gains in the medium range, consistent with the present findings.

The conceptual improvement observed in this study aligns with theoretical perspectives on conceptual change (Posner et al., 1982), which argue that learners restructure prior knowledge when confronted with compelling evidence or cognitive conflict. GIBL promotes this process by requiring students to formulate hypotheses, engage with evidence, and evaluate explanations. Conditions that facilitate the replacement of intuitive or naïve conceptions with scientifically accurate ones. Chengere et al. (2025) specifically reported that GIBLEI "supports student engagement, motivation, critical thinking, problem solving, and long-term knowledge retention," all of which contribute to deeper conceptual understanding.

Furthermore, inquiry-based learning environments promote deeper approaches to learning compared to surface-level memorization associated with teacher-centered instruction. Faraon et al. (2021), as cited in Panoy et al. (2022), argued that one of the core principles of inquiry-based learning is "measuring the development of information-processing abilities and conceptual understanding rather than focusing on the actual substance of the field." This orientation toward process over content is particularly important in biology education, where understanding complex mechanisms such as natural selection demands not only factual recall but also the ability to reason scientifically across novel scenarios (Nehm et al., 2022; de Lima & Long, 2023).

The findings of the present study are consistent with numerous studies reporting positive effects of inquiry-based learning on students' achievement and conceptual understanding in science (Johnston et al., 2022; Chengere et al., 2025; Panoy et al., 2022). However, not all studies have reported uniformly positive outcomes. Kirschner et al. (2006) argued that minimally guided inquiry places excessive demands on working memory, overwhelming novice learners who lack sufficient prior knowledge, while Furtak et al. (2012) found that the effectiveness of inquiry-based instruction varied considerably, yielding strong learning outcomes. These contrasting findings suggest that the effectiveness of inquiry-based learning depends not only on the instructional approach itself but also on the quality and structure of its implementation. In the present study, the structured guidance embedded within the GIBL intervention provided students with scaffolded frameworks for evidence examination, guided questioning, and teacher-facilitated discussion, reducing cognitive overload while maintaining meaningful investigative engagement (Hmelo-Silver et al., 2007). Furthermore, Minner et al. (2010) found that inquiry instruction actively involving students in investigation ad hoc-making produced significantly greater conceptual gains than passive formats, consistent with the achievement improvements observed here. These converging findings suggest that the observed gains are attributable not merely to inquiry as a general strategy, but to the structured and content-specific manner in which it was implemented.

3. Reduction of Common Evolution Misconceptions

The two-tier diagnostic analysis revealed a substantial reduction in evolution-related misconceptions across all five conceptual categories following the GIBL intervention. The most notable reduction was observed in misconceptions related to need-based evolution (from 78.2% to 29.1%), human evolution (from 65.5% to 18.2%), and the scientific nature of evolutionary theory (from 69.1% to 23.6%). These findings that active and inquiry-oriented instruction are consistent with a growing body of research demonstrating that active and inquiry-oriented instruction is more effective in reducing students' learning difficulty and persistent misconceptions.

The prevalence of misconceptions observed in this study before instruction is consistent with the broader literature. Bishop and Anderson (1990) were among the first to document that students persistently hold teleological conceptions of natural selection, the belief that organisms evolve "because they need" specific traits, even after instruction. Succeeding research has confirmed the persistence of such misconceptions among students at multiple educational levels (Nehm & Reilly, 2007; Bray Speth et al., 2009, 2014; Pobiner et al., 2018). Addressing such deep-rooted beliefs requires more than didactic instruction; it demands pedagogical approaches that create opportunities for cognitive conflict, evaluation of evidence, and conceptual reconstruction (Jensen & Finley, 1996; Alters & Nelson, 2002).

Robbins and Roy (2007) showed that an inquiry-based teaching unit yielded substantial improvements in students' explanations and overall acceptance of evolutionary theory, while Beggrow and Sbeglia (2019) argued that "targeting naïve ideas about evolution should be an instructional goal" in science education. The present study's results support these conclusions. By engaging students in inquiry activities that challenged their existing beliefs. By evidence-based exploration, GIBL facilitated meaningful conceptual change.

Nehm et al. (2022), as discussed in de Lima and Long (2023), reported positive learning gains in introductory biology settings where "differing intensities of active learning were paired with misconception-focused instruction," a design closely aligned with the GIBL approach employed in the present study. Similarly, Harrison et al. (2022) demonstrated that instructional activities specifically designed to challenge students' teleological concepts about natural selection improve both understanding and acceptance of evolution, precisely the type of targeted conceptual confrontation that characterizes well-designed guided inquiry lessons.

The relatively high pre-test rates of the "theory means guess" misconception (69.1%) also warrant attention. This misconception reflects a broader confusion between the colloquial and scientific uses of the term "theory" and has been documented in multiple contexts (McComas, 1998). The reduction of this misconception to 23.6% post-intervention highlights GIBL's effectiveness in promoting understanding of the Nature of Science (NOS), a finding consistent with Hofstein et al.'s (2004) contention that guided inquiry laboratory activities improve "students' meaningful learning, conceptual understanding, and understanding of the nature of science."

The persistence of a residual proportion of misconceptions post-intervention (ranging from 18.2% to 29.1% across categories) also merits acknowledgment. De Lima and Long (2023) cautioned that "influences of context often persist" even after effective instruction, and that "although instruction can increase the accuracy of students' explanation of evolution, contextual influences persist." This suggests that single-term GIBL interventions, while to be effective, may need to be supplemented with longitudinal reinforcement to fully address deeply held misconceptions.

4. Effect of GIBL on Students' Epistemic Beliefs

The findings indicated a statistically significant improvement in students' epistemic beliefs following the GIBL intervention, $t(54) = 4.26$, $p < 0.001$, with a moderate effect size (Cohen's $d = 0.57$). Students' mean epistemic belief scores increased from 26.96 to

32.29, suggesting a shift from naïve to more advanced beliefs about the nature, development, and justification of scientific knowledge.

The moderate effect size observed in epistemic beliefs as compared to the large effects found for achievement and understanding is consistent with the established view in the literature that epistemic beliefs are relatively stable cognitive constructs that are more resistant to change than domain-specific knowledge (Hofer & Pintrich, 1997; Conley et al., 2004). Nevertheless, the significant improvement observed confirms that GIBL can promote epistemic development, a finding echoed by multiple studies.

Schiefer et al. (2020) reported that implementing an inquiry-based learning strategy significantly increased students' advanced beliefs about the certainty, development, and justification of knowledge among primary school students. Similarly, Ozgelen (2012) found that inquiry-based laboratory instruction improved epistemic belief scores related to the certainty and sources of knowledge among pre-service science teachers. In a study within a Chinese university context, Shi et al. (2020) found that students who participated in inquiry-based laboratory activities "considerably improved their epistemic beliefs in comparison to those who engaged in recipe-based laboratory activities" (Shi et al., 2020, as cited in Ennis et al., 2023). These findings converge with the present results, suggesting that the active, investigative nature of GIBL creates conditions conducive to epistemic development.

The theoretical basis for epistemic development through inquiry aligns with Kuhn (1993), who argued that strong scientific epistemic beliefs are crucial for developing scientific thinking and reasoning in students. Kuhn and Weinstock (2002) further contended that introducing students to scientific epistemic beliefs early in their education helps build a foundation for understanding science. Within GIBL, students are positioned not merely as receivers of established knowledge but as active participants in the processes of knowledge construction, asking questions, collecting and interpreting evidence, revising hypotheses, and reaching evidence-based conclusions. This epistemic engagement challenges naïve beliefs that scientific knowledge is fixed, authoritative, or arrived at through simple observation, thereby promoting more advanced, dynamic views of science (Hong et al., 2016; Schiefer et al., 2020).

The improvement in epistemic beliefs is also pedagogically significant because there is evidence that advanced epistemic beliefs are positively associated with academic achievement and scientific reasoning. Bråten et al. (2011) and Schommer-Aikins (2004) reported that students who view knowledge as complex, tentative, and evidence-based are more likely to engage in deeper learning and to approach science tasks with greater persistence and critical thinking. In the context of evolution education, where the subject matter is often contested on cultural or religious grounds, the development of advanced epistemic beliefs may be particularly important in helping students distinguish between scientific and non-scientific ways of knowing (Lombrozo et al., 2008; Beniermann et al., 2021).

The observed improvement in students' epistemic beliefs is consistent with studies indicating that inquiry-oriented learning environments can promote more advanced views about scientific knowledge and knowing (Hong et al., 2016; Schiefer et al., 2020). Specifically, Hong et al. (2016) found that students engaged in structured inquiry developed a more nuanced understanding of the tentative and evidence-dependent nature of scientific knowledge, while Schiefer et al. (2020) demonstrated that collaborative argumentation within an inquiry setting was particularly effective in shifting students away from absolutist epistemic positions. Nevertheless, some studies have reported only modest or non-significant change in epistemic beliefs following instructional interventions, arguing that epistemic beliefs are relatively stable cognitive constructs that often require prolonged exposure to inquiry experiences before substantial change occurs Kampa et al., 2016; Shi et al., 2020). Kampa et al. (2016) specifically noted that single-topic or short-duration interventions frequently produced limited epistemic gains, suggesting that context-specificity and instructional duration are critical moderating factors. The positive changes observed in the present study may therefore be attributed to the explicit and repeated opportunities provided through GIBL for evidence evaluation, scientific argumentation, and reflective reasoning about evolutionary explanations mechanisms identified in the literature as most proximal to epistemic belief change (Hofer & Pintrich, 1997). That meaningful epistemic shifts were achieved within five instructional sessions further underscores the potency of structed inquiry as a catalyst for epistemic development, particularly when learning activities are deliberately designed to surface and challenges students' prior assumptions about scientific knowledge.

5. Implications of the Study

5.1. Theoretical Implications: Constructivism and Conceptual Change

Collectively, the findings of the present study provide strong support for the constructivist and conceptual change framework as theoretical foundations for science instruction. Constructivist theory, as articulated by Piaget (1970) and extended by Vygotsky (1978), holds that learners actively construct knowledge through experience, social interaction, and reflection. GIBL operationalizes these principles by engaging students in collaborative, evidence-based investigations with structured teacher guidance, a pedagogical approach that facilitates both the knowledge consolidation.

Posner et al.'s (1982) conceptual change model specifically states that students will revise prior conceptions when they find those conceptions inadequate and encounter intelligible, plausible, and fruitful alternatives. The systemic reduction of misconceptions observed in the present study suggests that GIBL successfully created the conditions for this conceptual restructuring process. These findings align with those of Chengere et al. (2025), who concluded that inquiry-based approaches support "deep learning" and long-term knowledge retention, and with the broader meta-analytic literature, which consistently demonstrates that constructivist and inquiry-based approaches yield significantly larger effects on science achievement and conceptual understanding (Heindl, 2019; Öztürk et al., 2022; Panoy et al., 2022).

The inquiry-based learning framework also aligns with Duschl's (2008) argument that science education must balance three learning goals: conceptual, epistemic, and social. The present study's findings across all three corresponding outcome measures, achievement (conceptual), epistemic beliefs (epistemic), and misconception reduction (reflecting both conceptual and epistemic dimensions), suggest that GIBL effectively addresses this tripartite goal structure.

5.1.2 Implications for Classroom Practice

Biology teachers at the secondary school level are strongly encouraged to adopt GIBL as a core instructional strategy for teaching evolution. GIBL's effectiveness in promoting achievement, conceptual understanding, and misconception reduction suggests that it should replace or substantially supplement conventional, lecture-based teaching approaches. Teachers should specifically design inquiry activities that directly confront common misconceptions, particularly those related to need-based evolution, goal-directedness, and the nature of scientific theory, rather than simply presenting correct scientific information alongside conventional content.

5.1.3 Implications for Curriculum Development

Curriculum developers and textbook authors should incorporate inquiry-based learning tasks, two-tier diagnostic assessments, and Nature of Science components into the Grade 12 Biology curriculum. The high pre-intervention prevalence of misconceptions documented in this study suggests that the current curriculum does not adequately challenge or address students' naïve conceptions of evolution. Structured misconception-targeting activities should be integrated systematically across grade levels, beginning in lower secondary education, to prevent the consolidation of naïve evolutionary beliefs before students reach Grade 12.

5.1.4 Implications for Teacher Education and Professional Development

Pre-service and in-service teacher education programs should include explicit training in guided inquiry-based pedagogy, with particular attention to Evolution, a topic that many teachers also find conceptually and pedagogically challenging. Professional development should address both content knowledge (evolutionary biology) and pedagogical knowledge (designing and facilitating inquiry activities, identifying and addressing misconceptions, promoting epistemic reflection).

5.1.5 Implications for Educational Policy

Education policymakers in Ethiopia and similar Sub-Saharan African contexts should support the systematic integration of inquiry-based learning through dedicated teacher training programs, provision of laboratory and inquiry materials, and revision of assessment systems to include conceptual and reasoning-based measures alongside factual recall. Policy framework should explicitly acknowledge and address the role of students' epistemic beliefs in science learning, recognizing that scientific literacy requires not only content knowledge but also an advanced understanding of how scientific knowledge is constructed and justified.

5.2. Design Principles

The study generated four evidence-based design principles for teaching evolution through Guided Inquiry-Based Learning (GIBL). These principles emerged through iterative cycles of designing, implementing, evaluating, and refining instructional activities based on classroom evidence.

1. Explicit Identification and Reconstruction of Misconceptions
Design: Evolution instruction should begin by identifying students' existing misconceptions through diagnostic activities, classroom discussions, and concept-based questioning.
Mechanism: When students' prior ideas are made visible, guided inquiry activities provide opportunities to examine evidence, compare explanations, and revise scientifically inaccurate conceptions.
Intended outcome: Students develop scientifically accepted explanations of evolutionary concepts and demonstrate improved conceptual understanding.

2. Integration of Evidence-Based Reasoning and Scientific Explanation
Design: GIBL activities should engage students in analyzing biological evidence, discussing findings, and constructing explanations based on scientific reasoning.
Mechanism: Students connect evidence with biological concepts through inquiry questions, reflection, and discussion, which promotes deeper understanding and scientific thinking.
Intended outcome: Students improve their ability to explain evolutionary processes, apply scientific reasoning, and achieve better learning outcomes.

3. Development of Scientific Epistemic Beliefs Through Inquiry
Design: Instruction should include opportunities for students to explore how scientific

knowledge is generated, justified, and revised based on evidence.
Mechanism: Through participation in inquiry activities, students experience science as an evidence-based process rather than fixed information, supporting more critical evaluation of scientific explanations.
Intended outcome: Students develop more sophisticated epistemic beliefs about the nature and validation of scientific knowledge.

4. Continuous Formative Assessment and Instructional Refinement
Design: GIBL implementation should include continuous assessment of student responses, learning difficulties, and classroom interactions throughout DBR cycles.
Mechanism: Evidence collected from each cycle is used to refine inquiry tasks, teacher guidance, and instructional strategies according to students' needs.
Intended outcome: The instructional approach becomes progressively improved and more effective in enhancing achievement, conceptual understanding, and epistemic beliefs.

Together, these principles represent the contribution of the DBR approach by showing not only what instructional strategies were developed, but also how and why they support students' learning in evolution education.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Evolution is the central, unifying framework of biological science, yet it remains one of the most misunderstood and misconception-laden topics in secondary school education globally and particularly in the Ethiopian context. This study investigated the impact of Guided Inquiry-Based Learning (GIBL) on Grade 12 students' learning achievement, conceptual understanding, and epistemic beliefs regarding evolution. The findings revealed significant improvements across all three areas. Students demonstrated higher achievement scores, substantial gains in conceptual understanding, reduced misconceptions, and more advanced epistemic beliefs following the intervention. These outcomes were achieved through a combination of carefully structured inquiry activities, misconception-focused discussions, evidence-based reasoning tasks, collaborative group investigations, guided questioning, and reflective classroom dialogue that actively engaged students in constructing and evaluating scientific explanations. Furthermore, explicit opportunities to compare scientific evidence with existing personal beliefs enabled students to distinguish scientific ways of knowing from religious and cultural perspectives without requiring them to abandon their personal values. Overall, the findings indicate that GIBL is an effective instructional approach for improving students' achievement, promoting conceptual change, and encouraging more advanced epistemic beliefs in evolution education. By creating opportunities for students to investigate evidence, challenge misconceptions, justify claims, and refine their thinking through guided inquiry. The findings therefore support the integration of GIBL into Ethiopian secondary biology education as a promising strategy for addressing persistent learning challenges associated with evolutionary biology and preparing scientifically literate citizens for the demands of the 21st century.

5.2. RECOMMENDATIONS

Based on the limitations of the present study, future research should extend the current work through additional Design-Based Research cycles conducted in different school contexts and with larger student populations. Further iterations could refine the Guided Inquiry-Based Learning (GIBL) materials, instructional strategies, and assessment tools to enhance their effectiveness and adaptability across diverse educational settings. In addition, future studies may employ quasi-experimental or true-experimental designs with matched control groups to complement the findings of this DBR study and provide stronger evidence regarding the effectiveness of GIBL on students' learning achievement, conceptual understanding, and epistemic beliefs about evolution. Furthermore, future studies should extend beyond short-term intervention by conducting longitudinal investigations that track students' conceptual development, persistence of misconceptions, and evolution of epistemic beliefs over one or more academic years. Such research would provide valuable insights into the long-term impact and instructional approach of GIBL while also contributing to a deeper understanding of how inquiry-based instructional approaches can improve lasting scientific literacy, evidence-based reasoning, and multi-directional views of scientific knowledge among secondary school students.

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APPENDICES

Appendix A. Pre-Test Conceptual Knowledge Test

Please read each question carefully and choose the best answer: Conceptual knowledge test (CKT)

1. Which statement best describes variation within a population?

A. Individuals differ in traits due to genetic and environmental factors. B. All individuals in a population are

genetically identical

C. Variation only appears after environmental changes D. Variation occurs only in animals, not plants

2. Which of the following is an example of inherited variation?

A. A scar from an injury B. Increased muscle due to exercise

C. Different eye colors among individuals D. Ability to swim learned through practice

3. Natural selection acts directly on:

A. Genes B. Populations

C. Phenotypes of individuals D. Mutations

4. If the environment changes suddenly, which individuals are most likely to survive?

A. Individuals with traits suited to the new environment B. The most intelligent individuals

C. The strongest individuals D. Individuals that try to adapt

5. An adaptation is best described as:

A. A behavior learned during an organism's life B. A trait that improves survival and reproduction

C. Any physical change in an organism D. A response to environmental stress

6. In evolutionary biology, fitness refers to an organism's:

A. Physical strength B. Ability to survive harsh conditions

C. Reproductive success D. Intelligence

7. Why are adaptations not always perfect?

A. Adaptations depend on available variation and trade-offs B. Natural selection plans ahead

C. Evolution stops once adaptation occurs D. Organisms choose adaptations

8. Which trait is most likely to be inherited?

A. Blood group B. Increased height due to nutrition

C. Ability to read D. Skill in sports

9. Speciation occurs when:

A. Individuals change their traits B. Populations become reproductively isolated

C. Organisms migrate D. Mutations stop occurring

10. Which statement best reflects scientific understanding of evolution?

A. Evolution results from natural processes B. Evolution is guided by needs

C. Evolution has a fixed goal D. Evolution only occurs in the past

11. A student says, “Giraffes evolved long necks because they needed to reach higher leaves.”

Which response is scientifically correct?

A. Correct, because need causes genetic change B. Correct, because effort changes traits

C. Incorrect, because individuals do not evolve; populations change over generations

D. Incorrect, because giraffes stopped evolving

12. Two islands have similar lizard species. On one island, predators are common; on the other, they are absent. Over

time, lizards develop different coloration patterns. What explains this?

A. Evolution has a goal B. Identical mutations

C. Random choice of traits D. Different selection pressures

13. Two species of birds have wings with similar bone structure but different functions. This is best described as:

A. Analogous structures B. Convergent evolution

C. Homologous structures D. Artificial selection

14. In a population of newborn humans, extremely low and extremely high birth weights have higher mortality rates.

Over time, most surviving babies have average weight. This is an example of:

A. Directional selection B. Stabilizing selection

C. Disruptive selection D. Genetic drift

15. Two species share 98% similarity in their DNA sequences. This most strongly suggests that:

A. They live in similar environments B. They have a recent common ancestor

C. Mutations never occur in their genomes D. They are identical species

16. What is the original source of new genetic variation in a population?

A. Natural selection
B. Mutation
C. Migration
D. Competition

17. Which situation best demonstrates genetic drift?

A. Dark-colored insects survive better on polluted trees
B. A flood randomly kills most individuals in a small population
C. Birds choose mates with brighter feathers
D. Organisms adapt to colder climates

18. Gene flow occurs when:

A. Individuals compete for resources
B. DNA mutates during reproduction
C. Individuals move between populations and reproduce
D. Species become extinct

19. Which statement about mutations is scientifically accurate?

A. Mutations always improve survival
B. Mutations occur because organisms need them
C. Mutations can be beneficial, harmful, or neutral
D. Mutations only happen in dangerous environments

20. Why can small populations evolve faster through genetic drift than large populations?

A. Small populations have more mutations
B. Chance events affect allele frequencies more strongly
C. Small populations are always better adapted
D. Large populations stop evolving

Appendix B. Post-Test Conceptual Knowledge Test

Part I: Multiple Choice Questions: Conceptual knowledge test(CKT)

1. The theory of natural selection was first clearly explained by

A. Gregor Mendel B. Charles Darwin
C. Louis Pasteur D. Alfred Wegener

2. One important difference between Lamarck's theory and Darwin's theory is that Lamarck believed:

A. Traits are inherited genetically B. Acquired characteristics can be inherited
C. Natural selection drives evolution D. Variation already exists in populations

3. According to modern evolutionary theory, the main source of genetic variation in populations is:

A. Mutation and recombination B. Practice and learning
C. Environmental pressure D. Need for survival

4. Which process is considered a major mechanism (cause) of evolution?

A. Conscious adaptation B. Individual effort
C. Environmental planning D. Natural selection

5. Genetic drift is best described as:

A. Evolution caused by environmental needs B. Random changes in allele frequencies
C. Intentional adaptation by organisms D. Mutation directed by the environment

6. Convergent evolution occurs when:

A. Related species become more different
B. Species stop evolving
C. Unrelated species develop similar traits
D. Organisms inherit acquired traits

7. Divergent evolution occurs when:

A. A single ancestral species gives rise to different species B. Different species become identical
C. Evolution stops D. Environmental conditions remain stable

8. Which example represents coevolution?

A. Migration of animals B. Two species living in separate habitats
C. Random mutation in a population D. Predator and prey evolving together

9. The geological time scale is important for evolutionary biology because it:

A. Shows the chronological order of Earth's history B. Explains why organisms choose to evolve
C. Prevents mutations from occurring D. Describes only human history

10. The earliest fossils of modern humans appear during the:

A. Paleozoic Era B. Mesozoic Era
C. Cenozoic Era D. Precambrian Era

11. Antibiotic resistance in bacteria is an example of evolution because:

A. Bacteria intentionally develop resistance
B. Antibiotics create resistant genes
C. Resistant bacteria survive and reproduce more
D. All bacteria become resistant equally

12. Which observation provides direct evidence of evolution occurring today?

A. Fossils in rock layers
B. Similar embryo development
C. Development of pesticide resistance in insects
D. DNA similarities among species

13. Why are homologous structures important evidence for evolution?

A. They prove organisms are identical
B. They indicate shared ancestry
C. They show organisms choose useful traits
D. They prevent extinction

14. Fossils found in deeper rock layers are generally:

A. More complex than newer fossils
B. Younger than surface fossils
C. Older than fossils near the surface
D. Unrelated to evolution

15. What does common ancestry mean?

A. All organisms live in similar habitats
B. Species never change over time
C. Different species descended from shared ancestors
D. Evolution happens only in animals

16. Which scenario best illustrates convergent evolution?

A. Two related species inherit similar traits from ancestors
B. Unrelated species develop similar adaptations in similar environments
C. One species splits into two species
D. Mutations stop occurring in populations

17. In Hardy-Weinberg equilibrium, allele frequencies remain constant when:

A. Selection and mutation are absent
B. Organisms evolve rapidly
C. Individuals choose stronger mates
D. Environmental changes are frequent

18. A small group of birds colonizes a remote island and forms a new population with limited genetic variation. This is:

A. Stabilizing selection
B. Founder effect
C. Artificial selection
D. Coevolution

19. Which statement best explains extinction in evolutionary terms?

A. Species choose not to survive
B. Species fail to adapt to changing conditions
C. Evolution prevents extinction
D. Extinction only occurs due to human

20. Which statement best explains why evolution is considered a scientific theory?

A. It is a guess without evidence
B. It cannot be tested
C. It is supported by extensive evidence and explains natural phenomena
D. Scientists disagree completely about it

Appendix C. Pre-Test Two-Tier Conceptual Understanding Test

Choose the best answer (Tier 1) AND the best reason (Tier 2).

1. Fish with larger/smaller eyes in murky water. What happens?

A) All develop larger eyes B) Eyes become smaller
C) Eyes disappear D) Eye size may change randomly or stay the same

Reason: A) Natural selection only favors needed traits B) No survival advantage, so selection won't act on eye size
C) Acquired traits are inherited D) Evolution always simplifies structures

2. Two squirrel populations separated by a river. River reconnects them. They can't produce fertile offspring. This is:

A) No evolution occurred B) Sympatric speciation
C) Allopatric speciation D) Squirrels chose to be different

Reason: A) Squirrels learned to be different B) Geographic isolation prevented gene flow; genetic differences accumulated
C) River caused mutations D) Squirrels forgot how to interbreed

3. "Evolution is just a theory, not a fact." Scientifically, this is:

A) Correct - theories are less certain B) Correct - evolution isn't proven
C) Incorrect - evolution is a law D) Incorrect - theories are well-supported explanations

Reason: A) "Theory" in daily language differs from scientific meaning B) Evolution has been directly observed
C) Theories explain facts with multiple evidence lines D) Scientists don't use "theory"

4. The fossil "Ardi" was significant because it showed:

A) It was the first human fossil B) It had a larger brain than modern humans
C) Human-chimpanzee common ancestor didn't resemble modern chimpanzees D) Humans evolved in Asia

Reason: A) Ardi was bipedal but also tree-adapted, unlike modern chimpanzees B) Ardi was found with chimpanzee fossils
C) Ardi lived 100,000 years ago D) Ardi had a tail

5. Humans and chimpanzees:

A) Humans evolved from chimpanzees B) Chimpanzees evolved from humans
C) Share a common ancestor from ~6 million years ago D) Evolved completely independently

Reason: A) Fossils show chimpanzees turning into humans B) DNA and fossils show divergence from common ancestor
C) Humans are more advanced D) Chimpanzees are more primitive

Appendix D. Post-Test Two-Tier Conceptual Understanding Test

Choose the best answer (Tier 1) and the best reason (Tier 2).

1. Early giraffe evolution is often misunderstood.

A. Giraffes developed long necks because they stretched them B. Giraffes with longer necks survived and reproduced more
C. All giraffes suddenly developed long necks D. Environmental change directly created long necks

Reason: A. Natural selection favors individuals with advantageous traits B. Effort causes genetic change
C. Evolution occurs instantly D. Traits appear because organisms need them

2. The fossil record shows many transitional forms between ancestral species and modern species.

A. Fossils prove evolution stopped B. Fossils show species never change
C. Fossils are random rocks D. Fossils provide evidence of evolutionary change

Reason: A. Fossils document gradual changes across geological time B. Species are fixed and unchanging
C. Fossils form instantly D. Fossils appear randomly

3. Antibiotic resistance in bacteria is an example of evolution.

A. Bacteria intentionally become resistant B. Antibiotics force bacteria to adapt instantly
C. Resistant bacteria survive and reproduce D. All bacteria become resistant equally

Reason: A. Genetic variation already exists in populations B. Organisms evolve because they want to survive
C. Chemicals create useful traits in all individuals D. Evolution always happens instantly

4. Human and chimpanzee DNA sequences are highly similar.

A. Humans evolved from chimpanzees B. Chimpanzees evolved from humans
C. Similarity is coincidence D. Both share a common ancestor

Reason :A. Genetic and fossil evidence indicates divergence from a common ancestor
B. One species directly transformed into the other
C. Similar environments produce identical DNA D. Evolution has a goal

5. The geological time scale shows major evolutionary events.

A. Evolution occurs only in modern times B. Evolution has occurred over billions of years
C. Evolution happened only once D. Evolution occurs instantly

Reason: A. Fossil and geological evidence show gradual change across time B. Species appear suddenly without history
C. Evolution happens in a single generation D. Geological evidence is unrelated to evolution

Appendix E. Epistemic Belief Questionnaire

Table 1: Epistemic Beliefs Questionnaire (EBQ) on Scientific Knowledge in Evolution

Response Scale:1 = Strongly disagree, 2 = Disagree, 3 = Neutral
4 = Agree and 5 = Strongly agree

No.	Statement	1	2	3	4	5
1	Scientific knowledge mainly comes from experts and textbooks.					
2	Scientific disagreements about the details of evolution can contribute to a deeper understanding					
3	Only experts can truly understand scientific knowledge.					
4	Scientific knowledge is certain and unchanging.					
5	Scientific knowledge aims to explain patterns in nature rather than merely describe them.					
6	Science and religion address different questions and can coexist.					
7	Scientific knowledge develops through research and investigation.					
8	New evidence can lead to the modification of scientific ideas.					
9	Experiments help determine whether scientific ideas are valid.					
10	Personal belief is enough to justify a scientific claim.					

Instruction 2. Epistemic Beliefs Questionnaire (EBQ)

Table 1: Epistemic Beliefs Questionnaire (EBQ) on Scientific Knowledge in Evolution

Response Scale:1 = Strongly disagree, 2 = Disagree, 3 = Neutral
4 = Agree, 5 = Strongly agree

No.	Statement	1	2	3	4	5
1	Organisms develop new traits because they need them in order to survive.					
2	Individual organisms evolve during their lifetime when they adapt to the environment.					
3	Humans evolved directly from the monkeys that exist today.					
4	Evolution occurs because organisms try to change themselves.					
5	Evolution always leads to more perfect or advanced organisms.					
6	Natural selection gives organisms the traits they need in order to survive.					
7	If an animal uses a body part more often, that body part will become stronger and be passed to its offspring.					
8	Species evolve mainly because the environment forces them to change.					
9	All members of a species evolve at the same time in the same way.					
10	Once a species is well adapted, it stops evolving.					

Appendix E. Observation Checklist

Title: Observation Checklist for Guided Inquiry-Based Learning (GIBL) Lessons on Evolution

Purpose: To monitor students' participation, inquiry practices, conceptual development, and epistemic engagement during the implementation of GIBL.

Rating Scale

Score	Description
1	Not Observed
2	Rarely Observed
3	Sometimes Observed
4	Frequently Observed
5	Consistently Observed

Section A: Student Engagement

No.	Observation Indicator	1	2	3	4	5
A1	Students actively participate in learning activities.	☐	☐	☐	☐	☐
A2	Students ask relevant questions during inquiry activities.	☐	☐	☐	☐	☐

A3	Students remain attentive throughout the lesson.	□	□	□	□	□
A4	Students demonstrate interest in evolutionary concepts.	□	□	□	□	□
A5	Students contribute ideas during group discussions.	□	□	□	□	□

Section B: Inquiry Skills

No.	Observation Indicator	1	2	3	4	5
B1	Students identify scientific problems or questions.	□	□	□	□	□
B2	Students generate explanations based on evidence.	□	□	□	□	□
B3	Students analyze information critically.	□	□	□	□	□
B4	Students justify claims using evidence.	□	□	□	□	□
B5	Students evaluate alternative explanations.	□	□	□	□	□

Section C: Conceptual Understanding of Evolution

No.	Observation Indicator	1	2	3	4	5
C1	Students correctly explain variation within populations.	□	□	□	□	□
C2	Students correctly explain natural selection.	□	□	□	□	□
C3	Students distinguish adaptation from intentional change.	□	□	□	□	□
C4	Students recognize common ancestry among organisms.	□	□	□	□	□
C5	Students identify and correct common misconceptions about evolution.	□	□	□	□	□

Section D: Epistemic Beliefs and Scientific Reasoning

No.	Observation Indicator	1	2	3	4	5
D1	Students recognize that scientific knowledge is evidence-based.	□	□	□	□	□
D2	Students acknowledge that scientific explanations may change with new evidence.	□	□	□	□	□
D3	Students differentiate scientific explanations from personal beliefs.	□	□	□	□	□
D4	Students use evidence rather than authority to support claims.	□	□	□	□	□
D5	Students demonstrate openness to revising ideas based on evidence.	□	□	□	□	□

Section E: Collaboration and Communication

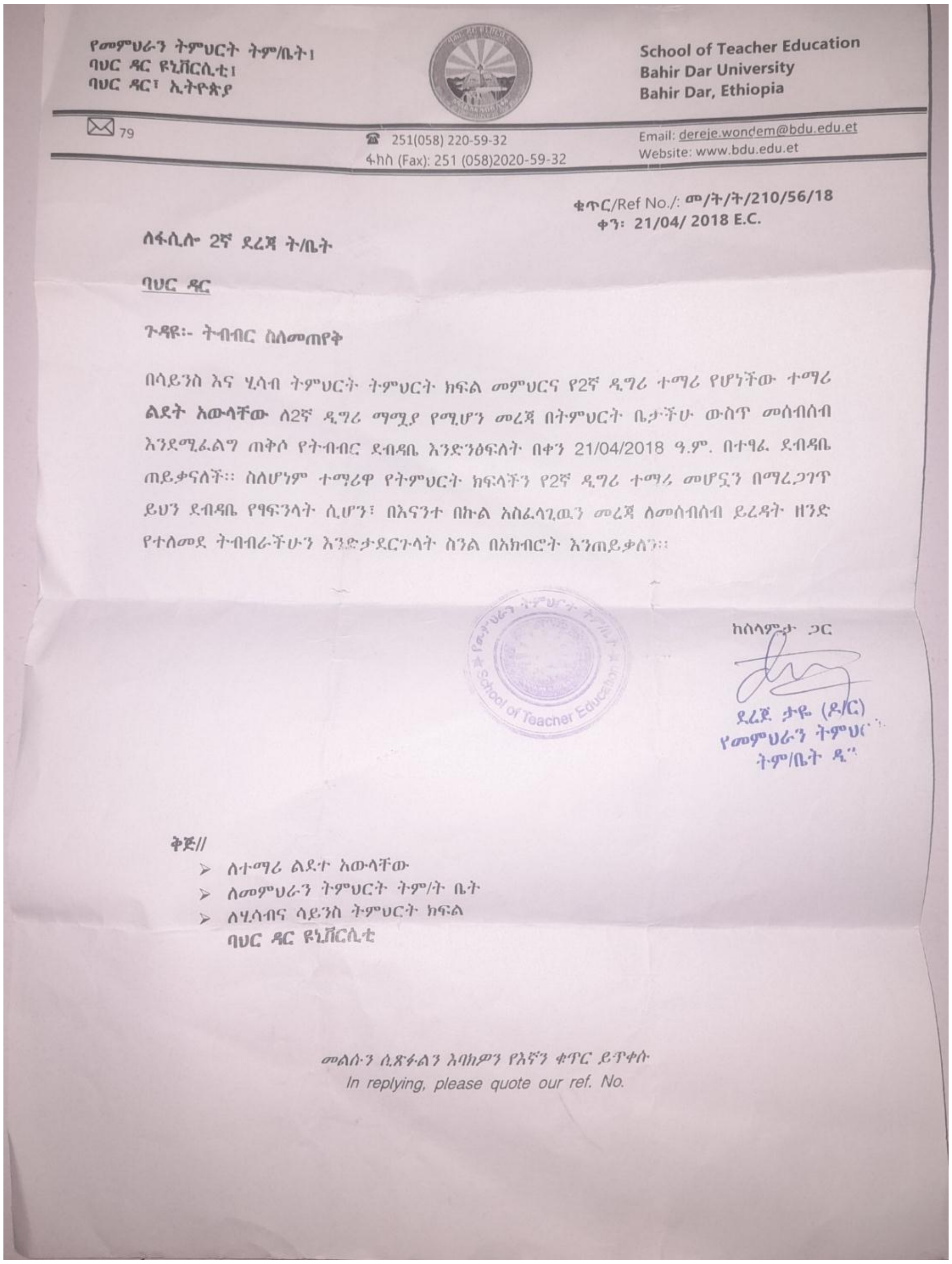
No.	Observation Indicator	1	2	3	4	5
E1	Students work cooperatively in groups.	□	□	□	□	□
E2	Students listen respectfully to peers' ideas.	□	□	□	□	□
E3	Students engage in productive scientific discussions.	□	□	□	□	□

E4	Students communicate explanations clearly.	□	□	□	□	□
E5	Students defend arguments using scientific evidence.	□	□	□	□	□

Section F: Fidelity of GIBL Implementation

No.	Observation Indicator	1	2	3	4	5
F1	The lesson follows the planned GIBL sequence.	□	□	□	□	□
F2	Inquiry questions guide student learning.	□	□	□	□	□
F3	Students are encouraged to investigate rather than memorize facts.	□	□	□	□	□
F4	The teacher provides appropriate guidance and scaffolding.	□	□	□	□	□
F5	Students have opportunities to construct explanations from evidence.					

Appendix G. Ethical Clearance and Permission Letters



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ባህር ዳር

ጉዳዩ፡- ትብብር ስለመጠየቅ

በሳይንስ እና ሂሳብ ትምህርት ትምህርት ክፍል መምህርና የ2ኛ ዲግሪ ተማሪ የሆነችው ተማሪ **ልደት አውላቸው** ለ2ኛ ዲግሪ ማሟያ የሚሆን መረጃ በትምህርት ቤታችሁ ውስጥ መሰብሰብ እንደሚፈልግ ጠቅሶ የትብብር ደብዳቤ እንድንፅፍለት በቀን 21/04/2018 ዓ.ም. በተፃፈ ደብዳቤ ጠይቃናለች፡፡ ስለሆነም ተማሪዋ የትምህርት ክፍላችን የ2ኛ ዲግሪ ተማሪ መሆኗን በማረጋገጥ ይህን ደብዳቤ የፃፍንላት ሲሆን፣ በእናንተ በኩል አስፈላጊዉን መረጃ ለመሰብሰብ ይረዳት ዘንድ የተለመደ ትብብራችሁን እንድታደርጉላት ስንል በአክብሮት እንጠይቃለን፡፡

School of Teacher Education

ከሰላምታ ጋር

ደረጀ ታዩ (ዶ/ር)
የመምህራን ትምህ
ትም/ቤት ዲ

ቅጅ//
- ለተማሪ ልደተ አውላቸው
- ለመምህራን ትምህርት ትም/ት ቤት
- ለሂሳብና ሳይንስ ትምህርት ክፍል
  ባህር ዳር ዩኒቨርሲቲ

መልሱን ሲጽፉልን እባክዎን የእኛን ቁጥር ይጥቀሱ
In replying, please quote our ref. No.

Appendix H. Photos during the intervention

Fasilo Secondary and Preparatory School

Students are doing classroom activities

Teacher preparing discussion topics in a classroom

Peer discussion among students