JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website: www.jriiejournal.com ISSN 2520-7504 (Online) Vol.10, Iss.3, 2026 (pp. 573 - 586)

Exploring the Impact of Inquiry-Based Learning Strategy on Academic Achievement in Biology: A Case Study of TTC Save, Rwanda

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Abstract: *The persistent challenge of low academic achievement in Biology among students has remained a major concern in science education, particularly in contexts where traditional teacher-centered instructional approaches continue to dominate classroom practice. This study explored the impact of inquiry-based learning strategy on students' academic achievement in Biology at TTC Save. The study was guided by cognitive and Social Constructivism Theories and adopted a mixed-methods research approach employing a quasi-experimental design. Data were collected through achievement tests, questionnaires, classroom observations, and interviews, and analyzed using descriptive and inferential statistics for quantitative data and thematic analysis for qualitative data. The findings revealed that inquiry-based learning was widely implemented through scientific investigations, experimentation, collaborative learning, problem-solving, and guided classroom discussions. The study established that inquiry-based learning had a significant positive impact on students' academic achievement by improving conceptual understanding, critical thinking, scientific reasoning, motivation to learn, and overall academic performance. However, challenges such as large class sizes, limited instructional time, classroom management difficulties, variations in students' prior knowledge, and inadequate instructional resources constrained its effective implementation. The study concluded that inquiry-based learning is an effective learner-centered pedagogical strategy for improving students' academic achievement in Biology. It recommends continuous professional development for Biology teachers, increased institutional support, adequate instructional resources, strengthened classroom management, and sufficient time allocation for inquiry-based activities. Future research should examine the long-term effectiveness of inquiry-based learning across different educational contexts.*

Keywords*: Inquiry-based learning, Academic achievement, Biology education, Constructivism theories, Competence-based curriculum, student engagement*

How to cite this work (APA):

Ndikumana, T. & Nizeyimana, G. (2026). Exploring the Impact of Inquiry-Based Learning Strategy on Academic Achievement in Biology: A Case Study of TTC Save, Rwanda. *Journal of Research Innovation and Implications in Education, 10*(3), 573 – 586. **https://doi.org/10.59765/ls7**

1. Introduction

Improving students' academic achievement in Biology remains a global priority because Biology education plays a fundamental role in developing scientific literacy, critical thinking, problem-solving abilities, and lifelong learning skills required in the twenty-first century (National Research Council, 2000). Inquiry-based learning (IBL) has been widely recognized as a learner-centered pedagogical approach that actively engages students in questioning,

investigating, experimenting, and constructing scientific knowledge through authentic learning experiences rather than passive reception of information (Lazonder & Harmsen, 2016). The successful implementation of IBL is consistent with constructivist learning theories, which emphasize active learner engagement and knowledge construction through exploration and social interaction (Piaget, & Vygotsky, 1978). Despite the increasing adoption of competence-based curricula that advocate inquiry-oriented teaching, evidence on the effectiveness of IBL in enhancing students' academic achievement in biology remains inconclusive, particularly in secondary teacher education institutions within developing countries. In Rwanda, empirical evidence on the implementation and impact of IBL in Teacher Training Colleges is still limited. Therefore, this study explores the impact of the inquiry-based learning strategy on students' academic achievement in Biology at TTC Save, with the aim of generating evidence to inform instructional practice, teacher education, and educational policy.

Despite sustained global efforts to improve science education through learner-centered pedagogies, students' academic achievement in biology remains a persistent concern in many education systems, particularly in developing countries (UNESCO, 2021). In response, inquiry-based learning (IBL) has been widely advocated as an effective instructional approach for promoting scientific inquiry, conceptual understanding, and higher-order thinking skills (Pedaste et al., 2015). Although numerous studies have reported positive effects of IBL on students' academic achievement, its implementation in classroom practice remains inconsistent due to factors such as limited teacher competence, inadequate instructional resources, insufficient professional development, and institutional constraints (Lazonder, 2016 & Dah et al., 2024).

The quality of science education has become a major concern worldwide because of its critical role in fostering scientific literacy, innovation, problem-solving skills, and socio-economic development. Among science subjects, biology occupies a central position in equipping learners with knowledge and skills necessary for understanding living organisms, environmental sustainability, health-related issues, and technological advancements. Consequently, improving students' academic achievement in biology has become a key priority for educators, policymakers, and researchers across the globe. Despite continuous curriculum reforms and investments in educational resources, students' achievement in biology remains unsatisfactory in many educational systems, particularly in developing countries where teacher-centered instructional approaches continue to dominate classroom practice (UNESCO, 2023).

In response to the limitations of traditional teacher-centered pedagogies, contemporary educational reforms have increasingly advocated for learner-centered approaches that actively engage students in the learning process. One such approach is inquiry-based learning (IBL), which emphasizes students' active participation in constructing knowledge through questioning, investigation, experimentation, analysis of evidence, and reflection (Pedaste et al., 2015). Inquiry-based learning is rooted in constructivist learning theories, which posit that knowledge is actively constructed by learners through interaction with their environment rather than passively transmitted by teachers (Piaget, 1972 &Vygotsky, 1978). Through inquiry-oriented activities, learners develop higher-order thinking skills, scientific reasoning, creativity, and a deeper understanding of scientific concepts, thereby enhancing academic achievement and lifelong learning competencies.

Globally, education systems are shifting from teacher centered to learner centered approaches that promote active participation, critical thinking, and problem- solving skills among students. Inquiry-based learning has emerged as one of the most effective student- centered pedagogical strategies. It emphasizes learning through questioning, investigating, and reflecting, which enables learners to construct their own understanding of concepts (Hmelo-Silver, Duncan, & Chinn, 2007). IBL transforms the traditional classroom into an active learning environment where students take ownership of their learning, thereby promoting deep conceptual understanding and retention of knowledge (Pedaste et al., 2015).

The significance of inquiry-based learning in science education has been highlighted by numerous scholars and educational organizations. According to the National Research Council (2000), inquiry-based instruction enables students to acquire scientific knowledge by engaging in authentic scientific processes similar to those employed by professional scientists. Likewise, Lazonder and Harmsen (2016) reported that inquiry-based learning positively influences students' cognitive development and academic performance when appropriate guidance is provided. Similarly, Furtak et al. (2012) found that inquiry-oriented instructional practices contribute significantly to students' conceptual understanding and achievement in science subjects. These findings suggest that inquiry-based learning has the potential to improve learning outcomes by promoting active engagement and meaningful learning experiences.

In Rwanda, the introduction of the CBC in 2016 marked a significant shift toward competency oriented and learner-centered pedagogies (REB,2015). Rwanda’s CBC emphasizes the development of critical thinking, creativity, collaboration, and problem-solving abilities competencies

that align closely with the principles of inquiry- based learning (REB,2020). This reform aims to produce learners capable of applying knowledge to real life situations rather than simply reproducing memorized information. Thus, adopting IBL strategies in science teaching, especially in biology lessons, is essential for achieving the CBC's intended outcomes (Ngabonziza & Yadav, 2021).

In view of the above, TTCs have a crucial role in ensuring that pre-service teachers are adequately prepared and equipped to implement the CBC effectively. The TTC curriculum was revised to advance learner centered including IBL, cooperative learning, and problem -based learning among others (Institute of Education East Africa, 2020). Teacher trainees must not only understand the theoretical foundations of inquiry- based learning but also develop the pedagogical competence to apply it in real classroom settings. However, research indicates that implementation of IBL in TTCs remains limited due to factors including resource constraints, large class sizes, and insufficient professional development for instructors (Twahirwa at al.,2022).

Numerous empirical studies conducted in different educational contexts report that IBL has a positive influence on students' academic achievement compared to traditional teacher-centered methods (Minne, Levy, & Century, 2010). However, despite this growing body of evidence supporting the effectiveness of IBL, several gaps remain in the literature.

First, much of the existing research has been conducted in developed countries, at general education and higher education levels, with limited empirical studies focusing on teacher training colleges like TTC Save (Furtak et al., 2012). For example, a systematic review by Furtak et al. (2012) found that the majority of empirical studies examining the effectiveness of inquiry-based science instruction were conducted in primary and secondary school settings, with very limited attention given to teacher training colleges. This creates uncertainty about whether the reported benefits of IBL can be generalized to teacher education institutions in Rwanda (Minner, Levy & Centrry, 2010).

Second, studies indicate that although competence-based curricula advocate for inquiry-oriented pedagogy, actual classroom practices often remain dominated by traditional, lecture-based instruction, leading to persistent low academic achievement among learners (Kirschner, Sweller, & Clark, 2006). This mismatch between policy expectations and instructional practice suggests a contextual problem that requires localized investigation.

Furthermore, while prior studies largely examine the theoretical benefits of IBL, fewer studies provide context-specific empirical evidence linking IBL implementation to measurable academic achievement in Biology and teacher preparation programs (Schweisfurth,2015). Evidence from studies conducted in Rwandan Teacher Training Colleges indicates that, despite the adoption of inquiry-based and learner-centered approaches in the competence-based curriculum, classroom practices remain largely teacher-centered due to constraints such as limited instructional resources, large class sizes, and insufficient pedagogical training. These challenges hinder the effective implementation of inquiry-based learning, thereby affecting students' active engagement and academic achievement in science subjects, including Biology (Harerimana, 2026 & Nizeyimana et al., 2024). This situation underscores the need for context-specific studies, such as the present research at TTC Save, to explore how inquiry-based learning strategies can be effectively implemented to improve students' academic achievement in biology.

Therefore, the research problem emerges from the lack of localized empirical evidence on the effectiveness of Inquiry-Based Learning in improving academic achievement at TTC Save, despite strong theoretical support and policy advocacy for learner-centered approaches. This gap necessitates an empirical exploration to determine whether and how IBL impacts academic achievement in this specific institutional context (Manishimwe at al.,2023). Additionally, teacher training Colleges may replicate the same teacher centered methods that the CBC seeks to move away from, thereby limiting the extent to which pre-service teachers internalize IBL pedagogies (Haug at al.,2023). Understanding how teacher training colleges implement IBL, the conditions necessary for its success, and how it correlates with student academic achievement in biology lessons in TTC Save remains a worthwhile area of study (Kopbayera, at al.,2026).

This study thus seeks to explore the impact of inquiry-based learning strategy on students' academic achievement in biology in TTC Save. The findings will contribute to understanding the extent to which IBL enhances learning outcomes, identify challenges faced in its implementation, and inform policies aimed at improving teacher education (Manishimwe at al.,2023). This study helps to shed light on the effectiveness, enablers and barriers of IBL implementation in the teacher education context, and how this relates to academic achievement outcomes in biology lessons among students. In doing so, it contributes to improving teacher preparation, pedagogical practice, and ultimately learner achievement in the Rwandan education system.

1.1 Statement of the problem and motivation

In recent years, educational reforms have increasingly emphasized learner-centered pedagogies as effective approaches for enhancing students' academic achievement in science education (UNESCO, 2015; Prince & Felder, 2006). The introduction of the CBC was a major educational reform designed to promote active learning, critical thinking, creativity, and problem-solving skills among students (REB, 2015). To achieve these goals, teachers are expected to employ learner centered approaches such as IBL, that engage students in questioning, investigating, and drawing conclusions through scientific reasoning (Pedaste et al., 2015).
However, many teachers in TTCs continue to rely on traditional lecture-based methods that emphasize memorization over exploration and inquiry (Habimana & Mutesa,2021). Consequently, teacher trainees may complete their studies without mastering the competencies required to apply IBL in their future classrooms. This situation threatens the long-term success of the CBC and undermines the development of critical thinking and problem-solving skills among learners in Rwandan schools.

Research from other educational contexts has shown that IBL significantly improves academic achievement, scientific reasoning, and student motivation, especially in science subjects such as biology (Uwitonze & Nizeyimana,2022). Particularly, biology, being an experimental and conceptual science, benefits greatly from inquiry approaches that allow learners to investigate biological phenomena and construct understanding from real life experiences. At TTC Save, students have consistently demonstrated good academic performance in biology; however, the instructional strategies contributing to this performance have not been empirically established.

Moreover, although inquiry-based learning is widely recognized in the literature as a strategy that promotes active engagement, scientific reasoning, and improved academic performance in Biology, its specific contribution to students' achievement in Teachers Training Colleges remains underexplored (Hmelo-Silver, & Century, 2010). There are no empirical studies in Rwanda that explored the impact of IBL on the academic performance of TTC Save students themselves. Most available studies focus on secondary school students rather than teacher training Colleges student -teachers. This creating a significant research gap (Manishimwe &Nsengimana,2022).

Therefore, this study seeks to bridge this knowledge gap by exploring the impact of inquiry- based learning on students' academic achievement in biology at TTC Save. The results will provide valuable insights for curriculum developers, policymakers, teachers and recommendations for strengthening the use of IBL in teacher training programs, improving student academic outcomes to strengthen practices and enhance teacher preparation aligned with the CBC's vision.

1.2 Research objectives

To determine the extent to which the inquiry-based learning strategy is implemented in the teaching and learning of Biology at TTC Save. Specifically, the study sought to:

1. To compare the test achievement of student-teachers in biology between the experimental and control groups before and the after the intervention.

2. To examine the extent of student-teachers' engagement in inquiry-based learning activities throughout learning of biology at TTC Save.

3. To explore the institutional factors influencing the effective implementation of the inquiry-based learning strategy in learning of biology at TTC Save.

Guided by foregoing problem, this study sought to address the following research questions:

1.Is there a significant difference in the test achievement of student-teachers in biology between the experimental and control groups before and after the intervention?

2. What is the level of student-teachers' engagement in inquiry-based learning processes during Biology instruction at TTC Save?
3. How do pedagogical and institutional factors influence the effective implementation of the inquiry-based learning strategy in the teaching and learning of Biology at TTC Save?

2. Literature Review

This chapter explored previous studies related to the study exploring the impact of inquiry-based learning strategy on academic achievement in biology at TTC Save. It provides the theoretical and empirical foundation of the study by exploring key concepts, relevant theories, and previous research on inquiry-based learning and academic achievement in biology (Crewell, 2023). The chapter also reviewed evidence from international, regional, and Rwandan contexts, highlighting the effectiveness of inquiry-based learning and the challenges associated with

its implementation (Snyder,2019). Finally, it identifies gaps in existing literature that justify the need for the current study and demonstrates its contribution to enhance biology teaching and learning at TTC Save.

2.1Theoretical Review

This study is underpinned by constructivist learning theories, specifically Jean Piaget's Cognitive Constructivist Theory and Lev Vygotsky's Social Constructivist Theory. Constructivism posits that learning is an active process in which learners construct knowledge by integrating new experiences with their existing cognitive structures through inquiry, exploration, reflection, and social interaction (Piaget, 1972 &Vygotsky, 1978). These theories provide a strong theoretical foundation for inquiry-based learning because they emphasize learner-centered instruction, collaborative knowledge construction, critical thinking, and authentic problem-solving, all of which are fundamental principles of inquiry-based pedagogy (Bruner, 1961& Fosnot, 2013).

Cognitive and social constructivist theories best support this topic by offering a coherent explanation of how IBL enhances students' academic achievement through active knowledge construction, making it theoretically and contextually suitable for exploring CBC aligned instructional practices in Rwanda in biology education (Piaget, &Vygotsky,1978). Therefore, IBL is recognized not only for supporting the construction of foundational knowledge, but for enhancing scientific reasoning, procedural competence, and adaptable problem-solving abilities outcomes emphasized by competence-based curricula such as Rwanda's CBC (REB, 2015).

In the context of biology education, constructivist theories explain how students develop conceptual understanding and scientific reasoning by actively engaging in investigations, experimentation, and evidence-based discussions rather than passively receiving information from teachers. Consequently, the theories provide an appropriate lens for examining how the implementation of the inquiry-based learning strategy influences students' academic achievement in biology, while also guiding the interpretation of the study findings and the relationships among the study variables.

2.2 Empirical Review

Empirical evidence generally indicates that inquiry-based learning (IBL) has a positive effect on students' academic achievement in biology, although its effectiveness depends on the quality of implementation. A comprehensive meta-analysis by Lazonder and Harmsen (2016) found that students taught through inquiry-based approaches achieved significantly better learning outcomes than those taught using traditional methods, particularly when teachers provided structured guidance throughout the inquiry process. More recently, Dah et al. (2024), in a systematic review of science education studies, concluded that IBL consistently enhances conceptual understanding, critical thinking, scientific reasoning, and academic performance by engaging learners in questioning, investigation, and evidence-based problem-solving. Similarly, Sam (2024) reported that inquiry-based instruction improves students' motivation, classroom participation, and academic achievement, especially when supported by adequate instructional resources and effective teacher facilitation.

Within the African context, Opanga and Nsengimana (2022) observed that although inquiry-based learning aligns with competence-based curricula, its implementation is frequently constrained by inadequate teacher preparation, limited laboratory facilities, overcrowded classrooms, and insufficient teaching resources. These findings suggest that pedagogical competence and institutional support are critical determinants of successful inquiry-based learning implementation.

In Namibia, a qualitative study by Shivolo and Mokiwa (2023) explored science teachers' conceptions of inquiry-based instruction. Although the national curriculum advocated learner centered inquiry, teachers reported that policy practice misalignment, large class sizes, lack of materials, and ingrained teacher centered culture limited meaningful IBL implementation (Shivolo & Mokiwa, 2023). Similarly, a broader comparative analysis by Mkimbili (2023) across several Sub- Saharan countries including Zimbabwe, South Africa, and Tanzania noted that despite curriculum adoption, student-centered inquiry practices remain weak due to exams, resource scarcity, and teacher inexperience (Mkimbili, 2023).

In Rwanda, Leon, R. (2012), In his PhD thesis observed that while lower secondary science teachers in Rwanda generally held positive attitudes toward the adoption of inquiry-based science teaching, their classroom practices remained predominantly traditional. The study highlighted that many teachers perceived primarily as structured experiments rather than as open ended, student driven investigations. Furthermore, Mugabo (2012) identified several systemic challenges constraining effective implementation, including limited instructional time, inadequate teaching resources, and insufficient professional development opportunities. These findings highlight the lack of alignment between teachers' positive attitude of inquiry-based approaches and their actual implementation in Rwandan science learning environment, point out the need for targeted training and resource provision to increase pedagogical effectiveness.

Twahirwa et al. (2022) underscores the gap regarding teachers' positive attitude of IBL and their real teaching practices, highlighting the need for continuous professional development and supportive systems to ensure effective implementation.

Despite the growing body of international evidence, few empirical studies have specifically examined the effectiveness of inquiry-based learning within Teacher Training Colleges in Rwanda, where future teachers are expected to acquire learner-centered pedagogical competencies. Consequently, there remains a contextual knowledge gap regarding the extent to which inquiry-based learning is implemented and its influence on student-teachers' academic achievement in biology at TTC Save. The present study addresses this gap by integrating quantitative and qualitative evidence to explore not only the impact of inquiry-based learning on academic achievement but also the pedagogical and institutional factors that influence its effective implementation.

3. Methodology

This study was guided by the pragmatist research paradigm, which supports the integration of quantitative and qualitative methods to provide a comprehensive understanding of the impact of inquiry-based learning on academic achievement in biology (Creswell & Creswell, 2018). The study adopted a mixed-methods approach, combining quantitative and qualitative data to gain a more complete understanding of the research problem through methodological triangulation. A quasi-experimental design was employed to explore the impact of the inquiry-based learning strategy on academic achievement in biology at TTC Save. This design enabled the exploration of the intervention under natural classroom conditions without random assignment of participants. The study was conducted at TTC Save, Rwanda, which was selected because it offers STEM education including Biology and provides an appropriate context for exploring the implementation of inquiry-based learning. The target population comprised 226 participants, including 222 student-teachers and four biology tutors at TTC Save. A representative sample of 147 participants was selected. Purposive sampling was used to select the biology tutors due to their expertise, while systematic random sampling was used to select the student-teachers to ensure fair representation.

Data were collected using a biology achievement test, questionnaires, semi-structured interviews, classroom observation checklists, and document review to capture both quantitative and qualitative evidence. The validity and reliability of the quantitative instruments were established through expert review and pilot testing. The trustworthiness of the qualitative data was ensured through credibility, dependability, confirmability, and triangulation. Data collection involved obtaining ethical approval and institutional permission, administering the pre-test, implementing the inquiry-based learning strategy, conducting the post-test, administering questionnaires, interviewing participants, observing classroom practices, and reviewing relevant documents. Quantitative data were analyzed using STATA through descriptive and inferential statistics, while qualitative data were analyzed using thematic analysis. Ethical principles were observed throughout the study by obtaining informed consent, ensuring voluntary participation, maintaining confidentiality and anonymity, and using the collected data solely for research purposes.

4. Results and Discussion

The first objective of the study compared the biology achievement test scores of student-teachers in the experimental and control groups before and after the implementation of the inquiry-based learning strategy. The pre-test results indicated no statistically significant difference in the mean achievement scores between the two groups, demonstrating that they were comparable prior to the intervention. However, the post-test findings revealed a statistically significant improvement in the achievement scores of the experimental group compared with the control group. Descriptive statistics, including means and standard deviations, were computed to compare the achievement levels of the two groups before the intervention. The pre-test results are presented in Table 1.

Table1: Pre-Test Scores of Experimental and control group

Group	Mean	Standard deviation
Experimental	40.06	7.53
Control	63.73	4.94

Source: Primary Data: June 2026.

Table 1 presents the pre-test and post-test mean scores of the experimental group (n = 57). The findings indicate that the mean score increased substantially from 40.06 in the pre-test to 86.07 in the post-test. This indicates that students performed much better after the intervention than before it.This remarkable improvement of 46.01 points

suggests that the instructional intervention had a positive effect on students' academic performance, leading to significantly higher achievement after the treatment compared to before the intervention.The pre-test results indicated that the control group (M = 63.73) had a higher mean achievement score than the experimental group (M = 40.06), suggesting that the control group demonstrated a stronger baseline performance in Biology before the intervention.

Post-test mean scores for experimental and control groups

Following the intervention, both groups showed improvement in their post-test achievement scores. However, the experimental group's mean score increased substantially from 40.06 to 86.07, representing a gain of 46.01 points, whereas the control group's mean score increased from 63.73 to 83.73, representing a gain of 20.00 points. The results are presented in Table 2.

Table 2: post-test mean scores for experimental group

Group	Mean	Standard deviation
Experimental	86.07	4.94
Control	83.73	7.18

Source: Primary data: June 2026

Although the control group initially outperformed the experimental group in the pre-test, the experimental group achieved a higher post-test mean score and exhibited a markedly greater improvement in academic achievement. These findings suggest that the inquiry-based learning strategy contributed more effectively to enhancing student-teachers' academic achievement in Biology than the conventional instructional approach.

Independent t-test in both groups.

An independent samples *t*-test was conducted to compare the mean scores of the experimental and control groups. The results are presented in Table 3.

Table3: Independent t-test for both groups

```
. ttest POSTTEST, by(GROUP)

Two-sample t test with equal variances
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Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0	86	63.73256	.7748482	7.185647	62.19195	65.27316
1	57	86.07018	.6545865	4.94202	84.75888	87.38147
combined	143	72.63636	1.061051	12.68833	70.53887	74.73386
diff		-22.33762	1.091324		-24.49509	-20.18014

```
    diff = mean(0) - mean(1)                                  t = -20.4684
Ho: diff = 0                     degrees of freedom =      141

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Source: Primary data, June 2026

Table 3 presents the results of the independent samples *t*-test comparing the post-test mean scores of the control and experimental groups. The findings show that the experimental group (Group 1) obtained a significantly higher mean score (M=86.070, SD=4.94, N=57) than the control group (Group 0) ($M = 63.73, SD = 7.19, n = 86$). The mean difference between the two groups was -

21.44, with a 95% confidence interval ranging from -24.49 to -20.47. The independent samples *t*-test revealed a statistically significant difference between the groups, t (141) = -20.18, p<0.001. Therefore, the null hypothesis was rejected, indicating that the inquiry-based learning strategy had a statistically significant positive impact on student-teachers' academic achievement in biology compared with the conventional teaching method.

Paired Sample T-Test for Pre-Test Scores and post-test in experimental group

A paired sample t-test was conducted to determine whether there was a statistically significant difference between the pre-test and post-test scores of the same participants before and after the intervention. This analysis was used to assess the effect of the treatment by comparing the mean scores of learners at two different points in time within the same group. The test is appropriate in this study because it measures changes in performance using related dependent samples from the pre-test and post-test results.

Table 4: Paired T-Test for Pre-Test Scores experimental group

```
. ttest PRETEST == POSTTEST

Paired t test
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Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
PRETEST	57	40.0614	.9979671	7.534486	38.06224	42.06057
POSTTEST	57	85.17544	.720329	5.438365	83.73245	86.61843
diff	57	-45.11404	.7624302	5.756221	-46.64137	-43.5867

```
    mean(diff) = mean(PRETEST - POSTTEST)                     t = -59.1714
Ho: mean(diff) = 0                             degrees of freedom =       56

Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Source: Primary Data: June, 2026.

In the table 4, the paired sample t-test results show that the mean pre-test score of the students was 40.06 (SD = 7.53), while the mean post-test score increased to 85.18 (SD = 5.44). The mean difference between the two tests was -45.11, indicating a substantial improvement in students' performance after the intervention. The calculated t-value was -59.17 with 56 degrees of freedom, and the p-value was 0.000, which is less than the significance level of 0.05. Therefore, the null hypothesis was rejected, and it was concluded that there was a statistically significant difference between the pre-test and post-test scores. This finding suggests that the intervention was highly effective in improving students' academic achievement.

Paired Sample T-Test for Pre-Test Scores and post-test in control group

The findings of the paired sample t-test presented in Table 12 indicate a statistically significant difference between students' pre-test and post-test scores following the implementation of the inquiry-based learning strategy. The mean score increased from 58.27 (SD = 7.47) in the pre-test to 63.73 (SD = 7.19) in the post-test among the 86 participating students. The mean difference between the two tests was -5.47, showing that post-test scores were substantially higher than pre-test scores. Furthermore, the calculated t-value of -9.9998 with 85 degrees of freedom and a p-value of 0.0000 ($p < 0.05$) indicates that the observed improvement was statistically significant. Since the p-value is less than the conventional significance level of 0.05, the null hypothesis that there is no difference between pre-test and post-test performance is rejected. These results suggest that the inquiry-based learning strategy had a positive and significant impact on students' academic achievement in biology at TTC Save, leading to improved learning outcomes and enhanced understanding of the subject matter.

Table 5: Findings of Paired t-test

```
. ttest PreTest == PostTest

Paired t test
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Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
PreTest	86	58.26744	.8053216	7.468246	56.66625	59.86864
PostTest	86	63.73256	.7748482	7.185647	62.19195	65.27316
diff	86	-5.465116	.5465218	5.068235	-6.551748	-4.378484

```
    mean(diff) = mean(PreTest - PostTest)                     t =  -9.9998
Ho: mean(diff) = 0                             degrees of freedom =       85

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Source: Primary Data: June, 2026

The observed difference suggests that student-teachers who were taught using the inquiry-based learning strategy achieved higher learning outcomes than those who received traditional instruction. These findings provide empirical evidence that the implementation of the inquiry-based learning strategy positively influenced student-teachers' academic achievement in biology, thereby supporting its effectiveness as a learner-centered pedagogical approach for improving learning outcomes.

Teachers' Professional Competence in Inquiry-Based Pedagogy

The triangulated findings from the questionnaires, interviews, and classroom observations revealed that Biology tutors possessed a moderate to high level of professional competence in implementing inquiry-based pedagogy. Questionnaire responses indicated that most student-teachers perceived their tutors as competent in facilitating learner-centered instruction, while interview findings showed that tutors demonstrated sound pedagogical knowledge and confidence in guiding students through questioning, investigation, experimentation, and collaborative learning activities. Classroom observations further confirmed that tutors effectively employed inquiry-oriented instructional practices, including facilitating discussions, encouraging critical thinking, providing constructive feedback, and promoting active student participation, although variations in the consistency of implementation were observed across lessons.

One Biology tutor stated:

> *"We have received professional training on learner-centered pedagogy and inquiry-based teaching through continuous professional development programs. This has improved our ability to design practical activities, facilitate scientific investigations, and support students in constructing their own understanding of biological concepts." (Biology Tutor 1).*

Another tutor added:

> *"Instead of simply explaining concepts, I guide students to observe, investigate, analyze evidence, and present their conclusions. My role is to facilitate learning rather than provide all the answers." (Biology Tutor 4)*

Similarly, a student-teacher commented:

> *"Our tutors are knowledgeable and well prepared. They guide us throughout practical activities, encourage us to ask questions, and help us understand difficult Biology concepts through investigation and project activities." (Student-Teacher 18).*

Pedagogical and institutional factors that influenced the effective implementation of the inquiry-based learning strategy

The triangulated findings from the questionnaires, interviews, classroom observations, and document review revealed that pedagogical and institutional factors significantly influenced the effective implementation of the inquiry-based learning strategy in biology at TTC Save. Teachers' pedagogical competence, learner-centered instructional practices, availability of instructional resources, and administrative support facilitated implementation, whereas inadequate teaching materials, limited laboratory facilities, large class sizes, and insufficient professional development constrained its effective application. Overall, the findings indicate that successful implementation of inquiry-based learning

requires both competent teachers and a supportive institutional environment.

Student Participation and Engagement during Inquiry-Based Learning

The findings indicated that inquiry-based learning promoted active participation among student-teachers. Questionnaires, the interview response and observation showed that learners were actively involved in asking questions, discussing biological concepts, conducting investigations, and presenting findings. Interview participants explained that inquiry activities increased confidence, motivation, and classroom participation. Classroom observations demonstrated that students worked collaboratively, shared ideas, and actively interacted with tutors throughout biology lessons. Document reviews supported these findings by indicating regular use of learner-centered classroom activities and continuous classroom participation records. One student-teacher explained:
"Inquiry-based learning has changed the way we learn Biology. Instead of listening to the tutor throughout the lesson, we actively investigate biological concepts, discuss ideas in groups, and present our findings. This approach has increased my confidence and participation during class." (Student-Teacher 6, 2026). Another student-teacher stated:
"When we are given practical investigations, everyone participates because we want to discover the answers ourselves. Working together with classmates has improved my understanding of Biology concepts and encouraged me to contribute during discussions." (Student-Teacher 12, Questionnaire, 2026).

Similarly, a biology tutor emphasized the positive effect of inquiry-based learning on students' engagement:
"Since adopting inquiry-based learning, I have observed a remarkable increase in students' participation. They ask thoughtful questions, conduct experiments with enthusiasm, and support their explanations with scientific evidence rather than waiting for direct answers from the tutor." (Biology Tutor 2, Interview, 2026).

The results of the current study revealed a statistically significant difference in achievement between student-teachers taught through inquiry-based learning and those taught using traditional methods. This agreement suggests that inquiry-based instruction creates opportunities for learners to actively engage with scientific content, thereby facilitating meaningful learning and knowledge retention. Correspondingly, Lazonder and Harmsen (2021) observed that inquiry-based learning positively influences students' academic achievement, particularly when learners receive appropriate guidance throughout the inquiry process. The researchers argued that guided inquiry enables learners to develop conceptual understanding while simultaneously strengthening their analytical and investigative skills.

Prince and Felder (2006) argued that active and inquiry-based learning strategies produce superior educational outcomes compared to traditional lecture-based instruction because they encourage learners to engage cognitively with content and participate actively in the learning process. In a similar vein, the findings of the present study showed that student-teachers exposed to inquiry-based learning achieved significantly higher scores in Biology than those taught through traditional methods. Moreover, the results suggest that inquiry-based learning promotes deeper cognitive engagement and facilitates meaningful knowledge construction.

Piaget (1972) proposed that learning occurs through active interaction with the environment, whereby learners construct knowledge by assimilating new experiences into existing cognitive structures and accommodating those structures when confronted with new information. Correspondingly, the findings of the present study strongly align with Piaget's theory, as student-teachers who engaged in inquiry-based learning demonstrated significantly higher achievement in Biology than those in the control group.

Vygotsky (1978) emphasized the social nature of learning and argued that knowledge is constructed through interaction and collaboration. Furthermore, the findings support Vygotsky's assertion that collaborative learning environments facilitate cognitive development and enhance academic achievement in science education.

Kang et al. (2023) found that inquiry-based science instruction significantly improved students' conceptual mastery, critical thinking skills, and engagement in learning activities. These findings are consistent with those of the current study, which demonstrated that student-teachers who participated in inquiry-based learning achieved significantly higher biology than those taught using traditional teaching methods.

Mwangi (2023) reported that inquiry-based science instruction positively influenced students' academic achievement, scientific reasoning, and problem-solving abilities. The study revealed that learners exposed to inquiry-oriented teaching methods demonstrated superior performance compared to those instructed through traditional teacher-centered approaches. These findings corroborate the results of the present study, where student-teachers taught biology through inquiry-based learning significantly outperformed their counterparts in the control group. The consistency between the two studies may be attributed to the ability of inquiry-based learning to foster active cognitive engagement, collaborative learning, and the practical application of scientific concepts. Both studies

therefore support constructivist learning theory, which posits that learners develop deeper understanding when they actively participate in the construction of knowledge through exploration and investigation.

Shivolo and Mokiwa (2023) found that inquiry-based instructional approaches improved students' environmental knowledge, scientific literacy, and problem-solving abilities. These findings align with the current study, where inquiry-based learning significantly improved student-teachers' achievement in Biology. The similarity in findings suggests that inquiry-oriented instruction fosters active engagement and meaningful learning, leading to enhanced academic performance in science education. Leon (2012) argued that inquiry-based learning promotes meaningful learning by engaging learners in scientific investigations that require observation, questioning, experimentation, and evidence-based reasoning. In a similar vein, the findings of the present study revealed that student-teachers exposed to inquiry-based learning achieved significantly higher post-test scores in Biology than those taught through traditional teaching approaches. Therefore, the current findings lend empirical support to Leon's assertion that active engagement in the learning process enhances conceptual understanding and academic achievement.

REB (2015) emphasized the adoption of learner-centered and inquiry-based pedagogical approaches within the Competence-Based Curriculum to promote critical thinking, problem-solving, creativity, and active learner engagement in science education. According to the curriculum framework, learners are expected to construct knowledge through investigation, experimentation, collaboration, and reflection rather than through passive reception of information. The findings of the present study strongly support this curricular orientation, as student-teachers exposed to inquiry-based learning in genetic engineering achieved significantly higher post-test scores than those taught through traditional teaching methods. The observed improvement in academic achievement demonstrates that inquiry-based learning operationalizes the competencies envisioned by the Rwanda Education Board, particularly scientific inquiry, critical analysis, and evidence-based reasoning. Consequently, the current study provides empirical validation of the pedagogical principles underpinning Rwanda's Competence-Based Curriculum and highlights the importance of strengthening inquiry-based instructional practices in teacher training institutions.

Ndayambaje et al. (2022) found that inquiry-based and learner-centered instructional strategies significantly improved students' participation, conceptual understanding, and academic performance in science subjects within the Rwandan educational context. These findings are consistent with the results of the present study, which revealed a statistically significant improvement in the academic achievement of student-teachers learning in Biology through inquiry-based learning. The convergence of findings suggests that inquiry-oriented pedagogy promotes meaningful learning by encouraging learners to investigate, question, and construct scientific knowledge independently. Moreover, the current study extends the findings of Ndayambaje at al. (2022) by demonstrating that the positive effects of inquiry-based learning are equally evident among student-teachers studying advanced biological concept, thereby reinforcing the applicability of this pedagogical approach across different educational levels.

The findings of this study demonstrated that inquiry-based learning is an effective pedagogical strategy for enhancing students' academic achievement in biology by promoting active engagement, critical thinking, scientific inquiry, and deeper conceptual understanding. The study also found that the effectiveness of inquiry-based learning is influenced by pedagogical and institutional factors, including the availability of teaching resources, teacher preparedness, and adequate instructional time. The consistency between the present findings and previous studies strengthens the credibility of the results and confirms the value of inquiry-based learning in improving science education. These findings are consistent with Lazonder and Harmsen (2021), who emphasized that well-supported inquiry-based learning enhances students' learning outcomes, and Aksela (2020), who argued that successful implementation of inquiry-based science teaching requires adequate resources, teacher competence, and supportive learning environments. Therefore, strengthening institutional support and promoting continuous professional development for Biology tutors are essential for maximizing the benefits of inquiry-based learning in Teacher Training Colleges.

5. Conclusion and Recommendation

This section presents the conclusions of this study based on the findings of this study in relation to the research objectives and provides recommendations for policy, practice, and future research.

5.1 Conclusion

The study concludes that the inquiry-based learning strategy significantly enhances student-teachers' academic achievement in biology at TTC Save. The findings revealed that student-teachers exposed to inquiry-based learning demonstrated greater improvement in post-test achievement than those taught through conventional instructional approaches, indicating the effectiveness of learner-centered pedagogy in promoting conceptual

understanding, critical thinking, and scientific reasoning. The study further established that successful implementation of inquiry-based learning is influenced by teachers' professional competence, active student engagement, and supportive institutional factors, including the availability of instructional resources, laboratory facilities, and continuous professional development. Generally, the findings provide empirical evidence that effective implementation of inquiry-based learning can improve the quality of biology teaching and learning in Teacher Training Colleges and contribute to the preparation of competent future biology teachers.

5.2 Recommendations

From the findings of this study, the following recommendations were made to enhance the effectiveness, sustainability, and scalability of inquiry-based learning in biology education.

Teacher education institutions should strengthen the implementation of inquiry-based learning through continuous professional development for tutors and the provision of adequate instructional resources and laboratory facilities.

Biology tutors should consistently adopt learner-centered instructional practices, while future studies should examine the effectiveness of inquiry-based learning across different educational contexts to strengthen the evidence base.
Student-teachers should actively participate in inquiry-based activities, collaborative learning, experiments, and investigations to maximize learning outcomes and develop scientific skills.

Future studies should employ longitudinal research designs to investigate the long-term effects of inquiry-based learning on students' academic achievement, scientific literacy, and higher-order cognitive skills. Such studies would provide a more comprehensive understanding of how inquiry competencies develop over time and whether learning gains are sustained beyond the intervention period.

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