HP JCER2026
Hummingbird Publications
Journal of Contemporary Education Research
www.hummingbirdjournals.com
©August, 2026
Vol. 13 No. 8

Comparative Effects of Guided, Structured, and Open Inquiry Instruction on Students' Achievement in Pollination Concepts in Biology Among Senior Secondary School Students in Minna Metropolis, Niger State

F. Ali[1]; A. A. B. Abubakar[2]; A. Sadiku[3]; F. M. Sobowale[4]; & S. Adeniran[5]

Corresponding Author: sadiku.abdul@futminna.edu.ng

DOI: https://doi.org/10.70382/hujcer.v13i8.058

Keywords: Guided Inquiry, Structured Inquiry, Open Inquiry, Academic Achievement, Biology Education, Pollination Concepts

Abstract

This study set out to compare the effects of guided, structured, and open inquiry-based instruction on senior secondary school students' achievement in pollination concepts in Minna Metropolis, Niger State, Nigeria. A quasi-experimental design was adopted, using a pre-test, post-test, non-equivalent control group arrangement. From a population of 4,225 Biology students, the target population was narrowed to 1,892 Senior Secondary School II students, from whom 553 were selected through a multi-stage sampling technique and distributed across three schools representing the guided, structured, and open inquiry groups. The Guided, Structured and Open Inquiry-Based Instruction Pollination Achievement Test (GSOIBIPAT) served as the data collection instrument; it was vetted by specialists in Biology Education, Educational Technology, and Measurement and Evaluation, and returned a reliability coefficient of 0.78. Research questions were answered using mean and standard deviation, while the stated hypotheses were tested with Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) at the 0.05 significance level, with Sidak post-hoc comparisons used to pinpoint where group differences lay. Guided inquiry produced the strongest gains (M = 35.03, SD = 2.98), ahead of structured

inquiry (M = 33.15, SD = 2.87) and open inquiry (M = 28.23, SD = 3.28), and the difference among the three groups was significant ($F = 154.748$, $p < 0.05$, $\eta^2 = .361$). A significant gender difference also emerged, though the gap within each group was fairly narrow, with female students edging out their male counterparts slightly. Taken together, these results point to guided inquiry as the more effective of the three approaches for raising achievement in Biology. On this basis, the study recommends that Biology teachers adopt guided inquiry strategies in their instruction and that curriculum planners give inquiry-based activities a firmer place in the secondary school Biology curriculum.

Introduction

At the senior secondary level in Nigeria, Biology holds a place among the core science subjects, largely because of what it offers toward scientific literacy, environmental sustainability, agriculture, medicine, and biotechnology. Beyond content knowledge, the subject is meant to build problem-solving ability and practical competence, both of which matter for national development and technological progress (Homar, 2023). Yet achievement in the subject has not matched this importance; over the years, Nigerian secondary school students have continued to struggle, and the difficulty is most pronounced in abstract, process-oriented topics such as pollination, genetics, ecology, and reproduction.

Much of the blame for this weak performance has been placed on the continued reliance on teacher-centred methods, which leave little room for students to participate, question, experiment, or think critically (Aliyu, 2023). Where rote memorisation is favoured over genuine conceptual understanding and investigation, as is often the case in traditional classrooms, students tend to lose interest and retain less, and the academic outcomes that follow reflect this.

In response, inquiry-based instruction has gained ground as a learner-centred alternative, one that appears capable of improving understanding, achievement, retention, and scientific reasoning all at once. It works by pulling students into the learning process itself, through questioning, investigation, experimentation, observation, and reasoning grounded in evidence (Angwaomaodoko, 2024). Chu et al. (2021) add that this approach also nurtures 21st-century skills, among them collaboration, communication, creativity, and critical thinking.

Science education typically distinguishes three modes of inquiry-based instruction: guided, structured, and open. In guided inquiry, students receive the research questions and some procedural direction but are left to work out solutions on their own. Structured inquiry goes a step further in providing both the procedures and the questions, whereas open inquiry hands most of this over to the learner, who formulates their own questions, procedures, and solutions

with minimal input from the teacher (Berie et al., 2022). What separates the three, essentially, is how much autonomy students are given and how much scaffolding the teacher retains.

A fair amount of research backs the claim that inquiry-based approaches lift achievement in science subjects. Blake et al. (2020), for instance, found it outperformed direct instruction in building students' content knowledge and understanding. Gabor et al. (2023) reported similar gains specifically for guided inquiry, which improved both conceptual understanding and achievement in chemistry classrooms, while John et al. (2022) found a positive relationship more broadly between inquiry-based teaching and achievement in science education.

Within Biology specifically, inquiry-based strategies seem well suited to the subject matter, since they push students toward exploration, observation, experimentation, and reasoning rather than passive listening. Pollination is a good example of a topic that benefits from this: understanding plant reproductive processes, the interactions between organisms, and the underlying biological mechanisms is not something students absorb easily just by being told about it. Zahid et al. (2018) make a related point, arguing that inquiry-oriented learning environments strengthen both conceptual understanding and practical competence by giving students authentic scientific experiences to work through.

Gender continues to be a point of interest in science achievement research, and the evidence is somewhat mixed. Some studies find male students ahead in science subjects, while others argue that inquiry-based environments can level the playing field for male and female students alike (Estrella et al., 2020). Given this lack of consensus, it becomes worth examining how gender interacts with achievement under the different inquiry-based modes.

It is against this backdrop that the present study examined how guided, structured, and open inquiry-based instruction affect Biology students' achievement in pollination concepts among senior secondary school students in Minna Metropolis, Niger State.

Aim and Objectives of the Study

This study aimed to investigate the effects of guided, structured, and open inquiry-based instruction on Biology students' academic achievement in pollination concepts among senior secondary school students in Minna Metropolis, Niger State. Specifically, the study sought to determine the:

1. effect of guided, structured, and open inquiry-based instruction on Biology students' academic achievement in pollination concepts among senior secondary schools in Minna Metropolis, Niger State; and
2. influence of gender on the academic achievement of Biology students taught pollination concepts using guided, structured, and open inquiry-based instruction among senior secondary schools in Minna Metropolis, Niger State.

Research Questions

The following research questions guided the study:

1. What is the difference in the mean achievement scores of Biology students taught pollination concepts using guided, structured, and open inquiry-based instruction among senior secondary schools in Minna Metropolis, Niger State?
2. What is the difference in the mean achievement scores of male and female Biology students taught pollination concepts using guided, structured, and open inquiry-based instruction among senior secondary schools in Minna Metropolis, Niger State?

Research Hypotheses

The following null hypotheses were formulated and tested at the 0.05 level of significance:

H_{O1}: There is no significant difference in the academic achievement scores of Biology students taught pollination concepts using guided, structured, and open inquiry-based instruction among senior secondary schools in Minna Metropolis, Niger State.

H_{O2}: There is no significant difference in the academic achievement scores of male and female Biology students taught pollination concepts using guided, structured, and open inquiry-based instruction among senior secondary schools in Minna Metropolis, Niger State.

Methodology

The study adopted a quasi-experimental pre-test, post-test, non-equivalent control group design. The population of the study comprised 4,225 Biology students in senior secondary schools within Minna Metropolis, Niger State. The target population consisted of 1,892 Senior Secondary School II students offering Biology. A sample of 553 students was selected using a multi-stage sampling technique from three senior secondary schools. The schools were assigned to guided inquiry, structured inquiry, and open inquiry instructional groups, respectively. Data were collected using the Guided, Structured and Open Inquiry-Based Instruction Pollination Achievement Test (GSOIBIPAT). The instrument was validated by experts in Biology Education, Educational Technology, and Measurement and Evaluation. The reliability coefficient of the instrument was established at 0.78 using appropriate reliability estimation procedures. Students in the three groups were exposed to different inquiry-based instructional modes in teaching pollination concepts over the treatment period. Data collected were analysed using mean and standard deviation for answering research questions, while ANOVA and ANCOVA were used for testing hypotheses at 0.05 level of significance. Sidak post-hoc analysis was used to identify group differences where significant variations existed.

Answering Research Questions

Research Question One: What is the difference in the mean achievement scores of Biology students taught pollination using guided, structured and open inquiry-based instruction? To address this research question, mean and standard deviations was computed as indicated in Figure 1.

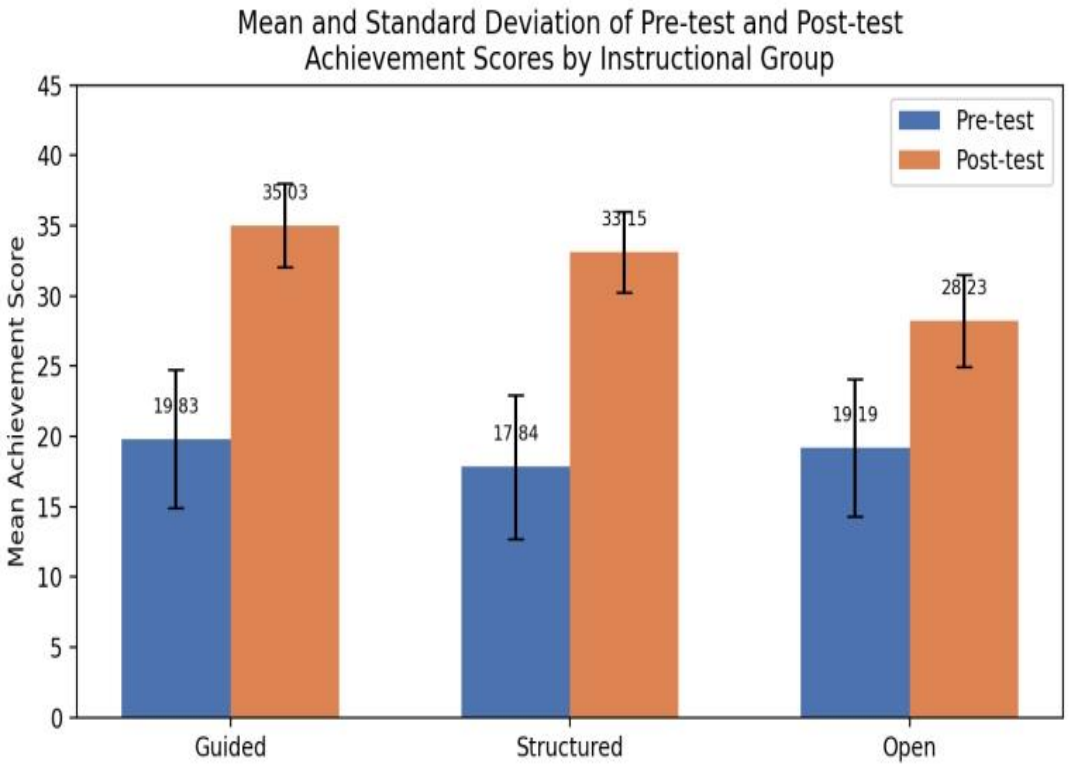


Figure 1: Mean and Standard Deviation of Pre-test and Post-test Achievement Scores

Figure 1 lays out the descriptive statistics, the means and standard deviations, for students' achievement scores across the three inquiry modes at both the pre-test and post-test stages. Students in the Guided Inquiry group moved from a pre-test mean of 19.83 (SD = 4.90) to a post-test mean of 35.03 (SD = 2.98), a gain substantial enough to suggest that the teacher-led scaffolding built into guided inquiry, paired with room for exploration, genuinely deepened students' grasp of pollination as a concept. The Structured Inquiry group also improved markedly, rising from a pre-test mean of 17.84 (SD = 5.11) to a post-test mean of 33.15 (SD = 2.87). Although this fell just short of the guided group's gain, the structured approach, which hands students a teacher-designed procedure but still requires them to analyse data and draw their own conclusions, clearly worked. Open Inquiry students improved too, moving from a pre-test mean of 19.19 (SD = 4.90) to a post-test mean of 28.23 (SD = 3.28), though the gain trailed behind the other two groups. This smaller gain hints that while open inquiry has real value in fostering learner autonomy and discovery, how well it works may depend on how ready students are, what prior knowledge they bring, and how demanding the task itself is.

Research Question Two: What is the difference in the mean achievement scores of male and female Biology students taught pollination using guided, structured and open inquiry-based instruction? To address this research question, mean and standard deviations was computed as indicated in Figure 2.

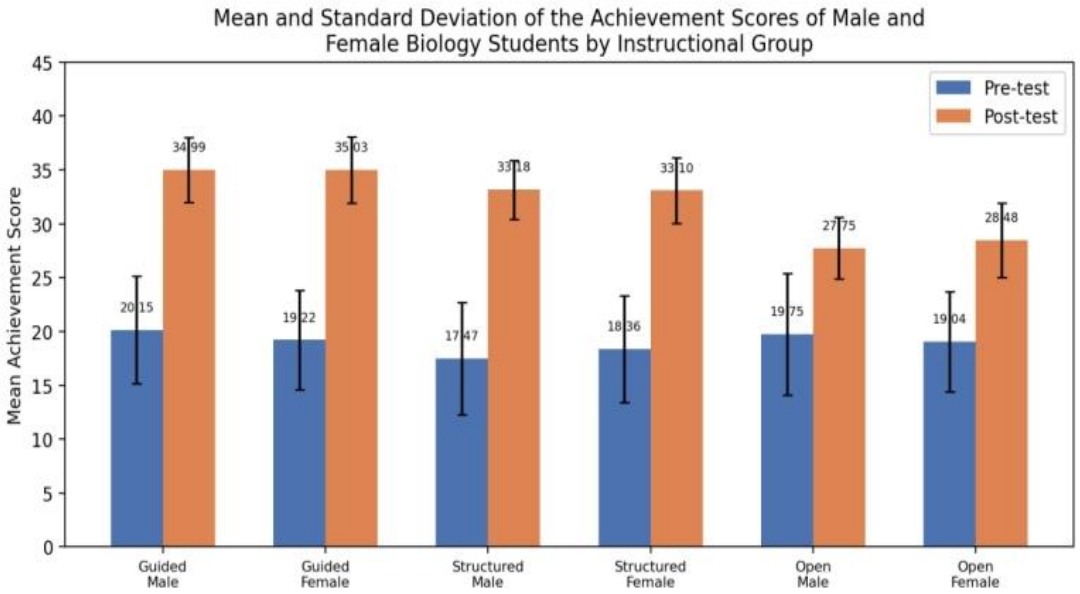


Figure 2: Mean and Standard Deviation of the Mean Achievement Score of Male and Female Biology Students

Figure 2 presents the mean and standard deviation of male and female Biology students' achievement scores before and after being taught the concept of pollination using guided, structured and open inquiry-based instructional strategies. For students exposed to guided instruction, male students had a pre-test mean of 20.15 (SD = 5.022) and a post-test mean of 34.99 (SD = 3.007), resulting in a mean gain of 14.84. Female students in the same group recorded a slightly lower pre-test mean of 19.22 (SD = 4.632) but a marginally higher post-test mean of 35.03 (SD = 3.074), with a mean gain of 15.81, indicating notable improvement in both sexes, with females gaining slightly more. Among students exposed to structured instruction, male participants had a pre-test mean of 17.47 (SD = 5.197) and post-test mean of 33.18 (SD = 2.734), resulting in a gain score of 15.71. Female students in this group showed a pre-test mean of 18.36 (SD = 4.973) and post-test mean of 33.10 (SD = 3.059), with a gain score of 14.74. This implies that both male and female students significantly benefited from structured inquiry, with males slightly outperforming females in gain scores. For the open inquiry-based instruction group, male students recorded a pre-test mean of 19.75 (SD = 5.674) and post-test mean of 27.75 (SD = 2.845), achieving a gain of 8.00, while females showed a pre-test mean of 19.04 (SD = 4.648) and post-test mean of 28.48 (SD = 3.438), with a gain of 9.44. This suggests that although both groups showed improvement, the gains were relatively lower compared to those in the guided and structured instruction groups.

Hypothesis Testing

Hypothesis One: There is no significant difference in the academic achievement scores of Biology students' taught pollination using guided, structured and open inquiry-based instruction.

Table 1: ANCOVA Result of the Post-test Mean Achievement Scores of Students Taught Pollination Using Guided, Structured and Open Inquiry-Based Instruction

Source	Sum of Squares	Df	Mean Square	F-value	P-value	Partial Eta Squared
Corrected Model	2783.226[a]	3	927.742	103.856	.000	.362
Intercept	35190.113	1	35190.113	3939.350	.000	.878
Covariate (Pre-test)	1.030	1	1.030	.115	.734	.000
***Achievement**	2764.718	2	1382.359	154.748	.000	.361
Error	4904.203	549	8.933			
Total	630941.000	553				
Corrected Total	7687.429	552				

****S = Significant at 0.05 level***

Table 1 presents the results of the Analysis of Covariance (ANCOVA) used to determine whether significant differences existed in the post-test achievement scores of students taught pollination using guided, structured and open inquiry-based instructional strategies, while statistically controlling for pre-test scores. The ANCOVA result revealed a statistically significant difference among the three instructional groups, $F(3, 550) = 154.748$, $p = 0.000$, indicating that the type of instructional approach had a significant effect on students' post-test performance when pre-test variations were accounted for. The partial eta squared ($\eta_p^2 = .361$) indicated a moderate effect size, suggesting that approximately 36.1% of the variance in students' achievement could be attributed to the instructional method employed. To further explore the specific sources of the significant difference observed among the instructional groups, a post hoc pairwise comparison was conducted using Sidak's adjustment method as presented in Table 2

Table 2 Sidak Post-Hoc Analysis of the Post-Test Means Achievement Scores of Students Taught Pollination Using Guided, Structured and Open Inquiry-Based Instruction

I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.[B]
Guided	Structured	1.869*	.292	.000
	Open Inquiry-Based	6.793*	.389	.000
Structured	Guided	-1.869*	.292	.000
	Open Inquiry-Based	4.924*	.422	.000
Open	Guided	-6.793*	.389	.000
	Structured	-4.924*	.422	.000

Based on estimated marginal means; *The difference in the means is significant at 0.05 level.

Table 2 presents the Sidak post-hoc analysis comparing the post-test mean achievement scores of students taught pollination using guided, structured and open inquiry-based instruction. The results show that the mean difference between students in the guided instruction group and the

structured instruction group was statistically significant (Mean Diff. = 1.869, $p < .000$), indicating a higher achievement for the guided group. Similarly, the guided group outperformed the open inquiry-based group with a significant mean difference of 6.793 ($p < .000$). Moreover, students in the structured instruction group also scored significantly higher than those in the open inquiry-based group (Mean Diff. = 4.924, $p < .000$). These findings indicate that all instructional modes differed significantly in effectiveness, with guided instruction producing the highest achievement, followed by structured instruction and lastly, open inquiry-based instruction.

Hypothesis Two: There is no significant difference in the academic achievement scores of male and female Biology students taught pollination using guided, structured and open inquiry-based instruction

Table 3: ANCOVA Result of the Post-test Mean Achievement Scores of Male and Female Biology Students Taught Pollination Using Guided, Structured and Open Inquiry-Based Instruction

Source	Sum of Squares	df	Mean Square	F-value	P-value	Partial Eta Squared
Corrected Model	2702.422a	6	450.404	49.332	.000	.352
Intercept	34055.613	1	34055.613	3730.058	.000	.872
Covariate (Pre-test)	1.879	1	1.879	.206	.650	.000
***Gender**	2683.914	5	536.783	58.793	.000	.350
Error	4985.006	546	9.130			
Total	630941.000	553				
Corrected Total	7687.429	552				

S = Significant at 0.05 level

Table 3 presents the Analysis of Covariance (ANCOVA) conducted to determine whether there were significant differences in the achievement scores of male and female Biology students taught using guided, structured and open inquiry-based instructional strategies. The ANCOVA revealed a statistically significant main effect of instructional approach, $F(3, 550) = 58.793$, $p = 0.000$, at the 0.05 level. The effect size, measured by partial eta squared ($\eta_p^2 = .350$), indicates a moderate effect, suggesting that 35% of the variance in achievement scores was attributable to the instructional strategies used. Although the result confirms that the guided inquiry approach was more effective than structured and open inquiry in improving students' achievement across both genders, the finding also revealed a significant difference in achievement between male and female students within each instructional group. This implies that gender significantly moderate the effect of the inquiry-based instructional methods on students' academic achievement. Thus, hypothesis four, which stated that there is no significant difference in the mean achievement scores of male and female students taught Biology using the different inquiry-based approaches, was rejected. The results of the post hoc analysis are presented in Table 4.

Table 4: Summary of Sidak Post-Hoc Analysis of Post-Test Achievement Scores by Instructional Method and Gender

Comparison	Mean Difference (I–J)	Std. Error	p-value	Decision
Guided Male vs Guided Female	-0.052	0.356	1.000	Not Significant
Guided Male vs Structured Male	1.777*	0.380	0.000	Significant
Guided Male vs Structured Female	1.863*	0.423	0.000	Significant
Guided Male vs Open Male	7.231*	0.708	0.000	Significant
Guided Male vs Open Female	6.491*	0.470	0.000	Significant
Guided Female vs Structured Male	1.829*	0.423	0.000	Significant
Guided Female vs Structured Female	1.915*	0.463	0.001	Significant
Guided Female vs Open Male	7.283*	0.734	0.000	Significant
Guided Female vs Open Female	6.544*	0.507	0.000	Significant
Structured Male vs Structured Female	0.086	0.477	1.000	Not Significant
Structured Male vs Open Male	5.454*	0.745	0.000	Significant
Structured Male vs Open Female	4.715*	0.522	0.000	Significant
Structured Female vs Open Male	5.368*	0.768	0.000	Significant
Structured Female vs Open Female	4.629*	0.555	0.000	Significant
Open Male vs Open Female	-0.739	0.795	0.999	Not Significant

Significant at $p < 0.05$.

Table 4 presents the Sidak post-hoc analysis comparing the post-test mean achievement scores of students taught pollination concepts in Biology using guided, structured, and open inquiry-based instruction. The findings show a statistically significant mean difference between the guided and structured instruction groups (Mean Diff. = 1.869, $p < .000$), with guided instruction producing higher scores. A much larger significant difference was found between the guided and open inquiry-based groups (Mean Diff. = 6.793, $p < .000$), indicating the strong effectiveness of the guided instructional method.

The structured group likewise came out ahead of the open inquiry group, by a mean difference of 4.924 ($p < .000$). Every mean difference reported in the table reaches significance at the 0.05 level, which leaves little doubt that the instructional method mattered for students' post-test performance. Ranked by effectiveness, guided instruction comes out on top, structured instruction follows, and open inquiry-based instruction trails behind the other two.

Discussion of Findings

Taken as a whole, the findings point to real differences in achievement depending on which inquiry-based approach students were taught under. Those in the guided inquiry group consistently outscored their structured and open inquiry counterparts, which suggests that the scaffolding guided inquiry provides is enough to help students work through a demanding

concept like pollination without shutting down the active participation and independent thinking that inquiry-based teaching is meant to encourage in the first place.

Why guided inquiry came out ahead may come down to balance: students get enough direction and procedural support to stay oriented, yet still have room to explore and work through problems on their own. This lines up with what Gabor et al. (2023) found in chemistry classrooms, where guided inquiry produced meaningful gains in both conceptual understanding and achievement, and with Blake et al. (2020), who reported that inquiry-based strategies outperformed traditional direct instruction on content knowledge.

These results also echo Aliyu (2023), whose emphasis was on how inquiry teaching lifts learning outcomes by drawing students into active engagement, critical thinking, and scientific reasoning, and Berie et al. (2022), who observed similar improvements in participation and conceptual understanding across science education more broadly.

The weaker showing from the open inquiry group is not entirely surprising, given how much independence that mode demands. Without much guidance, students may simply have struggled to generate their own procedures and work through problems unaided, a difficulty that fits with what Bogador et al. (2024) describe as the twin challenges of open inquiry: inadequate scaffolding and uneven learner readiness.

Gender differences also turned out to be statistically significant, though the actual gap within each group was fairly small. Female students edged out their male peers slightly across all three inquiry groups, a pattern that fits Estrella et al.'s (2020) argument that inquiry-based environments tend to narrow gender disparities and give both sexes more equitable footing in science learning.

There is also a theoretical explanation worth noting here. Constructivist learning theory holds that knowledge is built actively, through interaction, investigation, and experience, rather than absorbed passively, and this maps closely onto what inquiry-based instruction does in practice. David (2024) makes a similar point, arguing that meaningful learning depends on learners actively engaging with their environment and reflecting on their own inquiry process. Seen this way, inquiry-based instruction is not just a teaching technique but a route to deeper understanding and stronger academic performance in Biology.

Conclusion and Recommendations

On the whole, this study concludes that guided inquiry-based instruction is the more effective of the three approaches for raising Biology achievement in pollination concepts among senior secondary school students in Minna Metropolis, Niger State. It struck the right balance of support and active engagement, and it outperformed both structured and open inquiry on this measure. The study also found that inquiry-based instruction, in general, works reasonably well for both male and female students, even if a modest gender gap in outcomes remained. On this basis, guided inquiry-based instruction deserves a stronger place in Biology classrooms, both for what it does for achievement and for scientific understanding more broadly. The following recommendations follow from these findings:

1. Biology teachers should consider adopting guided inquiry-based strategies, not only for pollination but for other Biology concepts as well, given the gains observed in students' academic achievement.
2. Curriculum planners and educational authorities would do well to build inquiry-based learning activities more firmly into the secondary school Biology curriculum.
3. Schools should also invest in regular training and workshops that help Biology teachers implement inquiry-based approaches effectively in their science classrooms.

References

Aliyu, Y. A. (2023). The effectiveness of inquiry teaching method on students' learning outcome: A conceptual and empirical review. *Educational Extracts, 11*(2).

Angwaomaodoko, E. A. (2024). Critical thinking: Strategies for fostering a culture of inquiry in education. *Path of Science, 10*(9), 1001–1007.

Berie, Z., Damtie, D., & Bogale, Y. N. (2022). Inquiry-based learning in science education: A content analysis of research papers in Ethiopia (2010–2021). *Education Research International, 2022*(1), 6329643.

Blake, C. C., Andrew, C. T., Edward, W. O., Grady, T. R., & Pringle, M. R. (2020). Comparing the 5E method of inquiry-based instruction and the four-stage model of direct instruction on students' content knowledge achievement in an ENR curriculum. *Journal of Agricultural Education, 61*(3), 1–21. https://doi.org/10.5032/jae.2020.03001

Bogador, C. J., Camarao, M. K. G., Matunding, C. G., & Sombria, K. J. F. (2024). Challenges and benefits of inquiry-based learning in physics. *International Journal of Multidisciplinary: Applied Business and Education Research, 5*(7), 2716–2732.

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). *21st century skills development through inquiry-based learning from theory to practice*. Springer International Publishing.

David, T. H. (2024). Dewey's conception of an environment for teaching and learning.

Estrella, J., Christine, A., Karen, K., Kathleen, M., Rachel, K., & Nicholas, F. (2020). Inquiry and gender inequity in the undergraduate mathematics classroom.

Gabor, O., Orcid, L., Veronika, N., ORCID, L., Lajos, K., Orcid, L., Zoltan, S., Orcid, L., & Erzsebet, K. (2023). Guided inquiry-based learning in secondary-school chemistry classes: A case study. *Chemistry Education Research and Practice, 24*, 50–70.

Homar, J. (2023). Biology and biotechnology: Industrial applications in the 21st century. *Journal of Biotechnology Advances, 61*, 108–119.

John, J., Oliver, M., & Sam, S. (2022). The relationship between inquiry-based teaching and students' achievement: New evidence from a longitudinal PISA study in England.

Zahid, H., Engin, B., Alison, B., Monica, D., Andy, S., Paulo, B., & Ingmar, H. R. (2018). Design guidelines and empirical case study for scaling authentic inquiry-based science learning via open online courses and interactive Biology cloud labs. *International Journal of Artificial Intelligence in Education, 7*(3), 234–256.