Journal Homepage: www.ijarpr.com ISSN: 3049-0103 (Online)

International Journal of Advance Research Publication and Reviews

Vol 02, Issue 08, pp 293-302, August 2025

Effect of Inquiry-Based Learning and Digital Technologies on Secondary School Students Performance in Biology in Makurdi Local Government Area of Benue State.

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ABSTRACT

The study examines the performance of biology students in secondary schools in the Makurdi local government region in Benue State when they use inquiry-based learning and digital tools. Two research questions guided the investigation. We constructed and analyzed two hypotheses at the significance level of 0.05. The study design was quasi-experimental. The study's population consisted of 4,590 pupils from the 21 Government Grant-Aided Secondary Schools currently in operation in the Makurdi Local Government Area of Benue State. The sample consisted of 69 students from two full secondary school classes in the Makurdi Local Government Area of Benue State. The Biology Students Performance Test (BSPT) and the Digital Technology Test (DT) were used in the study. Descriptive statistics like mean and standard deviation were used to address the study issues, and Analysis of Variance (ANOVA) at the 0.05 level of significance was used to investigate the hypotheses. Students who were taught biology using digital technology did not significantly vary from male and female students who were exposed to inquiry-based biology instruction in terms of their mean academic performance scores. Inquiry-based biology instruction did not improve the mean academic performance scores of those kids. An inquiry-based approach and digital technology were found to have an effect on biology students' performance in secondary schools in Makurdi Local Government Area. It was proposed that biology teachers be encouraged to employ digital technology and the inquiry-based approach as their primary teaching methods because it enhances students' academic performance more than traditional lecture methods. School officials should also arrange seminars and workshops to instruct instructors on how to use inquiry-based teaching methods in the classroom.

Introduction

Inquiry-based learning is a teaching method that moves students away from relying solely on textbooks and encourages them to learn by doing (Chen, 2021). It focuses on students being actively involved in asking questions, exploring ideas, and using prior knowledge to construct new understanding (Shanmugavelu, 2020). This approach fosters student responsibility and supports the development of higher-order thinking skills. Through inquiry-based learning, students experience the scientific process by following well-structured steps that reflect key components of scientific reasoning (Fan & Ye, 2022). It enhances critical thinking, creativity, collaboration, and problem-solving by involving students in group discussions, hands-on activities, and real-world investigations (Li, 2019). Additionally, it builds essential 21st-century skills such as communication, adaptability, and digital literacy (Wen, 2023).

A core objective of inquiry-based learning is to deepen students' engagement with scientific topics, allowing them to construct their own knowledge and become independent, lifelong learners (Yuliati, 2018; Chang & Wang, 2008). Common characteristics of this method include formulating questions, using precise language, making comparisons,

analyzing data, integrating information, and developing models (Stone, 2023). Research evidence supports the effectiveness of this approach. Smith (2018) found a significant improvement in the performance of students taught using the inquiry-based approach compared to those taught using simulation. Similarly, Johnson and Adewale (2020) reported that students exposed to inquiry-based learning performed significantly better than those taught using conventional methods. With regard to gender, Johnson and Adewale (2020) also found that male and female Biology students exposed to inquiry-based learning performed equally well in achievement tests. Likewise, Williams (2021) reported no significant gender-based difference in the academic performance of students taught using the inquiry-based approach in Canada. These findings suggest that inquiry-based learning not only enhances overall academic achievement but also promotes equity in science education.

Digital technologies include a wide range of electronic tools, systems, devices, and resources that help create, store, and manage information. These technologies have become essential in shaping how modern society works in the 21st century. The spread of computers, the internet, mobile phones, and various software programs has changed how people communicate, how businesses operate, and how knowledge is shared (Apdillah, 2022). Digitalization the process of turning non-digital information into digital form makes these technologies work effectively. It allows for fast and easy storage, access, and sharing of large amounts of data (Brunetti, 2020). This shift has led to new ideas and growth in many fields, helping businesses develop new ways of working, improving communication, and speeding up scientific progress. One major change brought by digital technologies is the rise of "Industry 4.0" or the "smart factory" (Vaska, 2021). This means using tools like artificial intelligence (AI), big data, cloud computing, and the Internet of Things (IoT) to modernize traditional industries (Jang & Lee, 2025). These tools make work more efficient, increase automation, and help businesses make better decisions (Cieslak & Martínez, 2024). The ongoing digital revolution, also called the Fourth Industrial Revolution, is changing how societies and organizations function worldwide. It is lowering the costs of collecting and managing data, while also opening new business opportunities especially in developing countries through online trade and e-commerce (Gajdzik & Wolniak, 2021). The impact of digital technology goes beyond business, also affecting education, healthcare, government, and social life by connecting people and communities across the globe (Cortellazzo, 2019).

Student performance is a key measure of how well education is working and often predicts a student's future success in school and in their career. It refers to the knowledge, skills, and understanding that students gain during their time in school (Asiah, 2019). Teachers and schools measure student performance in different ways, such as through class participation, test results, and graduation rates (Taripe & Limpot, 2022). Academic performance not only shows how well a student understands their subjects but also how well they can use that knowledge to solve problems and think critically (Villarta, 2021). Studying student performance helps schools identify what students are doing well and where they need more support, so they can make improvements (Yang & Li, 2018). A student's academic success is influenced by many different factors, including how prepared they are for school, their family's income level, and the kind of support they get from their school (García-Martínez, 2023; Santos & Celis, 2020). Other factors like learning ability, gender, and race can also affect how students perform (Aloqleh & Teh, 2019). Interactions with teachers and classmates, support from family, and access to technology all play a role in how engaged and successful a student is (Kedia & Mishra, 2023). Social influences both in and out of the classroom also shape how students grow and learn (Carrillo, 2019). The use of technology, such as social media, in education can help students stay engaged, work with others, and connect with teachers, which may improve their performance (Alaslani & Alandejani, 2020). Because so many different factors affect student performance, it is important to look at the whole picture in order to fully understand and improve it (Picciano, 2019).

The success of science education, especially in biology, depends on teaching methods that help students think critically, solve problems, and deeply understand scientific ideas (Ruzaman & Rosli, 2020). Traditional teaching methods, such as lectures, often do not fully engage students or help them build these important skills (Vegas & Djukri, 2021). To improve learning in biology, educators are now using strategies like inquiry-based learning and digital technology (Vegas & Djukri, 2021). Inquiry-based learning focuses on active student participation. It encourages students to ask questions, explore scientific ideas, and learn by doing experiments (Bónus, 2024). At the same time, digital tools such as computers, simulations, software, and online platforms help students access information, visualize complex biological processes,

collaborate with classmates, and learn at their own pace (Mwanda, 2017). These technologies can provide inclusive learning environments that accommodate diverse learning styles and abilities.

Combining inquiry-based methods with digital technology can make biology lessons more interactive, personalized, and effective helping students get ready for future science-related careers. Teachers need to design biology lessons that align with the goals of 21st-century education, and technology can play a major role in supporting this effort (Retnowati, 2020). It is also important to teach students how to apply scientific knowledge in real life, as many of today's developments are based on practical science applications (Onu, 2020). Moreover, gender considerations are essential in modern biology education. Research has shown that girls and boys may engage differently with science content and technology due to various social, cultural, and educational influences (Asiyah, 2021; Effiong & Igiri, 2015). Therefore, teaching strategies should aim to bridge gender gaps by ensuring that both male and female students are equally encouraged, represented, and supported in biology classrooms. For instance, integrating gender-responsive digital tools and inclusive role models in science content may inspire greater participation, especially among girls who are traditionally underrepresented in science, technology, engineering, and mathematics (STEM) fields.

Statement of the Problem

Despite the importance of Biology in understanding the natural world, students' performance in the subject remains a concern. Biology is a fundamental subject that underpins many aspects of modern life, from medicine to conservation. However, students' lack of interest and poor academic achievement in Biology have far-reaching consequences, including limiting their career options and undermining their ability to make informed decisions about scientific issues. Research has shown that traditional teaching methods, which often rely heavily on rote memorization and textbook-based instruction, contribute to poor academic achievement and lack of engagement. These methods fail to connect biological concepts to real-life experiences and discourage active participation.

The integration of digital technology in Biology instruction offers a promising avenue to address these challenges. Tools such as interactive simulations, virtual labs, augmented reality (AR), and educational software can transform passive learning into an immersive and engaging experience. These technologies provide visual and hands-on opportunities for students to explore complex biological processes, conduct experiments in virtual environments, and receive instant feedback, thus enhancing their conceptual understanding.

Moreover, the inquiry-based approach, which emphasizes active exploration, investigation, and problem-solving, can be significantly enhanced by digital platforms that support student-centered learning. When combined with digital tools, inquiry-based learning allows students to construct their own knowledge through interactive models, collaborative online discussions, and real-world data analysis. However, despite these possibilities, many Biology students still struggle to apply scientific concepts to real-world problems, importance persistent gaps in critical thinking and problem-solving skills. This suggests the need for more strategic and effective integration of digital technologies within inquiry-based frameworks to truly transform how Biology is taught and learned in secondary schools.

Purpose of the Study

The primary objective of this study is to determine how digital technology and an inquiry-based approach impact the performance of biology students in secondary school in Makurdi Local Government Area. In particular, the project seeks to:

1. Compare the performance of biology students in Makurdi Local Government Area, Benue State, who receive instruction via digital technology to those who receive instruction via the inquiry method.

2. Find out if the performance of male and female students who received inquiry-based biology instruction differed.

Research Questions

The following research questions are put forth in order to guide the investigation.

1. How well do secondary school pupils in the Makurdi Local Government Area of Benue State do when biology is taught using an inquiry-based approach in contrast to digital technology?

2. How does an inquiry-based approach to teaching affect the performance of male and female students in the Makurdi Local Government Area in Benue State?

Research Hypotheses:

The following hypotheses are formulated and investigated at the 0.05 alpha significance level:

1. There is no appreciable difference in the performance of students taught biology using digital technology and the inquiry method in Makurdi Local Government Area, Benue State.

2. Male and female students' performance in inquiry-based biology classrooms in Benue State's Makurdi Local Government Area does not differ considerably.

2. Methodology

This study employed a quasi-experimental research design. The Makurdi Local Government Area in Benue State served as the study's site. The study's population consists of 4,590 students from the 21 Government Grant-Aided Secondary Schools currently in operation in the Makurdi Local Government Area of Benue State. The sample consisted of 69 students from two full secondary school classes in the Makurdi Local Government Area of Benue State. The Biology Students Performance Test (BSPT) and the Digital Technology Test (DT) were used in the study. The test items were closely scrutinized by the research supervisor. The researcher administered the test in classrooms with the assistance of one research assistant. Descriptive statistics like mean and standard deviation were used to address the study issues, and Analysis of Variance (ANOVA) at the 0.05 level of significance was used to investigate the hypotheses.

Research Question One

How well do senior high school biology students in Makurdi Local Government Area perform on average when taught the subject using digital technologies as opposed to an inquiry-based approach?

Table 1: Mean and Standard Deviation of Academic Performance Scores of Students taught Biology using Inquiry-Based Approach (IBA) and those taught using digital technology.

Method		Pre-test	Post-test	Mean gain
	Mean	11.03	19.68	8.65
IBA	N	37	37	
	Std. Deviation	2.021	2.688	
	Mean	11.09	16.72	5.53
DT	N	32	32	
	Std. Deviation	2.680	2.727	
Mean difference		0.06	2.96	3.02

Table 1 shows the mean performance scores of biology students who were taught using digital technology versus those who were taught using an inquiry-based method. The table shows that 37 students received teaching using the IBA Strategy, while 32 students received instruction using digital technology. The table shows that the mean academic performance scores of students who received biology instruction utilizing IBA were 11.03 on the pre-test and 19.68 on the post-test, with standard deviations of 2.21 and 2.69, respectively. The mean academic performance scores of students who get instruction through digital methods, on the other hand, are 11.09 with a standard deviation of 2.68 in the pre-test and 16.72 with a standard deviation of 2.72 (post-test). Furthermore, Table 1 shows that students who got biology education by IBA had an average gain score of 8.65, while students who received instruction through digital technology had an average score of 5.53. Biology students who were taught using the IBA technique had mean academic performance ratings that were 3.02 points lower than those of students who were taught using digital technology.

Research Question Two

What are the mean performance scores of male and female students taught Biology using inquiry-based approach (IBA) in senior secondary schools in Makurdi Local Government Area?

Table 2: Mean and Standard Deviation of Mean Performance Scores of Male and Female Students taught Biology using inquiry-based approach.

Method		Pre-test	Post-post	Mean gain
	Mean	11.05	19.41	8.36
Male	N	22	22	
	Std. Deviation	1.914	2.840	
	Mean	11.00	20.07	9.07
Female	N	15	15	
	Std. Deviation	2.236	2.492	
Mean difference		0.05	0.66	0.71

The Data in Table 2 show that the mean academic performance scores of male and female students who received biology instruction utilizing IBA are different. The table shows that 15 female students and 22 male students were introduced to biology using IBA. The table shows that male students who received instruction using the IBA technique had mean performance scores of 19.41 on the post-test and 11.05 on the pre-test, with corresponding standard deviations of 2.84 and 1.91. Additionally, Table 2 shows that the mean performance scores of female students taught using IBA are 11.00 with a standard deviation of 2.24 in the pre-test and 20.07 with a standard deviation of 2.49 in the post-test, but the mean gain of male students taught biology using IBA is 8.36. The mean academic performance scores of male and female students differ by 0.71 when biology is taught with IBA, favoring the female students.

Hypotheses One

There was no discernible difference in the mean performance scores of senior secondary school biology students in Makurdi Local Government Area who received instruction utilizing digital technology vs those who received instruction based on inquiry.

Table 3: ANCOVA of Academic Performance Scores of Students taught Biology using inquiry-based approach and those taught using digital technology in Makurdi Local Government Area.

Dependent Variable: Post-test

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	164.513[a]	2	82.257	11.403	.000	.257
Intercept	741.772	1	741.772	102.830	.000	.609
Pretest	14.481	1	14.481	2.007	.161	.030
Method	**151.344**	**1**	**151.344**	**20.980**	**.000**	**.241**
Error	476.096	66	7.214			
Total	23759.000	69				
Corrected Total	640.609	68				

a. R Squared = .257 (Adjusted R Squared = .234)

The information in Table 3 indicates that F (1, 66) = 20.98; p = 0.000 < 0.05. Hence, the null hypotheses, according to which there is no appreciable difference between students who learned biology through IBA and those who learned it using digital technology, are refuted. This implies that there is a significant difference in the mean academic performance ratings between biology students taught using IBA and those taught using digital technologies. strategies had a partial Eta square of 0.241, meaning that 2.41% of the students' performance ratings were explained by the strategies and tactics employed to teach biology.

Hypotheses Two

There was no significant difference in the mean performance ratings of male and female students who received inquiry-based biology instruction in senior secondary schools in Makurdi Local Government Area.

Table 4: ANCOVA of Performance Scores of Male and Female Students taught Biology using inquiry-based approach in Makurdi Local Government Area.

Dependent Variable: post-test

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9.815[a]	2	4.908	.667	.520	.038
Intercept	359.013	1	359.013	48.769	.000	.589
Pretest	5.958	1	5.958	.809	.375	.023
Gender	**3.964**	**1**	**3.964**	**.539**	**.468**	**.016**
Error	250.293	34	7.362			
Total	14584.000	37				
Corrected Total	260.108	36				

a. R Squared = .038 (Adjusted R Squared = -.019)

Data in Table 4 reveals that F (1,34) = 0.539; p = 0.468 > 0.05. Thus, the null hypothesis which states there is no significant difference in the mean performance scores of male and female students taught Biology using IBA is not rejected. This implies that there is no significant difference in the mean academic performance scores of male and female students exposed to IBA. The partial Eta square of 0.016 was obtained for gender meaning that only 1.6% of the biology performance scores is accounted for the influence of gender in Biology class when taught using inquiry-based approach.

Discussion of Findings

The results of Hypothesis One showed that senior secondary biology students taught using the inquiry-based approach and those taught using digital technology had significantly different mean academic performance scores. This suggests that students' academic performance in biology was improved by the inquiry-based approach. This finding is in line with Smith's (2018), who discovered that students who were taught using the inquiry-based approach performed noticeably better than those who were taught using simulation. In a similar vein, Johnson and Adewale (2020) found that pupils exposed to the inquiry-based approach outperformed those taught using traditional approaches. The results of Hypothesis Two demonstrated that the mean academic performance scores of male and female students exposed to the inquiry-based approach did not differ significantly. This suggests that when taught this way, male and female students did equally well. Johnson and Adewale's (2020) study, which indicated that male and female biology students exposed to inquiry-based learning fared equally well on achievement assessments, is supported by this conclusion. In a similar vein, Williams (2021) found no discernible gender-based differences in the academic achievement of Canadian students taught with the inquiry-based approach.

Conclusion

The study investigated the effect of inquiry-based approach on Biology students' performance in secondary school in Makurdi Local Government Area. The key finding revealed that:

1. There is significant difference in the mean academic performance scores of students taught Biology using IBA and those taught using digital technology.

2. There is no significant difference in the mean academic performance scores of male and female students exposed to IBA

Recommendations

1. Biology teachers should be encouraged to adopt the inquiry-based approach and digital technology as a primary method of instruction, as it enhances students' academic performance more effectively.

2. Educational stakeholders and school administrators should organize workshops and seminars to train teachers on the effective use of inquiry-based strategies in the classroom

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