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Epistemic Beliefs as Predictors of Students' Conceptual Understanding and Scientific Reasoning in Senior Secondary School Biology in Lagos State, Nigeria

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Abstract. Understanding how students learn biology meaningfully requires attention not only to instructional practices but also to learners' epistemic beliefs about knowledge and knowing. This study investigated epistemic beliefs as predictors of students' conceptual understanding and scientific reasoning in Biology in Lagos State, Nigeria. Guided by epistemic cognition and constructivist learning theories, the study adopted a correlational survey design with a predictive focus. The population comprised senior secondary school Biology students in Lagos State, from which a representative sample was selected using multistage sampling techniques. Data were collected using three validated instruments: an Epistemic Beliefs Questionnaire (EBQ, Cronbach alpha=0.92), a Biology Conceptual Understanding Test (BCUT, Kuder-Richardson 20=0.90), and a Scientific Reasoning Test (SRT, Kuder-Richardson 20=0.94). Data were analysed using descriptive statistics, Pearson correlation, and multiple regression analysis. Findings revealed that students' epistemic beliefs were significantly related to both conceptual understanding and scientific reasoning in Biology. Specifically, sophisticated epistemic beliefs—such as beliefs in the tentativeness, complexity, and justification of biological knowledge—significantly predicted higher levels of conceptual understanding and scientific reasoning. Conversely, naïve epistemic beliefs were associated with lower performance on both outcome variables. The regression model indicated that epistemic beliefs accounted for a statistically significant proportion of variance in students' conceptual understanding and scientific reasoning. The study concludes that students' epistemic beliefs play a critical cognitive role in shaping how biological concepts are understood and how scientific reasoning skills are developed. It therefore recommends that Biology instruction and curriculum implementation in secondary schools should explicitly foster sophisticated epistemic beliefs through inquiry-based, argumentation-focused, and reflective pedagogical approaches. The study contributes to Biology education research in Nigeria by providing empirical evidence on the predictive role of epistemic beliefs in students' learning outcomes.

Keywords: Epistemic beliefs, conceptual understanding, scientific reasoning, Biology education, secondary school students, Lagos State.

1. Introduction

Biology, as a core science subject, occupies a central position in secondary and tertiary education due to its relevance to understanding life processes, health, environmental sustainability, and technological advancement. Beyond the acquisition of factual knowledge, contemporary biology education emphasizes the development of deep conceptual understanding and scientific reasoning skills that enable learners to interpret biological phenomena, solve complex problems, and make informed decisions in everyday and professional contexts. However, persistent evidence from classroom practice, national examination reports, and international assessments suggests that many students struggle to develop coherent conceptual understanding and robust scientific reasoning in biology (WAEC Chief Examiner's reports, 2020-2025; Ogundiwin & Oladipo,2018; Oladipo & Ebabhi 2020; Fasuyi & Oladipo, 2022; Oladipo & Akhigbe, 2023). Instead, learning is often characterized by rote memorization, fragmented knowledge structures, and superficial engagement with scientific ideas (Oladipo, 2016; Ogundiwin & Oladipo,2018). Conceptual understanding in biology refers to learners' ability to meaningfully integrate biological concepts, explain relationships among ideas, and apply knowledge to novel situations (Oladipo,2009). Scientific reasoning, on the other hand, involves the capacity to generate hypotheses, interpret data, evaluate evidence, and draw logical conclusions based on scientific principles. These two constructs are closely interrelated: conceptual understanding provides the knowledge base upon which scientific reasoning operates, while reasoning processes deepen and reorganize conceptual knowledge (Conley, Pintrich, Vekiri, & Harrison, 2004; Driver, Asoko, Leach, Mortimer, & Scott, 1994). Despite their importance, many biology students exhibit misconceptions, alternative conceptions, and reasoning difficulties, particularly in abstract and complex topics such as genetics, cellular respiration, photosynthesis, homeostasis, and evolution.

Traditional instructional approaches in biology classrooms—often dominated by teacher-centered lectures, textbook-driven explanations, and examination-oriented practices—have been identified as major contributors to these learning challenges (Oladipo, 2016; Ogundiwin & Oladipo,2018; Oladipo, Adewumi, Ogundiwin 2019; Oladipo, Akhigbe & Udeani, 2023; Adewumi, Ogundiwin & Oladipo 2025). Such approaches tend to prioritize content coverage over understanding, discourage inquiry and argumentation, and position students as passive recipients of information rather than active constructors of knowledge (Oladipo,2016; Ogundiwin & Oladipo, 2018; Arigbabu & Awofala, 2023). In response, educational researchers have increasingly turned their attention to learner-related factors that shape how students engage with knowledge and reasoning processes. Among these factors, epistemic beliefs have emerged as a critical yet underexplored determinant of students' learning outcomes in science. Epistemic beliefs refer to individuals' beliefs about the nature of knowledge and knowing—what knowledge is, how it is constructed, how certain or tentative it is, and how claims are justified. These beliefs influence how learners interpret information, evaluate evidence, approach learning tasks, and regulate their cognitive strategies (Awofala & Akinoso, 2024). In biology education, students' epistemic beliefs can shape whether they view biological knowledge as a set of fixed facts to be memorized or as a dynamic, evidence-based system that evolves through scientific inquiry. Consequently, epistemic beliefs have profound implications for both conceptual understanding and scientific reasoning.

1.1 Research Questions

The following research questions were answered in this study:

- What are the dominant epistemic beliefs held by secondary school students about biological knowledge and knowing?
- What is the level of students' conceptual understanding in Biology?
- What is the level of students' scientific reasoning in Biology?
- What is the relationship between students' epistemic beliefs and their conceptual understanding in Biology?
- What is the relationship between students' epistemic beliefs and their scientific reasoning in Biology?
- Which dimensions of epistemic beliefs (certainty of knowledge, simplicity of knowledge, source of knowledge, justification of knowledge, and beliefs about learning) significantly predict students' conceptual understanding in Biology?
- Which dimensions of epistemic beliefs significantly predict students' scientific reasoning in Biology?

2. Conceptual Understanding and Scientific Reasoning in Biology

Conceptual understanding in biology involves more than the ability to recall definitions or label diagrams. It entails the integration of concepts into a coherent framework that allows learners to explain biological mechanisms, recognize patterns, and transfer knowledge across contexts (Oladipo & Ihemedu, 2018; Oladipo, Osokoya &Udeani, 2019; Oladipo, Adewumi, Ogundiwin 2019; Oladipo, Akhigbe & Udeani, 2023). For example, understanding cellular respiration requires students to connect molecular-level processes with organism-level functions, energy flow, and environmental conditions. When students lack such integrative understanding, they often rely on memorised sequences or isolated facts, which are easily forgotten or misapplied (Oladipo, Osokoya & Udeani, 2019).

Scientific reasoning complements conceptual understanding by enabling learners to think and act like scientists. It encompasses skills such as identifying variables, controlling for confounding factors, interpreting experimental data, constructing explanations, and evaluating competing claims. In biology, scientific reasoning is particularly important because many biological phenomena are complex, probabilistic, and influenced by multiple interacting variables. Students who possess strong reasoning skills are better equipped to navigate these complexities, resolve misconceptions, and construct scientifically valid explanations. Despite curricular reforms that emphasize inquiry-based learning and scientific practices, research consistently shows that students' conceptual understanding and scientific reasoning in biology remain weak (Oladipo, Osokoya & Udeani, 2019; Oladipo & Ihemedu, 2018). Examination reports frequently highlight students' inability to explain biological processes, interpret experimental results, or apply knowledge to unfamiliar situations. These challenges are not merely instructional but are deeply rooted in how students perceive knowledge and learning itself.

3. Epistemic Beliefs: Nature and Dimensions

Epistemic beliefs have their roots in epistemology, the branch of philosophy concerned with the nature, sources, and justification of knowledge. In educational research, epistemic beliefs are conceptualized as learners' implicit theories about knowledge and knowing, which develop over time through formal education and personal experiences (Sopekan & Awofala, 2019). These beliefs are not static traits but dynamic cognitive frameworks that influence learning behaviors and outcomes. Scholars commonly describe epistemic beliefs along several dimensions (Awofala, Lawani, Oraegbunam, 2019, Awofala et al., 2025). One key dimension concerns the certainty of knowledge—whether knowledge is viewed as absolute and unchanging or tentative and evolving. Another dimension relates to the simplicity of knowledge—whether knowledge consists of isolated facts or interconnected concepts. Additional dimensions include the source of knowledge (authority-based versus constructed through reasoning and evidence), the justification of knowledge (acceptance of claims based on authority versus critical evaluation of evidence), and the speed of learning (beliefs about whether learning occurs quickly or gradually through effort). In the context of biology education, these dimensions are particularly salient. Students who believe that biological knowledge is certain and handed down by authorities may focus on memorizing textbook content and teacher explanations. In contrast, students who view knowledge as evolving and evidence-based are more likely to engage in inquiry, question assumptions, and seek conceptual coherence. Similarly, beliefs about the simplicity of knowledge influence whether students attempt to integrate concepts or treat them as disconnected units (Awofala, Lawani, Oraegbunam, 2019, 2020).

3.1 Epistemic Beliefs and Conceptual Understanding in Biology

A growing body of research suggests that epistemic beliefs play a crucial role in shaping conceptual understanding in science. Students with sophisticated epistemic beliefs—those who view knowledge as complex, tentative, and constructed—tend to adopt deep learning strategies, such as elaboration, organization, and self-explanation (Hofer, 2001; Schommer-Aikins, 2004). These strategies facilitate the integration of new information with prior knowledge, leading to more robust conceptual understanding. In biology, where many concepts are abstract and counterintuitive, epistemic beliefs can either support or hinder learning (Muis, 2007). For instance, students who believe that learning biology involves memorizing facts may struggle to understand processes like gene expression or energy transformation, which require systems thinking and causal reasoning. Conversely, students who recognize that understanding emerges through explanation and evidence are more likely to confront misconceptions and restructure their knowledge. Research has also shown that epistemic beliefs influence how students respond to cognitive conflict—situations in which their existing ideas are challenged by new evidence (Kallery & Psillos, 2001). Learners with naive epistemic beliefs may resist revising their conceptions, attributing discrepancies to errors or anomalies (Awofala et al., 2025). In contrast, those with more advanced beliefs are more open to conceptual change, viewing conflict as an opportunity for deeper understanding (Awofala et al., 2025).

3.2 Epistemic Beliefs and Scientific Reasoning in Biology

Scientific reasoning is inherently epistemic, as it involves judgments about evidence, explanation, and justification. Students' epistemic beliefs shape how they engage in reasoning tasks, such as designing experiments, interpreting data, and evaluating claims. For example, students who believe that scientific knowledge is derived from authority may accept conclusions without critically examining the evidence. In contrast, students who view knowledge as justified through empirical evidence are more likely to scrutinize data, consider alternative explanations, and engage in argumentation (Oladipo, Osokoya &Udeani, 2019; Awofala & Lawal, 2022). In biology education, scientific reasoning is often challenged by the complexity and variability of biological systems. Epistemic beliefs influence whether students approach these challenges with curiosity and critical thinking or with a search for simple, definitive answers. Beliefs about the certainty and simplicity of knowledge can lead students to oversimplify biological phenomena or ignore uncertainty, thereby undermining their reasoning processes (Awofala, Lawani, Oraegbunam, 2019, 2020). Moreover, epistemic beliefs interact with motivational and metacognitive factors to influence reasoning. Students who believe that understanding requires effort and reflection are more likely to persist in challenging tasks, monitor their reasoning, and revise their conclusions based on feedback (Awofala et al., 2019; Oladipo, Osokoya & Udeani, 2019). These behaviors are essential for the development of scientific reasoning in biology.

4. Theoretical Perspectives Linking Epistemic Beliefs, Conceptual Understanding, and Scientific Reasoning

Several theoretical frameworks provide insight into the relationship between epistemic beliefs, conceptual understanding, and scientific reasoning. Constructivist learning theory posits that learners actively construct knowledge by integrating new information with prior conceptions. Epistemic beliefs influence this process by shaping how learners interpret information and engage in meaning-making activities. Students with constructivist-oriented beliefs are more likely to engage in deep learning and conceptual integration. Conceptual change theory further emphasizes the role of epistemic beliefs in learning. According to this perspective, conceptual change occurs when learners recognize the inadequacy of their existing conceptions and adopt more scientifically accurate ones. Epistemic beliefs about the nature of knowledge and justification play a critical role in determining whether learners are willing to revise their ideas in response to evidence. From a socio-cognitive perspective, epistemic beliefs also influence participation in scientific practices, such as argumentation and inquiry. Students' beliefs about authority, evidence, and explanation shape how they interact with peers, teachers, and learning materials. These interactions, in turn, contribute to the development of conceptual understanding and scientific reasoning.

While existing research has established links between epistemic beliefs and learning outcomes in science, several gaps remain. First, much of the research has focused on general academic achievement rather than specific outcomes such as conceptual understanding and scientific reasoning in biology. Second, studies often examine epistemic beliefs in isolation, without considering their predictive relationships with multiple learning outcomes. Third, there is a paucity of context-specific research, particularly in secondary school biology settings in developing countries. Moreover, few studies employ advanced analytical approaches to model the complex relationships among epistemic beliefs, conceptual understanding, and scientific reasoning. Understanding these relationships is essential for designing instructional interventions that address not only what students learn but also how they think about knowledge and learning. Against this backdrop, the present study seeks to examine epistemic beliefs as predictors of students' conceptual understanding and scientific reasoning in biology. By investigating how different dimensions of epistemic beliefs relate to learning outcomes, the study aims to contribute to theoretical understanding and inform instructional practice in biology education. The findings of this study are expected to have significant implications for theory, research, and practice. Theoretically, the study would extend existing models of science learning by integrating epistemic beliefs as key predictors of conceptual understanding and scientific reasoning. Methodologically, it would provide empirical evidence using robust analytical techniques to elucidate the relationships among these constructs. Practically, the study would inform biology teachers, curriculum designers, and policymakers about the importance of fostering sophisticated epistemic beliefs to enhance meaningful learning and scientific reasoning.

5. Methodology

5.1 Research Philosophy

This study is grounded in a post-positivist paradigm, which acknowledges that although social phenomena cannot be known with absolute certainty, they can be approximated through systematic observation and rigorous measurement. The post-positivist stance uses quantitative methods to test theories and hypotheses, emphasizing objectivity, measurement precision, and statistical inference. Given the predictive nature of the research questions, the study adopts quantitative approaches that facilitate the analysis of relationships among latent constructs such as epistemic beliefs, conceptual understanding, and scientific reasoning.

5.2 Research Design

A correlational research design was employed, specifically predictive correlational research, because the study sought to determine the extent to which epistemic beliefs predicted students' conceptual understanding and scientific reasoning in biology. Correlational designs are appropriate when the aim is to examine relationships among variables without manipulating them (Creswell & Creswell, 2018). In this design, epistemic beliefs serve as the predictor (independent variable), while conceptual understanding and scientific reasoning are the criterion (dependent variables).

5.3 Population of the Study

The target population consists of senior secondary school year three students (SS3) in Shomolu Local Government Area of Lagos State, Nigeria who are currently enrolled in schools with Biology as a subject. Senior Secondary year three (SS3) students were chosen because they have completed most foundational biology topics and are sufficiently exposed to the conceptual and practical aspects of the subject. Shomolu has 10 public senior secondary schools, with a total population of 7,968, and a total of 2,550 SS3 students.

5.4 Sample Size and Sampling Techniques

5.4.1 Sample Size Determination

A sample size that is statistically adequate for regression analysis is critical. Regression analysis requires large sample sizes to yield stable parameter estimates. Following guidelines from Kline (2016) and Hair et al. (2019), a minimum sample of 300 respondents is targeted. This sample size satisfies the rule of thumb of at least 10 respondents per estimated parameter in regression and enhances the statistical power to detect predictive relationships. To account for potential non-responses and incomplete data, a buffer of 10% was added, increasing the planned sample size to approximately 330 students.

5.4.2 Sampling Techniques

A multi-stage sampling technique was used:

Stage 1 – Selection of Local Government Area (LGA): Lagos State has 20 LGAs. One LGA was chosen through a simple random sampling technique. This was achieved by writing the name of each LGA on a rolled paper. A student was asked to pick one rolled paper from the basket, and a Shomolu LGA was picked.

Stage 2 – Purposive Selection of Schools: From Shomolu LGA, only public schools were selected, and there were only 10 senior secondary schools in the LGA. SS3 students were purposively selected because they have completed most foundational biology topics and are sufficiently exposed to the conceptual and practical aspects of the subject.

Stage 3 – Selection of Students: Within the 10 schools, SS3 Biology classes were identified. From these classes, students were randomly sampled using systematic random sampling (e.g., selecting every nth student from class registers) to achieve the required number of participants.

These procedures ensure that the sample was representative of the larger student population while minimizing selection bias.

5.5 Research Instruments

The study used three primary instruments:

- Epistemic Beliefs Questionnaire on Biology (EBQ-Bio)
- Conceptual Understanding Test in Biology (CUT-B)
- Scientific Reasoning Test in Biology (SRT-B)

These instruments were developed, adapted, and validated for the study.

Epistemic Beliefs Questionnaire on Biology (EBQ-Bio): The purpose of this instrument was to measure students' beliefs about the nature of biological knowledge and knowing. It has 30 items delineated into five domains including: Certainty of knowledge, Simplicity of knowledge, Source of knowledge, Justification of knowledge, Speed and nature of learning. Each item was anchored on 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).
Conceptual Understanding Test in Biology (CUT-B): The purpose of this instrument was to assess students' deep understanding of key biology concepts beyond recall. The structure of the CUT-B entailed 25 two-tier multiple-choice items in which Tier 1 = Conceptual answer and Tier 2 = Reasoning explanation. The content areas included cell biology, photosynthesis, cellular respiration, genetics, homeostasis, and ecology.
Scientific Reasoning Test in Biology (SRT-B). The purpose of this instrument was to assess students' scientific reasoning within biological contexts. It contains 25 two-tier multiple-choice items covering control of variables, hypothesis testing, evidence evaluation, probabilistic reasoning, and causal reasoning.

5.6 Validity and Reliability of the Instruments

To assess content validity, the three instruments were reviewed by five experts in biology education, measurement and evaluation, and science pedagogy. They evaluated items for relevance, representativeness, clarity, and appropriateness. Their corrections were incorporated into each of the instruments. The Content Validity Index (CVI) was computed for each instrument, ranging from 0.92 to 0.96. Items with low CVI (< 0.80) were revised or removed. Reliability assesses consistency. The study used internal consistency, in which Cronbach's alpha coefficient was calculated for each instrument and subscale. For the EBQ-Bio, the reliability coefficient was 0.92, which was considered an acceptable threshold ($\alpha \geq 0.70$). For two-tier tests, Kuder-Richardson 20 (KR-20) reliability was computed. CUT-B and SRT-B had reliability coefficients of 0.90 and 0.94, respectively.

5.7 Data Collection Procedure

The data collection process followed these steps. First, permissions and approvals were obtained from the Lagos State Ministry of Education and relevant school authorities. Second, letters of introduction and consent forms were taken to the schools and participants. Third, trained research assistants administered the questionnaires and tests during scheduled class periods. Students completed EBQ-Bio, CUT-B, and SRT-B in one session (approximately 90–120 minutes). Instructions were clearly explained before the administration of the instruments, and students were assured of confidentiality, anonymity, and voluntariness. Completed questionnaires were checked for completeness immediately after administration. Data were coded and entered into Statistical Package for the Social Sciences (SPSS v27) for analysis.

5.8 Data Analysis Techniques

Preliminary analyses included descriptive statistics of mean and standard deviation. The research questions were answered using the Pearson product-moment correlation coefficient and multiple regression analysis.

6. Results

Preliminary Data Screening and Assumptions Testing

Prior to substantive analyses, the data were screened for missing values, outliers, and normality. Missing data constituted less than 5% of the dataset and were handled using mean substitution. Skewness and kurtosis values for all variables fell within the acceptable range of ±2, indicating approximate normal distribution. Multicollinearity diagnostics showed tolerance values above 0.40 and variance inflation factor (VIF) values below 2.5, confirming the absence of multicollinearity among predictor variables.

Research Question One: What are the dominant epistemic beliefs held by secondary school students about biological knowledge and knowing?

Descriptive statistics were computed for the five dimensions of epistemic beliefs. The results indicate that students demonstrated moderately sophisticated epistemic beliefs overall (M = 3.42, SD = 0.61). Students scored highest on Justification of Knowledge (M = 3.78, SD = 0.58), indicating a relatively strong belief that biological knowledge should be supported by evidence. Scores on Certainty of Knowledge (M = 3.21, SD = 0.64) suggest that many students still perceive biological knowledge as relatively fixed. Simplicity of Knowledge recorded a moderate mean (M = 3.18, SD = 0.67), indicating partial recognition of biology as an interconnected body of knowledge. Source of Knowledge (M = 3.36, SD = 0.59) shows that students moderately rely on authority while also acknowledging personal construction of knowledge. Nature and Speed of Learning (M = 3.57, SD = 0.62) suggests that many students believe effort contributes to learning biology.

Research Question Two: What is the level of students' conceptual understanding in Biology?

Students' scores on the Conceptual Understanding Test in Biology (CUT-B) ranged from 14 to 46 out of a possible 50, with a mean score of 31.84 (SD = 6.92). Using a norm-referenced categorisation: 23.5% of students demonstrated low conceptual understanding. 49.2% demonstrated moderate conceptual understanding. 27.3% demonstrated high conceptual understanding. This result indicates that while a majority of students possess moderate understanding, a substantial proportion still struggle with deep biological concepts.

Research Question Three: What is the level of students' scientific reasoning in Biology?

Scores on the Scientific Reasoning Test in Biology (SRT-B) ranged from 12 to 45 out of 50, with a mean score of 29.76 (SD = 7.14). Categorisation revealed: 28.7% of students exhibited low scientific reasoning. 46.1% exhibited moderate scientific reasoning. 25.2% exhibited high scientific reasoning. Overall, students' scientific reasoning ability was found to be moderate, indicating challenges in hypothesis testing, control of variables, and evidence evaluation.

Research Question Four: What is the relationship between students' epistemic beliefs and their conceptual understanding in Biology?

Table 1: Correlation between epistemic beliefs and conceptual understanding in biology

Variables	Mean	SD	R	p
Epistemic belief	3.42	0.61	0.48	0.00
Conceptual understanding	31.84	6.92		

Pearson Product Moment Correlation analysis revealed a significant positive relationship between overall epistemic beliefs and conceptual understanding ($r = 0.48$, $p < 0.01$). This indicates that students with more sophisticated epistemic beliefs tend to demonstrate higher levels of conceptual understanding in Biology.

Research Question Five: What is the relationship between students' epistemic beliefs and their scientific reasoning in Biology?

Table 2: Correlation between epistemic beliefs and scientific reasoning in biology

Variables	Mean	SD	R	p
Epistemic belief	3.42	0.61	0.52	0.00
Scientific reasoning	29.76	7.14		

Correlation analysis showed a moderate positive relationship between epistemic beliefs and scientific reasoning ($r = 0.52$, $p < 0.01$). This finding suggests that students who view biological knowledge as tentative, complex, and evidence-based are more likely to engage in effective scientific reasoning.

Research Question Six: Which dimensions of epistemic beliefs significantly predict students' conceptual understanding in Biology?

Table 3: Multiple Regression Analysis of epistemic beliefs on conceptual understanding

Predictor	β	t	p
Justification of knowledge	0.31	8.94	0.00
Simplicity of knowledge	0.24	6.72	0.00
Nature and speed of learning	0.19	4.23	0.00
Certainty of knowledge	0.08	0.85	0.88
Source of knowledge	0.07	0.83	0.92

R^2=0.32

Multiple regression analysis was conducted with the five epistemic belief dimensions as predictors and conceptual understanding as the criterion variable. In Table 3, the regression model was statistically significant: $F(5, 324) = 19.87$, $p < 0.001$, explaining 32% of the variance in conceptual understanding ($R^2 = 0.32$). Significant predictors included: Justification of Knowledge ($\beta = 0.31$, $p < 0.001$). Simplicity of Knowledge ($\beta = 0.24$, $p < 0.01$). Nature and Speed of Learning ($\beta = 0.19$, $p < 0.05$). Certainty of knowledge and source of knowledge were not statistically significant predictors.

Research Question Seven: Which dimensions of epistemic beliefs significantly predict students' scientific reasoning in Biology?

Table 4: Multiple Regression Analysis of epistemic beliefs on conceptual understanding

Predictor	β	t	p
Justification of knowledge	0.34	7.22	0.00
Simplicity of knowledge	0.02	0.83	0.78
Nature and speed of learning	0.21	5.52	0.00
Certainty of knowledge	-0.22	-5.57	0.00
Source of knowledge	0.04	0.97	0.87

R^2=0.35

Multiple regression analysis revealed a statistically significant model: $F(5, 324) = 22.45$, $p < 0.001$, accounting for 35% of the variance in scientific reasoning ($R^2 = 0.35$). In Table 4, significant predictors were: Justification of Knowledge ($\beta = 0.34$, $p < 0.001$). Certainty of Knowledge ($\beta = -0.22$, $p < 0.01$). Nature and Speed of Learning ($\beta = 0.21$, $p < 0.01$). The negative beta for certainty of knowledge suggests that students who view biological knowledge as fixed tend to exhibit weaker scientific reasoning skills.

7. Discussion

7.1 Students' Epistemic Beliefs about Biological Knowledge

The findings revealed that secondary school students in Lagos State possess moderately sophisticated epistemic beliefs about biological knowledge. Students demonstrated relatively higher sophistication in the justification of knowledge dimension, indicating an emerging recognition that biological claims should be supported by evidence rather than accepted solely on authority. However, moderate scores on certainty and simplicity of knowledge suggest that many students still view biology as a body of fixed facts rather than a dynamic, evolving discipline. This pattern aligns with the developmental view of epistemic beliefs proposed by Perry (1970) and later expanded by Hofer and Pintrich (1997), which posits that learners often transition gradually from absolutist to evaluativist epistemic positions. The findings also corroborate earlier studies (Schommer-Aikins, 2004; Muis, 2007; Awofala et al., 2025) indicating that students may simultaneously hold sophisticated beliefs in some dimensions while maintaining naïve beliefs in others. In the Lagos State context, this mixed epistemic profile may be attributed to teacher-centred instructional practices, examination-driven curricula, and limited exposure to inquiry-based learning. These systemic factors often reinforce the perception of knowledge as certain and authoritative, thereby constraining epistemic development.

7.2 Level of Students' Conceptual Understanding in Biology

Results indicated that students' conceptual understanding of Biology was moderate, with a substantial proportion demonstrating low understanding of core biological concepts. This finding suggests that while students may recall biological facts, many struggle with explaining underlying mechanisms, linking concepts, and applying knowledge to novel situations. This outcome supports earlier research that identifies biology as conceptually demanding due to its abstract processes, multiple representations, and hierarchical structures (Chi, 2005; Duit, 2009; Oladipo & Ihemedu, 2018; Oladipo et al 2019). Persistent misconceptions in topics such as genetics, respiration, and evolution have been widely documented (Bishop & Anderson, 1990; Smith et al., 1993; Oladipo, 2009; Ogundiwin &Oladipo, 2020), and the present findings suggest that such misconceptions remain prevalent in Lagos State secondary schools. From a conceptual change perspective (Posner et al., 1982), moderate conceptual understanding implies that instructional approaches may not sufficiently create cognitive conflict or support the restructuring of students' alternative conceptions.

7.3 Level of Students' Scientific Reasoning in Biology

The study found that students' scientific reasoning ability was also moderate, with notable weaknesses in hypothesis testing, control of variables, and evidence evaluation. This suggests that many students engage with Biology primarily at a descriptive level rather than through the epistemic practices of science. These findings are consistent with Lawson's (2000) assertion that scientific reasoning does not automatically develop through content instruction alone. Similar results have been reported by Oladipo (2009), Zimmerman (2007) and Driver et al. (1996), who observed that students often lack opportunities to engage in authentic scientific inquiry. In the Nigerian context, limited laboratory resources, large class sizes, and emphasis on examination performance may further restrict the development of scientific reasoning skills, reinforcing procedural rather than epistemic engagement with Biology.

7.4 Relationship between Epistemic Beliefs and Conceptual Understanding

The results revealed a significant positive relationship between students' epistemic beliefs and their conceptual understanding in Biology. Students who viewed knowledge as tentative, complex, and evidence-based demonstrated higher levels of conceptual understanding. This finding supports theoretical propositions that epistemic beliefs shape how learners process information, respond to conceptual conflict, and integrate new ideas (Hofer, 2001; Muis, 2007). Learners with sophisticated epistemic beliefs are more likely to engage in deep learning strategies such as elaboration, self-explanation, and metacognitive monitoring, which facilitate conceptual integration. Empirically, this result aligns with studies by Kallery and Psillos (2004) and Oktay and Kaya (2016), who found that epistemic beliefs significantly influence students' understanding of scientific concepts. The present study extends these findings by providing context-specific evidence from Lagos State.

7.5 Relationship between Epistemic Beliefs and Scientific Reasoning

The findings also demonstrated a moderate positive relationship between epistemic beliefs and scientific reasoning. Students who recognised the evidential and tentative nature of biological knowledge were more capable of engaging in scientific reasoning processes. This result reinforces the view that scientific reasoning is inherently epistemic, involving judgments about evidence, uncertainty, and justification (Zohar & Nemet, 2002). Students with naïve epistemic beliefs may struggle to evaluate evidence critically or consider alternative explanations, thereby limiting their reasoning capacity. The findings are consistent with Conley et al. (2004) and Lederman, Lederman, and Antink (2013), who reported that epistemic beliefs predict students' argumentation and reasoning in science. The implication is that strengthening epistemic beliefs may serve as a lever for improving reasoning skills.

7.6 Predictors of Conceptual Understanding

Regression analysis revealed that justification of knowledge, simplicity of knowledge, and nature of learning were significant predictors of conceptual understanding. Among these, justification of knowledge emerged as the strongest predictor. This finding underscores the importance of helping students understand that biological knowledge is generated through evidence and reasoning rather than memorisation. Students who value evidence are more likely to interrogate explanations, reconcile conflicting ideas, and engage in conceptual change. The non-significance of certainty and source of knowledge suggests that believing knowledge comes from authority does not necessarily hinder conceptual understanding unless it is accompanied by beliefs that knowledge is fixed and unchallengeable.

7.7 Predictors of Scientific Reasoning

The results showed that justification of knowledge, certainty of knowledge, and nature of learning significantly predicted scientific reasoning. Notably, certainty of knowledge negatively predicted scientific reasoning, indicating that students who perceive biological knowledge as fixed tend to demonstrate weaker reasoning skills. This finding aligns with epistemic cognition theory, which posits that reasoning thrives in contexts where uncertainty and evaluation are acknowledged (Greene et al., 2016). Students who expect absolute answers may be less inclined to test hypotheses or evaluate evidence critically.

8. Conclusion

The present study set out to examine the predictive role of students' epistemic beliefs on their conceptual understanding and scientific reasoning in Biology. Drawing on epistemic belief theory, conceptual change theory, and models of scientific reasoning, the study adopted a robust quantitative approach to explore these relationships among secondary school students in Lagos State. The findings revealed that students possess moderately sophisticated epistemic beliefs, characterised by relatively strong beliefs in the justification of knowledge but lingering naïve beliefs regarding the certainty and simplicity of biological knowledge. This mixed epistemic profile reflects a transitional stage of epistemic development, where students recognise the role of evidence yet continue to view Biology as a largely fixed and authoritative body of knowledge. Students' levels of conceptual understanding and scientific reasoning were also found to be moderate. While many students demonstrated basic comprehension of biological concepts, a significant proportion struggled with explaining underlying mechanisms, integrating ideas across topics, and applying knowledge in novel contexts. Similarly, scientific reasoning skills—such as hypothesis formulation, control of variables, and evidence evaluation—were not sufficiently developed among many learners.

Most importantly, the study established that epistemic beliefs significantly predict both conceptual understanding and scientific reasoning in Biology. Students who viewed biological knowledge as tentative, complex, and evidence-based demonstrated deeper conceptual understanding and stronger reasoning skills. Among the epistemic belief dimensions, justification of knowledge emerged as the strongest predictor of both outcomes, underscoring the centrality of evidence-based thinking in science learning. This finding provides empirical support for integrated models of science learning that position epistemic cognition as a foundational regulator of cognitive engagement. Overall, the study concludes that improving students' conceptual understanding and scientific reasoning in Biology cannot be achieved through content-focused instruction alone. Rather, there is a need for deliberate attention to students' epistemic beliefs and reasoning practices within Biology classrooms.

9. Recommendations

Based on the findings of this study, the following recommendations are proposed:

- Biology teachers should adopt inquiry-oriented instructional strategies that emphasise evidence generation, hypothesis testing, and explanation rather than rote memorisation.
- Teachers should explicitly address the nature of biological knowledge, helping students understand that scientific knowledge is tentative, evolving, and subject to revision based on evidence.
- Classroom practices should encourage students to justify their answers, critique explanations, and evaluate alternative viewpoints.
- Continuous professional development programmes should be organised to equip teachers with skills for integrating epistemic and reasoning-focused pedagogy into Biology instruction.
- School administrators should support the provision and utilisation of laboratory facilities and instructional resources that promote hands-on and minds-on learning.
- Timetables should allow adequate time for practical activities, discussions, and inquiry-based lessons.
- School leadership should promote a school culture that values critical thinking and reasoning over examination drilling.
- Biology curricula should explicitly incorporate epistemic goals, such as understanding the nature of scientific knowledge and reasoning processes.
- Assessment formats used by bodies such as WAEC and NECO should include items that assess conceptual understanding and scientific reasoning, not merely factual recall.
- Curriculum documents should provide guidance on pedagogical strategies that foster epistemic development and reasoning skills.

10. Implications of the Study

The findings have significant implications for educational policy in Lagos State and Nigeria at large. Current science education policies emphasise curriculum coverage and examination performance, often at the expense of deep understanding and reasoning. This study suggests that: Science education policies should explicitly recognise epistemic beliefs and reasoning skills as key learning outcomes. Teacher education and certification policies should require training in epistemic cognition, inquiry pedagogy, and scientific argumentation. Policy frameworks should support systemic shifts from content-heavy syllabi to competency-based science education. For classroom practice, the study highlights the need for a pedagogical shift: Biology teaching should move from transmissive methods to student-centred, inquiry-driven approaches. Teachers should design learning activities that confront misconceptions, stimulate cognitive conflict, and promote conceptual change. Assessment practices at the classroom level should reward reasoning, explanation, and evidence use. Such practices are likely to foster more sophisticated epistemic beliefs, leading to improved learning outcomes in Biology. The study contributes to the growing body of literature on epistemic beliefs in science education, particularly within the Nigerian context. It opens several avenues for further research: Future studies could employ longitudinal designs to examine how epistemic beliefs and reasoning develop over time. Experimental studies could investigate the effects of epistemic-focused instructional interventions on students' learning outcomes. Qualitative approaches, such as classroom observations and interviews, could provide deeper insights into how epistemic beliefs are enacted in classroom interactions. Further research could extend this model to other science subjects such as Chemistry and Physics or to different educational levels.

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