impact International Journals and Publications

© IIJP 2026 | Volume 2, Issue 3, pp. 2411-2426 | ISSN: 2636-4484

EFFECTS OF INQUIRY-BASED FLIPPED CLASSROOM, GUIDED INQUIRY, AND CONVENTIONAL TEACHING METHODS ON JUNIOR SECONDARY STUDENTS' ACHIEVEMENT, SELF-CONCEPT AND SCIENCE PROCESS SKILLS IN BASIC SCIENCE AND TECHNOLOGY IN NASARAWA STATE, NIGERIA

***SIMON Pannan Danlami, PhD[1]; NYAMWUL William Ninyar[2]; ANZAKU Micah Adamu[3]**

[1]*Science Department, Model Government Girls Secondary School, Kwandare, Lafia*
[2]*Ministry of Science and Technology, Jos.*
[3]*Government Secondary School Adogi, Nasarawa State.*
****Corresponding Author:** Pannansimon01@gmail.com*

ARTICLE INFO
Article No.: 0595
Accepted Date: 25/08/2026
Published Date: 23/09/2026
Type: Research

ABSTRACT

Traditional teacher-centered methods of teaching in Nigerian junior secondary schools have been largely ineffective and outdated in developing students' achievement, self-concept, and acquisition of science process skills in Basic Science and Technology. This study examined the effects of Inquiry-Based Flipped Classroom (IBFC), Guided Inquiry (GI), and Conventional Teaching Method on these three outcome variables. A quasi-experimental pretest-posttest non-equivalent control group design was adopted. The sample consisted of 313 JSS II students (158 males, 155 females) selected from six intact classes across six co-educational public secondary schools in Nasarawa State through multi-stage sampling. Participants were intact class arms assigned to three groups based on existing structure: Inquiry-Based Flipped Classroom (n = 105), Guided Inquiry (n = 104), and Conventional Teaching Method, which served as the control group (n = 104). Data were collected using three validated instruments: Basic Science and Technology Achievement Test (BSTAT), Basic Science Self-Concept Scale (BSSCS), and Science Process Skills Test (SPST). Analysis was performed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at a 0.05 level of significance. Findings showed that, after controlling for pretest scores, instructional approach had a statistically significant effect on students' achievement, $F(2, 309) = 13.796$, $p < .001$, partial $\eta^2 = .082$; self-concept, $F(2, 309) = 7.343$, $p = .001$, partial $\eta^2 = .045$; and science process skills, $F(2, 309) = 6.330$, $p = .002$, partial $\eta^2 = .039$. The IBFC group recorded the highest posttest means and mean gains on all three outcomes, followed by the GI group and then the conventional group. The study concludes that the Inquiry-Based Flipped Classroom is the most promising of the three instructional approaches for enhancing multiple learning outcomes in Basic Science and Technology. It recommends its adoption in Nigerian secondary schools, supported by adequate infrastructure, teacher professional development, and curriculum reforms.

Keywords: Inquiry-Based Learning, Flipped Classroom, Guided Inquiry, Science Process Skills, Self-Concept, Achievement.

Introduction

The product and quality of science education in Nigerian secondary schools remain a source of concern for educators, policymakers, and other stakeholders. Traditional teacher-centered approaches, such as talk/chalkboard and demonstration methods, have been widely criticized for their inadequacy in developing students' basic thinking skills, scientific literacy, and deep conceptual understanding (Eggon & Agu, 2020). This challenge is particularly evident in Basic Science and Technology (formerly Integrated Science), a foundational core subject taught in Nigerian junior secondary schools. It integrates fundamental concepts from Physics, Chemistry, and Biology to help students understand natural phenomena through systematic observation, experimentation, and analysis (Ogunode, 2020; Olamoyegun et al., 2023). The subject aims to build scientific literacy, encourage manipulative skills, and prepare students for specialized science courses at the senior secondary level by highlighting the interconnectedness of scientific disciplines in everyday life and the environment.

In response to these challenges, the 2025 revised Nigerian curriculum developed by the Nigerian Educational Research and Development Council (NERDC) renames and restructures Integrated Science (previously Basic Science and now Intermediate Science) as a compulsory subject for JSS 1-3. The new curriculum reduces content overload, incorporates relevant topics such as emerging scientific issues, career opportunities in science, Biotechnology, earth science, health, and technology, and strongly promotes inquiry-based learning (NERDC, 2025; Treesun, 2025; Olatoye, 2025). The curriculum further emphasizes 21st-century skills including reflective thinking, digital literacy, and innovation through subjects such as Integrated Science, Digital Technologies, and Technology & Innovation, which include elements of coding, artificial intelligence, and entrepreneurship. Successful implementation of this ambitious curriculum requires innovative, student-centered pedagogies that align with its practical and project-based focus.

Current educational research has increasingly advocated for student-centered instructional strategies that actively engage learners in knowledge construction and learning. Among these, inquiry-based learning has emerged as a promising approach for enhancing student results in science education. Research consistently shows that inquiry-based science teaching significantly improves academic achievement compared to conventional lecture methods (Ajala, 2025). Guided inquiry, a structured form of inquiry-based learning, has demonstrated effectiveness. Studies in Nigeria have found that students taught Basic Science and Technology using guided inquiry strategies achieved significantly higher mean scores in academic achievement than those taught with conventional methods (Ige et al., 2025; Adonu et al., 2021). Beyond achievement, guided inquiry has also been shown to enhance students' self-concept in science (Gathage et al., 2021; Anwo et al., 2025) and improve the acquisition of science process skills (Nworgu & Otum, 2013).

In recent years, the integration of technology with inquiry-based approaches has led to the emergence of the inquiry-based flipped classroom model. This approach inverts traditional instruction by having students engage with core content (often through videos or readings) before class, thereby freeing up classroom time for hands-on, application-oriented, and inquiry-driven activities. This model cultivates deeper engagement, active participation, and higher-order thinking (Tan et al., 2020). Empirical studies in Nigeria have reported significant gains in academic achievement and students' self-concept in science subjects when the flipped classroom model is implemented (Konyeme & Alordiah, 2024; Inengite & Zipamone, 2024; Abbas & Idris, 2022). In addition, combining flipped classroom with guided inquiry creates a powerful hybrid: students

arrive prepared and mentally activated, while class time is dedicated to structured, scaffolded inquiry experiences that enhance conceptual understanding and science process skills (Tan et al., 2020).

In the Nigerian context, and particularly in Nasarawa State, innovative instructional strategies have shown promise in coping with persistent challenges such as resource constraints and low student participation. Studies conducted in Nasarawa State indicate that innovative approaches, including collaborative learning and laboratory-based instruction, significantly improve students' achievement and self-concept in Basic Science and Technology compared to traditional methods (Ketelhut, 2007; Eggon & Agu, 2020; Uy Jr, & Azuelo, 2022).

Despite these encouraging findings, there remains limited empirical evidence on the combined effect of inquiry-based flipped classroom and guided inquiry approaches on multiple learning achievements simultaneously, relative to conventional instruction. Again, the specific context of Basic Science and Technology education among junior secondary school students in Nasarawa State presents unique cultural, technological, and pedagogical considerations that have not been adequately addressed in existing literature. This study therefore seeks to investigate the effects of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on junior secondary school students' achievement, self-concept, and acquisition of science process skills in Basic Science and Technology in Nasarawa State.

Purpose of the Study

The main objective of this study is to investigate the effects of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' achievement, self-concept, and acquisition of science process skills in Basic Science and Technology among junior secondary school students in Nasarawa State. By examining the inquiry-based flipped classroom and guided inquiry approaches alongside a conventional teaching method baseline, this paper seeks to provide a comprehensive understanding of how these instructional approaches influence various dimensions of student learning and development.

Research Questions

1. What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' achievement in Basic Science and Technology?
2. What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' self-concept in Basic Science and Technology?
3. What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' acquisition of science process skills in Basic Science and Technology?

Hypotheses

The following null hypotheses guided the study and were tested at the 0.05 significance level.

Ho1: There is no significant difference in the mean achievement scores of students taught Basic Science and Technology using inquiry-based flipped classroom, guided inquiry, and conventional teaching method.

Ho2: There is no significant difference in the mean self-concept scores of students taught Basic Science and Technology using inquiry-based flipped classroom, guided inquiry, and conventional teaching method.

Ho3: There is no significant difference in the mean science process skills acquisition scores of students taught Basic Science and Technology using inquiry-based flipped classroom, guided inquiry, and conventional teaching method.

Justification for the Inclusion of a Conventional Teaching Method Group

Although the study's central interest lies in comparing the Inquiry-Based Flipped Classroom (IBFC) and Guided Inquiry (GI) approaches, a third group taught with the Conventional Teaching Method was retained as a control condition, for three main reasons. First, in a quasi-experimental design of this kind, a conventional/control group provides an untreated baseline against which the magnitude of improvement produced by each innovative strategy can be benchmarked; without it, an observed difference between IBFC and GI alone cannot establish whether either approach represents a genuine improvement over the prevailing teacher-centered status quo. Second, because random assignment of individual students was not possible and intact classes were used, including a conventional group strengthens the internal validity of the pretest-posttest non-equivalent control group design by helping to rule out maturation, testing, and history effects common to all three groups. Third, using a conventional/lecture-method group as the standard comparator is consistent with, and extends, prior Nigerian studies evaluating innovative science pedagogies (Eggon & Agu, 2020; Ogunjimi & Gbadeyanka, 2023), situating the present findings within the existing body of literature. Accordingly, the conventional group's data are reported and discussed as a necessary reference point alongside the primary IBFC-GI comparison, and the research questions and hypotheses above reflect this three-group design explicitly.

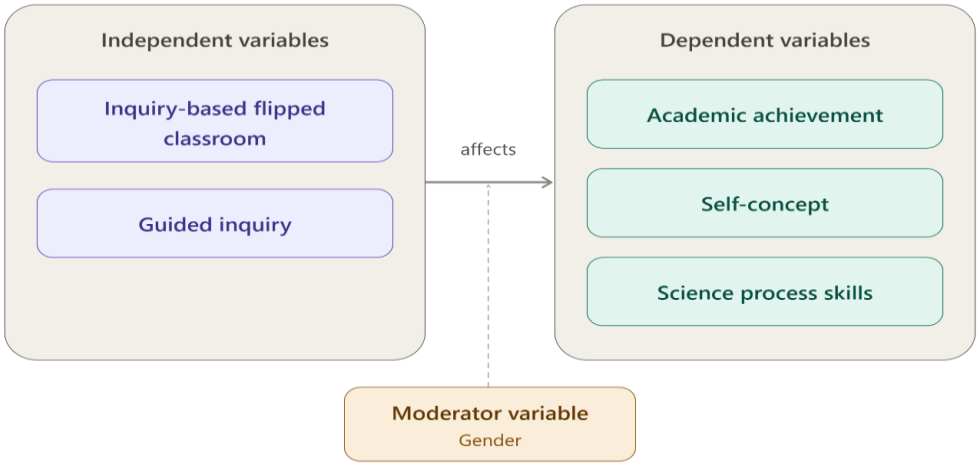
Theoretical Framework

This study is anchored on constructivist learning theory, which holds that learners build knowledge for themselves rather than absorbing it passively. According to this perspective, knowledge is constructed through the dynamic interaction between a learner's prior experiences and their interaction with the learning environment (Piaget, 1970; von Glasersfeld, 1995). This theory strongly supports student-centered instructional approaches such as inquiry-based learning, where students are encouraged to explore, question, investigate, and reflect on scientific concepts. By positioning learners as active participants in the knowledge-building process, constructivism promotes deeper conceptual understanding and meaningful learning (Bruner, 1996).

Building upon constructivist principles, social constructivism emphasizes that learning is fundamentally a socially mediated process. This also highlights the important role of social interaction, collaboration, dialogue, and scaffolding with peers and more knowledgeable others in the co-construction of knowledge (Vygotsky, 1978; Wertsch, 1985). In this study, social constructivist theory provides the basis for guided inquiry approaches that integrate peer collaboration, group discussion, and teacher facilitation. Together, constructivist and social constructivist theories offer a robust theoretical lens for examining how students construct scientific understanding through active exploration and meaningful social engagement in the learning process.

Empirical Literature Review

Having established the theoretical dimensions of the study, attention now shifts to the conceptual or independent variables, to review and explain how the inquiry-based flipped classroom and guided inquiry instructional approaches influence students' academic achievement, self-concept, and acquisition of science process skills.



To establish the uniqueness of this study, the empirical literature was reviewed under two sub-headings. The discussion further clarifies the concepts of students' self-concept and acquisition of science process skills.

Inquiry-Based Flipped Classroom Models

The inquiry-based flipped classroom approach is an instructional method that moves activities from regular instructional time to homework, leaving more time during class for enhanced learning through group discussion. Lotter & Ramnarain, (2025) described the inquiry-based flipped classroom as a relatively new teaching strategy that aims to enhance students' engagement and performance by using technology to deliver lectures outside the classroom, while bringing homework, exercises, and concept-based learning activities inside the classroom. Nisa (2026) defined inquiry-based flipped classroom learning as a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively with the subject matter. This approach has been observed to have several advantages over the traditional teacher-centered method of teaching. One advantage, according to Sari et al. (2023), is that students have the opportunity to use class time to apply what they have learnt from the videos, which allows teachers to accurately assess whether students understand the content and to use various formative techniques to assess understanding.

Basic Science as a subject area is highly amenable to the inquiry-based flipped classroom model of instruction because of its loaded content and the need for in-depth practice. There are three main models of inquiry-based flipped classroom learning: traditional, partial, and holistic (Milman, 2012). The three models differ mainly in the degree of structure, strictness of out-of-class requirements, monitoring, and integration of learning spaces. In the traditional model, students prepare for the lesson by watching short explanatory or tutorial videos before class. The partial flipped classroom is a more flexible model in which students are encouraged, but not strictly required or penalized, to access digital content outside class, reducing barriers while still freeing time for active learning (Akçayır & Akçayır, 2018). This model suits contexts where technology access is uneven, student readiness varies, or a gradual transition from traditional teaching is needed. The holistic flipped classroom, by contrast, treats all learning spaces - home, mobile, and

physical - as fully integrated and continuously monitored environments where every activity is supported and recorded across platforms (Hyypiä et al., 2019).

Alsancak Sirakaya and Ozdemir (2018) investigated the effect of an inquiry-based flipped classroom model on university students' academic achievement, self-directed learning readiness, motivation, and retention. The study adopted a quasi-experimental design with 66 students enrolled in a "Scientific Research Methods" course at Ahi Evran University, Turkey. One class served as the experimental group (inquiry-based flipped classroom), while the other was the control group (classical blended learning). Data were collected using an achievement test (KR-20 = 0.90), a self-directed learning readiness scale, and a motivation scale, and analysed with t-test, MANOVA, and ANCOVA.

The findings revealed that the inquiry-based flipped classroom model significantly improved students' academic achievement, motivation, and knowledge retention compared to the classical blended learning approach, although no significant difference was reported in self-directed learning readiness. The current study extends the inquiry-based flipped classroom approach to Junior Secondary School II students in Basic Science and Technology in Nasarawa State, Nigeria, with emphasis on different learning outcomes, including students' self-concept and science process skills acquisition, relative to a conventional teaching baseline. This creates a contextual gap in terms of educational level, subject area, and setting.

Guided Inquiry Instructional Approach

Guided inquiry is an approach to teaching in which students are guided by the teacher to find facts for themselves. It is student-centered and activity-oriented (Ogunjimi & Gbadeyanka, 2023). The approach helps to increase students' interest, confidence, innovativeness, and problem-solving ability, and consequently improves their performance in both theory and practice. It also helps students engage in relatively sophisticated mental processes, such as formulating problems for investigation, formulating hypotheses, designing experiments, synthesizing knowledge, and displaying scientific attitudes, among other skills (Kapon & Schvartzer, 2024). In guided inquiry, students acquire new experience in accordance with guidelines provided by the teacher, usually in the form of questions that lead them to the expected solutions.

Shemang (2025) investigated the effect of guided inquiry strategy on learning outcomes of low-achieving SS2 Physics students in Kaduna metropolis, Nigeria. The study employed a pretest-posttest quasi-experimental design. From a population of 1,714 SS2 science students, two schools were randomly selected and assigned to groups; 91 low-achieving students were purposively selected (43 experimental, 48 control). The experimental group was taught the concept of "Light" using guided inquiry, while the control group used the lecture method for six weeks. The present study extends this by examining inquiry-based flipped classroom, guided inquiry, and conventional teaching on JSS II students' achievement, self-concept, and science process skills in Basic Science and Technology in Nasarawa State.

Effect of Inquiry-Based Flipped Classroom and Guided Inquiry on Students' Self-Concept

The Inquiry-Based Flipped Classroom (IBFC) approach is also likely to have a positive effect on students' self-concept. Self-concept refers to students' beliefs about their own abilities and competence in a subject. Because IBFC combines pre-class video/content exposure with active, student-centered inquiry in class, learners experience greater autonomy, mastery of concepts, and successful problem-solving. These experiences typically strengthen academic self-concept, especially in science, as students feel more capable and in control of their learning. Research on flipped classrooms consistently shows improvements in self-esteem, self-efficacy, and domain-specific self-concept due to increased engagement and visible progress.

Guided Inquiry also supports active learning, but the added structure and flexibility of the flipped model appear to amplify these psychological benefits further. As Anwo et al. (2025) note, students' self-concept refers to their perceptions of their own abilities and identity in academic domains, which plays an important role in engagement and achievement in Basic Science and Technology. Research indicates that the guided inquiry approach, in which teachers provide structured support as students investigate scientific phenomena, formulate hypotheses, conduct experiments, and reflect on findings, significantly enhances self-concept compared to traditional lecture methods. By enhancing active participation, autonomy, and successful problem-solving experiences, guided inquiry helps students develop greater confidence, positive attitudes toward science, and a stronger sense of competence in scientific tasks, with studies showing higher post-intervention self-concept gains among secondary students exposed to this approach.

Effects of the Two Approaches on Science Process Skills Acquisition

Inquiry-Based Flipped Classroom combines inquiry-based learning (active investigation during class time) with the flipped model (pre-class content distribution via texts and videos). Supornpanitkul et al. (2025) explain that an inquiry-based flipped classroom approach significantly enhances the acquisition of science process skills by shifting passive knowledge acquisition to out-of-class time, thereby freeing up crucial classroom hours for active, hands-on scientific inquiry. Under traditional instruction, limited class time often restricts students to lower-level cognitive tasks such as remembering and understanding facts. In contrast, assigning foundational pre-class activities, such as educational videos, simulations, or case studies, allows learners to build basic conceptual knowledge at their own pace before entering the classroom. When students come prepared, teachers transition from lecturers into facilitators, creating dedicated space for guided and open inquiry activities. This active environment directly enhances essential science process skills, such as experimental design, data collection, problem analysis, observation, and collaborative evidence evaluation. By shifting higher-order cognitive tasks such as applying, analyzing, evaluating, and creating into the collaborative classroom setting, the flipped model enables deeper engagement with the scientific method and helps bridge the gap between theoretical knowledge and practical investigation (Jose, 2026).

Guided Inquiry provides structured teacher guidance (questions, materials, scaffolding) while students actively explore phenomena, design investigations, and draw conclusions, positioning it between fully open inquiry and direct instruction. This combination of structured teacher support with student-led investigation significantly improves both science process skills (SPS) acquisition and learning outcomes in science. In a study of eighth-grade students, those taught with guided inquiry achieved higher SPS scores (mean = 75.95) and greater conceptual gains (N-Gain = 75.97%, high category) than those taught with a standard inquiry approach, with large and medium effect sizes respectively, demonstrating that guided inquiry enhances active engagement, higher-order thinking, and meaningful learning, especially for students who tend to be passive learners (Fitriyana et al., 2025).

Methodology

This study adopted a quasi-experimental research design with a pretest-posttest non-equivalent control group approach. Three intact groups were used: an inquiry-based flipped classroom group (experimental group 1, n = 105), a guided inquiry group (experimental group 2, n = 104), and a conventional teaching method group (control group, n = 104), for a total sample of 313 students. Instructional method (inquiry-based flipped classroom, guided inquiry, and conventional method) was the fixed factor examined for its effect on students' achievement, self-concept, and science process skills acquisition in Basic Science and Technology, with each

outcome's pretest score entered as a covariate. Random assignment was not possible due to the use of existing classroom structures in Nasarawa State.

The population comprised all JSS II students in public co-educational secondary schools in Nasarawa State, Nigeria (approximately 13,500 students). A multi-stage sampling technique was used to select 313 students (158 males and 155 females) from six schools across the three Area Offices. Three instruments were utilized: Basic Science and Technology Achievement Test (BSTAT), Basic Science Self-Concept Scale (BSSCS), and Science Process Skills Test (SPST). These instruments were validated by experts, and their reliabilities were established through a pilot test (KR-21 ranging from 0.79-0.82 and Cronbach's Alpha from 0.81-0.85). Ethical approval from schools, informed consent from both students and teachers, confidentiality, and voluntary participation were strictly observed throughout the study. Data were analysed using mean and standard deviation to answer the research questions and Analysis of Covariance (ANCOVA) to test the hypotheses at the 0.05 level of significance, with the pretest score on each outcome entered as the covariate.

Results and Discussion

To achieve the objective of this study, the researchers sought empirical evidence for the following questions. The results were interpreted and discussed immediately after each question.

Research Question 1: What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' achievement in Basic Science and Technology?

Table 1: Mean and Standard Deviation Achievement Scores of Basic Science Students Based on Treatment

Treatment	N	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Gain/Loss
Inquiry-Based Flipped Classroom (IBFC)	105	26.82	7.82	45.57	13.38	18.75
Guided Inquiry (GI)	104	27.22	7.88	38.71	12.88	11.49
Conventional Teaching Method (control)	104	26.44	7.12	36.44	11.63	10.82

The study compared the effects of Inquiry-Based Flipped Classroom (IBFC), Guided Inquiry (GI), and the Conventional Teaching Method on students' achievement in Basic Science. A total of 313 students participated (IBFC: n = 105; GI: n = 104; control: n = 104). Pretest mean scores were similar across groups, indicating comparable initial knowledge (IBFC: M = 26.82, SD = 7.82; GI: M = 27.22, SD = 7.88; control: M = 26.44, SD = 7.12). After the intervention, the IBFC group obtained a posttest mean of 45.57 (SD = 13.38), the GI group scored 38.71 (SD = 12.88), and the control group scored 36.44 (SD = 11.63). The IBFC group recorded the highest mean gain of 18.75 points, compared with 11.49 points for GI and 10.82 points for the control group. These results indicate that both IBFC and GI improved students' achievement in Basic Science relative to the conventional method, with IBFC producing the largest gain overall.

Ho1: There is no significant difference in the mean achievement scores of students taught Basic Science and Technology using inquiry-based flipped classroom, guided inquiry, and conventional teaching method.

Table 2: ANCOVA Analysis of Students' Achievement Based on Treatment

Tests of Between-Subjects Effects

Dependent Variable: posttestachievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7,250.567[a]	3	2,416.856	14.379	< .001	.123
Intercept	53,252.215	1	53,252.215	316.813	< .001	.506
Pretest achievement	0.930	1	0.930	0.006	.939	.000
Approach	4,637.657	2	2,318.829	13.796	< .001	.082
Error	51,556.460	309	166.850			
Total	760,101.000	313				
Corrected Total	58,807.027	312				

a. Model terms: (Constant), Pretest achievement, Approach. Corrected model df = 3 because the model includes one covariate and a three-level treatment factor (2 df).

The table 2 shows that, with pretest achievement controlled, instructional approach had a statistically significant effect on students' posttest achievement, $F(2, 309) = 13.796$, $p < .001$, partial $\eta^2 = .082$, a medium effect size. The overall model was also significant, $F(3, 309) = 14.379$, $p < .001$, whereas the pretest covariate was not, $F(1, 309) = 0.006$, $p = .939$. Since $p < .05$, Ho1 was rejected: the mean achievement scores of students taught with the inquiry-based flipped classroom, guided inquiry, and the conventional method differ significantly. The posttest means in Table 1 indicate the direction of the difference, with IBFC (M = 45.57) ahead of GI (M = 38.71) and the conventional method (M = 36.44). This ordering is descriptive, as the omnibus F-test does not identify which specific pairs of groups differ. The finding is consistent with earlier Nigerian studies that reported significant achievement gains under flipped classroom instruction (Konyeme & Alordiah, 2024; Inengite & Zipamone, 2024; Abbas & Idris, 2022). A plausible explanation is that moving content delivery to pre-class time leaves more class time for applying concepts and receiving immediate feedback (Sari et al., 2023).

Research Question 2: What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' self-concept in Basic Science and Technology?

Table 3: Mean and Standard Deviation Self-Concept Scores of Basic Science Students Based on Treatment

Treatment	**N**	**Pretest $\bar{X}$**	**Pretest SD**	**Posttest $\bar{X}$**	**Posttest SD**	**Mean Gain/Loss**
Inquiry-Based Flipped Classroom (IBFC)	105	47.80	13.16	59.95	7.52	12.15
Guided Inquiry (GI)	104	47.08	13.06	56.91	8.85	9.83
Conventional Teaching Method (control)	104	46.62	12.44	52.88	7.16	8.17

All three groups improved students' self-concept in Basic Science, as shown by higher posttest mean scores compared with pretest scores. Students in the Inquiry-Based Flipped Classroom

(IBFC) group increased from a mean of 47.80 to 59.95, a mean gain of 12.15; those in the Guided Inquiry (GI) group improved from 47.08 to 56.91, a mean gain of 9.83; and the Conventional Teaching Method group improved from 46.62 to 52.88, a mean gain of 8.17. IBFC had the greatest impact on students' self-concept, followed by GI, with the conventional method showing the smallest gain. The lower posttest standard deviation in IBFC (7.52) also suggests that self-concept scores were more consistent in that group.

Table 4: ANCOVA Analysis of Students' Self-Concept Based on Treatment

Tests of Between-Subjects Effects

Dependent Variable: posttestself-concept

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1,409.820[a]	3	469.940	5.538	.001	.051
Intercept	97,964.112	1	97,964.112	1,435.857	< .001	.823
Pretest self-concept	78.271	1	78.271	1.147	.285	.004
Approach	1,002.238	2	501.119	7.343	.001	.045
Error	20,413.079	309	66.062			
Total	1,363,501.000	313				
Corrected Total	21,822.899	312				

a. Model terms: (Constant), Pretest self-concept, Approach. Corrected model df = 3 because the model includes one covariate and a three-level treatment factor (2 df).

Table 4 shows that, after controlling for pretest self-concept, instructional approach had a statistically significant effect on students' posttest self-concept, $F(2, 309) = 7.343$, $p = .001$, partial $\eta^2 = .045$, a small-to-medium effect size. The overall model was significant, $F(3, 309) = 5.538$, $p = .001$, while the pretest covariate was not, $F(1, 309) = 1.147$, $p = .285$. Ho2 was therefore rejected. The posttest means in Table 3 show the same descriptive ordering as achievement, with IBFC (M = 59.95) above GI (M = 56.91) and the conventional method (M = 52.88); as before, the omnibus test does not identify which specific pairs of groups differ. The result agrees with studies linking guided inquiry to improved self-concept in science (Gathage et al., 2021; Anwo et al., 2025) and suggests that the successful, self-directed problem-solving experiences in inquiry-based lessons strengthen students' belief in their own ability in Basic Science and Technology.

Research Question 3: What is the effect of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' acquisition of science process skills in Basic Science and Technology?

Table 5: Mean and Standard Deviation Students' Acquisition of Science Process Skills Scores of Basic Science Students Based on Treatment

Treatment	N	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Gain/Loss
Inquiry-Based Flipped Classroom (IBFC)	105	29.72	6.64	43.82	10.28	14.04
Guided Inquiry (GI)	104	29.14	6.27	40.75	7.11	11.60
Conventional Teaching Method (control)	104	28.81	5.89	38.78	6.82	10.71

Table 5 shows that the pretest mean science process skills score for students taught using the inquiry-based flipped classroom was $\bar{X}$ = 29.72, SD = 6.64, for those taught using guided inquiry was $\bar{X}$ = 29.14, SD = 6.27, and for the conventional method group was $\bar{X}$ = 28.81, SD = 5.89. The three groups were closely comparable before treatment, indicating similar baseline science process skills. At posttest, the inquiry-based flipped classroom group scored $\bar{X}$ = 43.82, SD = 10.28 (mean gain of 14.04); the guided inquiry group scored $\bar{X}$ = 40.75, SD = 7.11 (mean gain of 11.60); and the conventional method group scored $\bar{X}$ = 38.78, SD = 6.82 (mean gain of 10.71).

Table 6: ANCOVA Analysis of Students' Acquisition of Science Process Skills Based on Treatment

Tests of Between-Subjects Effects

Dependent Variable: posttestprocess skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1,590.701[a]	3	530.234	6.580	< .001	.060
Intercept	34,774.833	1	34,774.833	431.825	< .001	.583
Pretest process skills	0.254	1	0.254	0.003	.955	.000
Approach	1,020.014	2	510.007	6.330	.002	.039
Error	24,887.816	309	80.543			
Total	798,828.000	313				
Corrected Total	26,478.517	312				

a. Model terms: (Constant), Pretest process skills, Approach. Corrected model df = 3 because the model includes one covariate and a three-level treatment factor (2 df).

Table 6 shows that the pretest science process skills covariate was not significant, F(1, 309) = 0.003, p = .955. After controlling for pretest scores, instructional approach had a statistically significant effect on posttest science process skills, F(2, 309) = 6.330, p = .002, partial η^2 = .039, a small-to-medium effect size. The overall model was also significant, F(3, 309) = 6.580, p < .001. Ho3 was therefore rejected. Table 5 shows the descriptive ordering of posttest means (IBFC, M = 43.82; GI, M = 40.75; conventional, M = 38.78), which, as with the other outcomes, cannot by itself indicate which specific pairs of groups differ. The finding is in line with earlier reports that inquiry-based flipped classroom and guided inquiry instruction promote science process skills (Tan et al., 2020; Supornpanitkul et al., 2025; Nworgu & Otum, 2013).

Summary of Major Findings

The following deductions were made after the interpretation and discussion of the results.

1. Instructional approach had a significant effect on students' achievement in Basic Science and Technology, F(2, 309) = 13.796, p < .001, partial η^2 = .082 (Ho1 rejected). The Inquiry-Based Flipped Classroom (IBFC) produced the largest mean gain (18.75 points), compared with 11.49 points for Guided Inquiry (GI) and 10.82 points for the Conventional Teaching Method.
2. Instructional approach had a significant effect on students' self-concept, F(2, 309) = 7.343, p = .001, partial η^2 = .045 (Ho2 rejected). IBFC produced the largest mean gain (12.15 points), compared with 9.83 points for GI and 8.17 points for the Conventional Teaching Method.
3. Instructional approach had a significant effect on students' acquisition of science process skills, F(2, 309) = 6.330, p = .002, partial η^2 = .039 (Ho3 rejected). IBFC showed the largest

mean gain (14.04 points), compared with 11.60 points for GI and 10.71 points for the Conventional Teaching Method.

Conclusion

This study examined the effects of inquiry-based flipped classroom, guided inquiry, and conventional teaching method on students' academic achievement, self-concept, and acquisition of science process skills. After controlling for pretest scores, ANCOVA showed a statistically significant effect of instructional approach on all three outcomes, and all three null hypotheses were rejected. Descriptively, both inquiry-based approaches, inquiry-based flipped classroom (IBFC) and guided inquiry (GI), produced greater gains than the conventional teaching method among Junior Secondary School II students in Basic Science and Technology, and the IBFC group consistently recorded the largest gains across all three outcomes (achievement gains of 18.75 versus 11.49 versus 10.82; self-concept gains of 12.15 versus 9.83 versus 8.17; science process skills gains of 14.04 versus 11.60 versus 10.71, for IBFC, GI, and the conventional method respectively). The three groups had comparable pretest means. Because the omnibus tests do not identify which pairs of groups differ, and pairwise comparisons of the adjusted means were not reported, the superiority of IBFC over GI should be interpreted with caution.in Basic Science and Technology. Although the three groups began from statistically comparable baselines, the IBFC group consistently recorded the largest gains across all three outcomes (achievement gains of 18.75 versus 11.49 versus 10.82; self-concept gains of 12.15 versus 9.83 versus 8.17; science process skills gains of 14.04 versus 11.60 versus 10.71, for IBFC, GI, and the conventional method respectively). Confirmation of the statistical significance of these differences awaits the authors' re-run ANCOVA using Approach as a three-level factor, as described above.

These results will contribute to the existing literature in three concrete ways. First, the study is, to the authors' knowledge, among the first in Nasarawa State to examine IBFC and GI simultaneously, against a conventional baseline, on the same cohort across three complementary outcomes, whereas earlier studies assessed guided inquiry alone on single measures (Nworgu & Otum, 2013; Shemang, 2025), and prior flipped-classroom studies (Konyeme & Alordiah, 2024; Inengite & Zipamone, 2024) did not compare the two active approaches head-to-head. Second, by contrasting two active pedagogies against a conventional baseline rather than a single active-versus-lecture design, the study addresses a more practically useful question for teachers already committed to inquiry. Third, the evidence is situated in Nasarawa State JSS II Basic Science and Technology, an under-studied setting, and therefore speaks directly to the 2025 NERDC curriculum's explicit call for inquiry-based, technology-integrated instruction.

Recommendations

Based on the objectives and findings from the study, the following recommendations are made.

i. Science teachers should actively adopt inquiry-based instructional strategies, especially the Inquiry-Based Flipped Classroom and Guided Inquiry approaches, because the ANCOVA results show significant treatment effects on achievement, self-concept, and science process skills.
ii. Teachers should integrate technology thoughtfully in flipped classroom models, deliberately develop science process skills, promote collaborative learning, and ensure gender-sensitive implementation to create inclusive and engaging learning environments.
iii. School Administrators should provide necessary infrastructure, well-equipped laboratories, reliable technology (computers, internet, projectors), and organize regular professional development programs for teachers on these innovative approaches.

iv. Educational Policymakers should revise the Basic Science and Technology curriculum, teacher education programs, and assessment policies to prioritize inquiry-based learning, science process skills, and technology integration.
v. Teacher Education Institutions should adequately equip pre-service teachers with practical skills in inquiry-based flipped classroom and guided inquiry methods.
vi. Students should actively and collaboratively engage in inquiry activities and develop necessary digital literacy skills to maximize the benefits of these approaches.
vii. Parents and Communities should support these innovative practices by providing enabling home environments for learning and advocating for better educational resources in schools.

References

Abbas, M., & Idris, A. (2022). Flipped classroom learning and academic achievement in genetics concepts among secondary school students in Gusau, Zamfara State, Nigeria. *FNAS Journal of Mathematics and Science Education*.

Adonu, C. J., Nwagbo, C. R., Ugwuanyi, C. S., & Okeke, I. O. (2021). Improving students' achievement and retention in biology using flipped classroom and PowerPoint instructional approaches: implication for physics teaching. *International Journal of Psychosocial Rehabilitation*, 25(2), 234-247.

Ajala, O. O. (2025). Effect of flipped classroom instructional strategy on secondary school students' academic achievement and retention in chemistry in Osun state, Nigeria. *International Journal of Contemporary Issues in Integrated Science,* 1(1), 294-303.

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. Computers & education, 126, 334-345.

Alsancak Sirakaya, D., & Ozdemir, S. (2018). The effect of a flipped classroom model on academic achievement, self-directed learning readiness, motivation and retention. *Malaysian Online Journal of Educational Technology,* 6(1), 76-91.

Anwo, A. O., Gana, C. S., Hassan, A. A., Moses, A. S., Bashir, A. U., & Muhammad, M. K. (2025). Enhancing secondary school students' self-concept through Vee-diagram and guided-inquiry strategies. Physics Education, 60(5), 055031.

Bruner, J. S. (1996). The culture of education. Harvard University Press.

Eggon, A. P., & Agu, P. A. (2020). Effect of Peer Collaboration Learning Strategy on Basic Science and Technology Students' Achievement in Nasarawa State, Nigeria. *International Journal of Scientific Advances,* 1(3).

Fitriyana, S., Farhan, A., Susanna, S., Hamid, A., & Mahzum, E. (2025). The effect of guided inquiry learning model on students' science process skills and learning outcomes in physics science lessons. Jurnal Pendidikan Fisika, 13(3), 555-571.

Gathage, J., Embeywa, H., & Koech, P. (2021). The effect of inquiry-based science teaching approach on self-concept of secondary school physics students in Kitui county, KENYA.

Hyypiä, M., Sointu, E., Hirsto, L., & Valtonen, T. (2019). Key components of learning environments in creating a positive flipped classroom course experience. *International Journal of Learning, Teaching and Educational Research,* 18(13), 61-86.

Ige, A. M., Abanum, C. I., Odekeye, O., Akintula, O. E., Onowugbeda, F. U., & Mustapha, A. G. (2025). Beyond the classroom walls: assessing the contrasting difference between flipped learning and traditional based instruction in biology education. *Open Journal of Educational Development* (ISSN: 2734-2050), 6(1), 43-53.

Inengite, I., & Zipamone, A. T. (2024). Effect of flipped classroom instructional model on students' achievement in biology among secondary schools in Bayelsa State. *Scholarly Journal of Science and Technology Research and Development,* 3(5), 1-12.

Jose, M. A. (2026). Flipped Inquiry-Based Learning in Science.

Kapon, S., & Schvartzer, M. (2024). Guided inquiry into a physics equation. Cognition and Instruction, 42(1), 159-206.

Ketelhut, D. J. (2007). The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in River City, a multi-user virtual environment. *Journal of science education and technology,* 16(1), 99-111.

Konyeme, J. E., & Alordiah, C. O. (2024). Effect of flipped classroom strategy on secondary school student academic achievement in biology in Delta State. Studies in Education.

Lotter, L., & Ramnarain, U. (2025). An exploratory study on the use of a flipped classroom model for supporting inquiry-based learning in natural sciences classrooms. *African journal of research in mathematics, science and technology education,* 29(1), 99-112.

Milman, N. B. (2012). The flipped classroom strategy: What is it and how can it best be used?. Distance learning, 9(3), 85-87.

Nigerian Educational Research and Development Council. (2025). National senior secondary education curriculum. NERDC Press.

Nisa, L. C. (2026). Active Learning Strategies in Higher Education Biology: A Literature Review of Inquiry-Based Learning, Problem-Based Learning, and Flipped Classroom Approaches. *International Journal of Sustainable Social Culture, Science Technology, Management, and Law Humanities*, 3(1), 43-48.

Nworgu, L. N., & Otum, V. V. (2013). Effect of guided inquiry with analogy instructional strategy on students' acquisition of science process skills. *Journal of Education and Practice*, 4(27), 35-40.

Ogunjimi, M. O., & Gbadeyanka, T. A. (2023). Effect of guided inquiry and explicit-instructional strategies on lower basic students' academic performance in mathematics. *Indonesian Journal of Teaching in Science,* 3(1), 23-32.

Ogunode, N. J. (2020). Challenges facing implementation of science program in FCT secondary schools, Abuja, Nigeria. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3703501

Olamoyegun, S. O., Okolo, M. M., & Ogunode, N. J. (2023). Motivation, teachers' job performance and students' academic performance in post-basic education and career development (PBECD), Nigeria. *International Journal on Integrated Education*, 6(7), 1-10.

Olatoye, R. A. (2025, February 25). Science education in Nigeria: The emergence, challenges and prospects [Inaugural lecture]. Obafemi Awolowo University.

Piaget, J. (1970). Genetic epistemology. Columbia University Press.

Sari, F. D., Subagiyo, L., & Syam, M. (2023). The effect of guided inquiry learning model with flipped classroom method toward critical thinking. Jurnal Penelitian Pendidikan IPA, 9(1), 57-65.

Shemang, L. (2025). Effects of mastery learning strategy on performance in wave concept among senior school physics students in Kafanchan education zone, Kaduna. *CUSTECH International Journal of Education,* 2(1), 270-282.

Supornpanitkul, Y., Poonputta, A., & Prasitnok, O. (2025). Development of Science Process Skills and Learning Achievement Using Flipped Classroom Learning Management through Inquiry-Based Learning for Grade 8 Students. *Journal of Education in Science, Environment and Health*, 11(1), 74-81.

Tan, R. M., Yangco, R. T., & Que, E. N. (2020). Students' Conceptual Understanding and Science Process Skills in an Inquiry-Based Flipped Classroom Environment. *Malaysian Journal of Learning and Instruction,* 17(1), 159-184.

Treesun. (2025, September 3). New curriculum: JSS, SS subjects (Full list) [Forum post]. Nairaland.

Uy Jr, R. F., & Azuelo, A. G. (2022). Students' academic self-concept in earth science through online process oriented guided inquiry learning approach. *International Journal of Applied Science and Research*, 6(01), 73-79.

von Glasersfeld, E. (1995). Radical constructivism: A way of knowing and learning. Falmer Press.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.
Wertsch, J. V. (1985). Vygotsky and the social formation of mind. Harvard University Press.