Journal of Studies in Science and Mathematics Education
ISSN: 2630-662x
Published: 10.08.2026
Volume (issue): 6(1)
Page: 148–157

Effect of Flipped-Classroom Strategy on Senior Secondary School Students' Attitude towards Inorganic Chemistry in Makurdi Metropolis, Benue State, Nigeria

Onehi Akpe Onehi*, Ramatu Ematum Umahaba, and Samson Joseph

Department of Science Education, Ahmadu Bello University, Zaria, Kaduna State, Nigeria

***Corresponding Author:** onehiakpe@gmail.com

Abstract

Students' attitude towards Chemistry influence their engagement and learning outcomes; however, evidence regarding the effectiveness of the flipped-classroom strategy in improving attitude remains limited in Nigerian secondary schools. This study examined the effect of the flipped-classroom strategy on students' attitude towards Inorganic Chemistry and investigated gender differences in students' attitude under the strategy. A quasi-experimental pretest-posttest non-equivalent control group design was adopted. The population comprised 1,754 SS II Chemistry students, from which 116 students (66 males and 50 females) were selected from two purposively chosen schools. Data were collected using the Students' Attitude to Inorganic Chemistry Questionnaire, validated by experts and found reliable using Cronbach's alpha ($\alpha = .813$). Mean and standard deviation answered the research questions, while ANCOVA and an independent-samples *t*-test tested the hypotheses at $\alpha = .05$. After controlling for pretest attitude scores, the flipped-classroom strategy had no statistically significant effect on students' attitude, $F(1, 113) = 3.61$, $p = .060$, partial $\eta^2 = .031$, and no significant gender difference was observed, $t(60) = -1.07$, $p = .286$. The findings suggest that a longer period of implementation and improved access to digital learning resources may enhance the strategy's potential to improve students' attitude towards Inorganic Chemistry.

Keywords: flipped-classroom strategy, attitude, inorganic chemistry, gender, senior secondary school students

1 Introduction

Science education plays a fundamental role in preparing individuals with the knowledge, skills, and dispositions required to address societal challenges and contribute to national development (Nja et al., 2022a). Within science education, Chemistry occupies a central position because it provides the conceptual foundation for understanding the composition, properties, and transformations of matter and underpins learning across many scientific disciplines (Mahaffy et al., 2019). Beyond cognitive achievement, however, students' attitude towards Chemistry are equally important because they influence learners' interest, motivation, classroom participation, persistence, and willingness to pursue science-related careers (Flaherty, 2020). Consequently, improving students' attitudes towards Chemistry has become an important objective of contemporary science education. Attitude is generally regarded as a learned predisposition to respond favourably or unfavourably towards an object, idea, person, or situation (Ajzen, 2020). In educational settings, students' attitude influence how they perceive learning experiences, engage with instructional activities, and respond to academic challenges. Positive attitude towards Chemistry have been associated with increased motivation, confidence, persistence, and improved academic outcomes, whereas negative attitude often manifest as anxiety, avoidance of learning tasks, low participation, and declining interest in science-related studies (Pongsophon, 2024). Consequently, promoting positive attitude has become an important goal of Chemistry instruction alongside improving academic performance.

Positive attitude are increasingly recognised as essential for developing scientifically literate citizens who are capable of applying scientific knowledge to solve real-life problems and make informed decisions on issues relating to health, industry, and the environment. Contemporary science education therefore places equal emphasis on cognitive achievement and affective outcomes because both influence students' long-term engagement with science learning and their readiness to participate in an increasingly knowledge-driven society (OECD, 2023; UNESCO, 2021). Despite the recognised importance of Chemistry, many secondary school students continue to experience difficulties in developing positive attitude towards the subject. Inorganic Chemistry, in particular, presents concepts that students frequently perceive as abstract, resulting in reduced engagement and diminished confidence during classroom instruction. Previous studies have associated

this negative attitude with low motivation, limited classroom participation, and poor learning outcomes (Tan et al., 2025; Olatunji & Akinsulire, 2022). Such attitude not only affect immediate classroom learning but may also discourage students from pursuing further studies and careers in science, technology, engineering, and mathematics (STEM).

This situation has become a major concern because secondary school science education provides the foundation for developing the scientific and technological workforce required for national development. Students who develop unfavourable attitude towards Chemistry are less likely to participate actively in science learning, enrol in science-related programmes, or pursue careers in STEM disciplines, thereby limiting the availability of skilled human resources required to drive innovation and sustainable development (UNESCO, 2021; Bybee, 2013). Identifying instructional approaches capable of promoting positive attitude towards Chemistry is therefore essential for improving both educational outcomes and future workforce development. One factor frequently associated with students' negative attitude is the continued reliance on conventional teacher-centred instructional approaches. Although the conventional method enables teachers to cover prescribed content within limited instructional time, it often provides few opportunities for active participation, collaborative learning, self-directed inquiry, or meaningful interaction with instructional materials. Consequently, students frequently assume passive roles during lessons, reducing opportunities for conceptual engagement and sustained interest in Chemistry (Onyi et al., 2022). These limitations have intensified calls for learner-centred instructional approaches capable of improving both cognitive and affective learning outcomes.

Among the innovative instructional approaches receiving increasing attention is the flipped-classroom strategy (FCS). In this instructional model, students study lesson materials before classroom instruction through teacher-prepared videos or other learning resources, while classroom time is devoted to discussion, collaborative learning, problem-solving, and clarification of misconceptions (Bergmann & Sams, 2012). By transferring direct instruction outside the classroom and allowing students to engage actively during face-to-face sessions, the FCS has the potential to improve learning experiences, strengthen students' confidence, and promote more favourable attitude towards Chemistry. Recent studies have similarly reported that learner-centred instructional approaches characterised by active participation, peer collaboration, and technology-supported learning can improve students' engagement, learning satisfaction, and attitude towards science learning (Kefalis et al., 2025; Liday, 2025). Although the flipped-classroom strategy has attracted considerable research attention, existing evidence regarding its influence on students' attitude remains inconclusive. While several studies have reported positive effects of the strategy on students' attitude towards science learning, others have found little or no statistically significant improvement, suggesting that contextual factors such as educational level, subject matter, duration of implementation, technological access, and classroom environment may influence its effectiveness. In addition, the mixed findings reported in previous studies suggest that the effectiveness of the flipped-classroom strategy is context-dependent and may vary according to subject content, classroom implementation, students' technological readiness, teacher competence, and institutional support (Nja et al., 2022b; Lo & Hew, 2017). These variations make it difficult to generalise findings across different educational settings without further empirical investigation. Furthermore, much of the available Nigerian evidence has concentrated on students' academic performance, with comparatively fewer studies examining attitudinal outcomes, particularly in Inorganic Chemistry at the senior secondary school level. Evidence from Benue State remains especially limited, and studies investigating whether male and female students respond differently to the flipped-classroom strategy are equally scarce. Consequently, there remains a need for context-specific evidence on the effectiveness of the flipped-classroom strategy in improving students' attitude towards Inorganic Chemistry among Nigerian secondary school students, particularly in public schools where instructional conditions and access to learning technologies may differ considerably from those reported in previous studies.

Against this background, the present study examined the effect of the flipped-classroom strategy on senior secondary school students' attitude towards Inorganic Chemistry in Makurdi Metropolis, Benue State, Nigeria. Specifically, the study investigated whether students taught using the flipped-classroom strategy differed in attitude from those taught using the conventional method and whether attitude differed between male and female students exposed to the strategy. By addressing these issues, the study contributes additional evidence to the growing body of literature on technology-supported instructional strategies in Chemistry education and provides information that may guide teachers, curriculum planners, and educational policymakers in selecting instructional approaches capable of fostering more positive attitude towards Chemistry.

The study was guided by the following research questions:

1. What is the difference between the mean attitude scores of students taught Inorganic Chemistry using the flipped-classroom strategy and those taught using the conventional method?
2. What is the difference between the mean attitude scores of male and female students taught Inorganic Chemistry using the flipped-classroom strategy?

2 Literature Review/Theoretical Framework

The flipped-classroom strategy is grounded in constructivist and multimedia learning perspectives, which emphasise active knowledge construction, meaningful learner engagement, and the effective use of instructional resources to facilitate learning. This study is underpinned by Vygotsky's Social Constructivist Theory (Vygotsky, 1978) and Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2009). Vygotsky argued that learning occurs through social interaction, collaboration, and teacher guidance within the learner's Zone of Proximal Development, where learners acquire new knowledge and skills through interaction with more knowledgeable others. The theory views learning as an active and socially mediated process rather than the passive reception of information. Similarly, Mayer proposed that meaningful learning occurs when learners actively process information presented through appropriately integrated verbal and visual representations. According to the theory, multimedia instruction enhances learning by enabling learners to select relevant information, organise it into coherent mental representations, and integrate it with their existing knowledge. Within a flipped classroom, students first engage independently with multimedia instructional materials before participating in collaborative classroom activities where concepts are reinforced through discussion, problem-solving, and teacher facilitation. Consequently, both theories provide a strong conceptual explanation for how the flipped-classroom strategy may improve students' attitude towards Inorganic Chemistry by encouraging active participation, self-directed learning, collaborative knowledge construction, and greater confidence during classroom learning.

Empirical evidence generally supports the use of learner-centred instructional approaches for improving students' engagement and attitude towards science learning. Studies conducted in Nigeria and other educational contexts have shown that flipped-classroom instruction promotes greater classroom participation, learner autonomy, confidence, and positive attitude than conventional teacher-centred instruction (Nja et al., 2022b; Sağlam & Arslan, 2018). However, the reported benefits of the strategy have not been consistent across studies. While Nja et al. (2022b) and Sağlam and Arslan (2018) found statistically significant improvements in students' attitude following flipped-classroom instruction, Lo and Hew (2017), in their critical review of K–12 flipped-classroom implementation, argued that the effectiveness of the strategy depends largely on factors such as instructional design, students' preparedness, teacher competence, and the availability of technological support. These contrasting findings suggest that the positive influence of the flipped-classroom strategy is not universal but is shaped by contextual conditions under which the intervention is implemented. Variations in educational level, subject matter, duration of implementation, access to digital learning resources, and the quality of classroom facilitation may explain why some studies report substantial improvements in students' attitude whereas others observe only modest or non-significant effects. Consequently, further context-specific evidence remains necessary, particularly within Nigerian secondary schools where instructional environments and technological resources differ considerably across settings.

Another area of inconsistency in the literature concerns whether gender influences students' attitude under the flipped-classroom strategy. Evidence remains mixed. Abubakar (2024) found no significant gender difference in the attitude of undergraduate Biology Education students, suggesting that learner-centred instructional approaches provide comparable learning opportunities for both male and female students. In contrast, Almasri et al. (2021) reported gender-related differences in students' attitude within collaborative learning environments, indicating that classroom interaction patterns, group composition, and instructional design may influence attitudinal outcomes. These conflicting findings may also reflect differences in educational level, subject discipline, participant characteristics, and learning context. Consequently, it remains uncertain whether gender influences students' attitude towards Inorganic Chemistry among Nigerian secondary school students exposed to the flipped-classroom strategy, thereby providing further justification for the present study.

3 Materials and Methods

3.1 Research Design

This study adopted a quasi-experimental pretest–posttest non-equivalent control group design. The design was considered appropriate because intact classes were used and random assignment of students to experimental and control groups was not feasible within the participating schools. The study was conducted in Makurdi Metropolis, Benue State, Nigeria, among Senior Secondary School (SS II) Chemistry students. The experimental group was taught selected Inorganic Chemistry concepts for the term using the flipped-classroom strategy, while the control group received instruction through the conventional teacher-centred method. Students' attitude towards Inorganic Chemistry were measured before and after the intervention to determine the effect of the instructional strategy.

3.2 Sampling Procedure

The population for the study comprised 1,754 SS II Chemistry students enrolled in the nine public secondary schools offering Chemistry in Makurdi Metropolis during the 2025/2026 academic session. A sample of 116 students (66 males and 50 females) was selected using a multistage sampling procedure. In the first stage, purposive sampling was used to identify schools that met the requirements for implementing the flipped-classroom strategy. The inclusion criteria were the availability of qualified Chemistry teachers, functional computer facilities, prior exposure of teachers and students to information and communication technology (ICT), a mixed-gender student population, and a consistent record of presenting candidates for the Senior Secondary Certificate Examination (SSCE). Four schools satisfied these criteria. In the second stage, simple random sampling was used to select two schools from the four eligible schools. The selected schools, designated as School A and School B, served as the experimental and control group, respectively. One intact SS II Chemistry class was selected from each school, giving 62 students in the experimental group and 54 students in the control group. Because intact classes were used, individual students were not randomly assigned to treatment conditions, consistent with the quasi-experimental design. To minimise the influence of pre-existing differences between the groups, pretest attitude scores were statistically controlled during data analysis using Analysis of Covariance (ANCOVA).

3.3 Research Instrument

Data were collected using the Students' Attitude to Inorganic Chemistry Questionnaire (SAICQ). The instrument was adapted from the Chemistry attitude questionnaire by George and Osuafor (2023) and modified to suit the selected Inorganic Chemistry concepts taught in the study. The questionnaire consisted of 30 items measured on a four-point Likert response scale comprising Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). Higher scores indicated more positive attitude towards Inorganic Chemistry. The items assessed students' attitude towards learning Inorganic Chemistry within the context of the flipped-classroom instructional strategy.

3.4 Validity and Reliability

The SAICQ was subjected to face and content validation by two experts from Ahmadu Bello University, Zaria: one from the Department of Curriculum Foundations and the other from the Department of Psychology and Counselling. The validators assessed the questionnaire for clarity, relevance, appropriateness, and adequacy of coverage of the constructs measured in relation to the objectives of the study. Their comments and recommendations were used to revise the instrument before its final administration. The reliability of the SAICQ was established through a pilot testing conducted using one intact SS II Chemistry class comprising 49 students from Government Secondary School, North Bank, Makurdi, a school that was not included in the main study but possessed characteristics similar to those of the participating schools. Responses obtained from the pilot administration were analysed using Cronbach's alpha to determine the internal consistency of the questionnaire. The analysis yielded a reliability coefficient of $\alpha = .813$**.** According to George and Mallery (2024), a Cronbach's alpha coefficient of 0.70 or higher is considered acceptable, indicating adequate internal consistency. Therefore, the obtained reliability coefficient demonstrated that the SAICQ possessed satisfactory internal consistency and was considered reliable for data collection in the study.

3.5 Procedure for Data Collection

Prior to the commencement of the study, the researcher visited the participating schools with an introductory letter from the Department of Science Education, Ahmadu Bello University, Zaria, to obtain permission from the school authorities and explain the purpose and procedures of the study. Before the commencement of instruction, the SAICQ was administered as a pretest to both the experimental and control groups under standardised conditions to determine students' initial attitude towards Inorganic Chemistry. During the intervention, the Chemistry teacher in the experimental school assisted with classroom coordination, the administration of the research instrument, and the distribution of the instructional materials to students before each lesson. The Chemistry teacher in the control school similarly assisted with classroom coordination and the administration of the research instrument to ensure uniformity in the data collection process.

The intervention lasted six weeks, during which six Inorganic Chemistry concepts prescribed in the SS II Chemistry scheme of work for the term in which the study was conducted; Water, Air, Hydrogen, Oxygen, Nitrogen, and Halogens were taught. Before the commencement of instruction, the SAICQ was administered as a pretest to both the experimental and control groups under standardised conditions to establish their initial attitude towards Inorganic Chemistry. Students in the experimental group received researcher-developed instructional videos and supporting learning materials before each classroom lesson and were expected to engage with these materials independently before attending class. Classroom sessions were subsequently devoted to discussion, clarification of misconceptions, collaborative problem-solving, teacher guidance, and reinforcement activities. Students in the control group were taught the same content over the same period using the conventional method, where classroom instruction consisted primarily of teacher explanations, demonstrations, note-taking, and question-and-answer sessions.

To ensure fidelity of implementation, the researcher monitored the instructional process throughout the intervention. Lesson plans and instructional materials were standardized for each lesson, while the classroom teacher adhered to the prescribed instructional procedures. The researcher observed the implementation periodically to confirm that pre-class instructional videos were distributed before each lesson and that classroom activities followed the planned flipped-classroom sequence of discussion, collaborative problem-solving, clarification of misconceptions, and teacher facilitation. The control group was similarly monitored to ensure that instruction remained consistent with the conventional teacher-centred approach throughout the intervention. At the end of the six-week intervention, SAICQ was re-administered as a posttest to both the experimental and control group under conditions similar to those of the pretest to assess changes in students' attitude towards Inorganic Chemistry. The complete questionnaires were collected immediately after administration for coding and statistical analysis.

3.6 Ethical Considerations

An introductory letter was obtained from the Department of Science Education, Ahmadu Bello University, Zaria, and presented to the authorities of the participating schools. Approval to conduct the study was granted by the respective school authorities before data collection commenced. Participation in the study was voluntary, and students were informed that the information collected would be used solely for research purposes. Confidentiality and anonymity were maintained throughout the study, and no identifying information was included in the analysis or reporting of the findings.

3.7 Data Analysis

Data were analysed using IBM SPSS Statistics version 24. Prior to inferential analysis, the assumptions of normality and homogeneity of variance were assessed and found to be satisfactorily met. Mean and standard deviation were used to answer the research questions. Analysis of Covariance (ANCOVA) was employed to determine the effect of the flipped-classroom strategy on students' attitude towards Inorganic Chemistry while controlling for differences in pretest attitude scores, whereas the hypothesis on gender difference in attitude among students exposed to the flipped-classroom strategy was tested using an independent-samples *t*-test, with significance determined at the 0.05 level.

4 Results

The findings are presented according to the research questions and corresponding hypothesis.

Research Question One: What is the difference between the attitude level of students taught Inorganic Chemistry using the flipped-classroom strategy and those taught using the conventional method?

Table 1

Mean and standard deviation of pretest and posttest attitude scores of students taught Inorganic Chemistry using the flipped-classroom strategy and the conventional method.

		Pretest		Posttest		
Groups	**N**	**M**	**SD**	**M**	**SD**	**MD**
Experimental	62	93.90	7.18	98.53	7.94	2.29
Control	54	94.94	8.50	96.24	8.19	

Hypothesis One

There is no significant difference between the attitude level of students taught Inorganic Chemistry using the flipped-classroom strategy and those taught using the conventional method.

Table 2

Analysis of Covariance (ANCOVA) of Posttest Attitude Scores of Students Taught Inorganic Chemistry Using the Flipped-Classroom strategy and Conventional Method.

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	**Partial Eta Squared**
Corrected Model	1101.951[a]	2	550.975	9.660	<.001	.146
Intercept	3039.279	1	3039.279	53.288	<.001	.320
Pre_Attitude	950.394	1	950.394	16.663	<.001	.129
Group	205.731	1	205.731	3.607	.060	.031
Error	6444.911	113	57.035			
Total	1109492.000	116				
Corrected Total	7546.862	115				

An analysis of covariance (ANCOVA) was conducted to determine the effect of instructional strategy on students' posttest attitude scores after controlling for pretest attitude. There was no statistically significant effect of instructional group on posttest attitude, $F(1, 113) = 3.61$, $p = .060$, partial $\eta^2 = .031$**.** The adjusted mean difference between the instructional groups was 2.676, 95% CI [-1.115, 5.47]), which included zero, consistent with the nonsignificant result. Pretest attitude was a significant covariate, $F(1, 113) = 16.66$, $p < .001$, partial $\eta^2 = .129$.

Research Question Two: What is the difference between the attitude levels of male and female students taught Inorganic Chemistry using the flipped-classroom strategy?

Table 3

Mean and standard deviation of attitude scores of male and female students taught using the flipped-classroom strategy.

Gender	**N**	**Mean**	**SD**	**MD**
Male	41	97.76	7.58	2.29
Female	21	100.05	8.58	

Hypothesis Two

There is no significant difference between the attitude level of male and female students taught Inorganic Chemistry using the flipped-classroom strategy.

Table 4

Independent-samples t-test comparing posttest attitude scores of male and female students taught using the flipped-classroom strategy.

Groups	N	Mean	SD	df	t-value	p-value	Remark
Male	41	97.76	7.58	60	-1.07	0.286	Not Significant
Female	21	100.05	8.58				

An independent-samples t-test showed that there was no statistically significant difference in posttest attitude scores between male and female students taught using the flipped-classroom strategy, $t(60) = -1.07$, $p = .286$, 95% CI [-6.546, 1.962]. Because the confidence interval includes zero, the observed mean difference was not statistically significant.

5 Discussion

This study investigated the effect of the flipped-classroom strategy on students' attitude towards Inorganic Chemistry and examined whether gender influenced students' attitude under the instructional approach. The findings revealed that the flipped-classroom strategy did not produce a statistically significant improvement in students' attitude towards Inorganic Chemistry. Although students taught using the flipped-classroom strategy demonstrated a slightly higher posttest mean attitude score than those taught using the conventional method, the observed difference was not statistically significant. The findings was further supported by the confidence interval for the adjusted mean difference (95% CI [-1.115, 5.467]), which included zero, indicating that the observed difference between the experimental and control groups could reasonably be attributed to sampling variability rather than a true effect of the instructional strategy. This finding supports earlier observations in the literature that the effect of the flipped-classroom strategy on students' attitude is not always consistent across learning contexts. While Nja et al. (2022b) reported a significant improvement in students' attitude towards Chemistry following flipped-classroom instruction, the present study did not find a statistically significant improvement. Similarly, Sağlam and Arslan (2018) found that students exposed to the flipped-classroom model developed more favourable attitude than those taught using conventional instruction. The difference between these studies and the present finding may be associated with contextual factors such as the duration of implementation, students' familiarity with learner-centred instruction, access to technology, the quality of classroom facilitation, and the level of engagement with pre-class learning materials. As observed by Lo and Hew (2017), the successful implementation of the flipped-classroom strategy depends not only on the instructional model itself but also on learners' preparedness, teachers' pedagogical competence, and the availability of appropriate technological support. These factors may explain why the positive attitudinal outcomes reported in some studies were not replicated in the present study.

The finding is consistent with the assumptions of Vygotsky's Social Constructivist Theory, which emphasises that learning develops through continuous interaction, collaboration, and teacher guidance. Likewise, Mayer's Cognitive Theory of Multimedia Learning explains that multimedia instructional materials enhance meaningful learning by promoting active cognitive processing. However, improvements in cognitive engagement may not immediately translate into changes in students' attitude, particularly where the instructional strategy is implemented over a relatively short period. Attitude are developed gradually through repeated learning experiences and sustained positive interactions with instructional activities. Consequently, a six-week intervention may have been sufficient to familiarise students with the instructional approach but insufficient to produce measurable changes in their affective dispositions towards Inorganic Chemistry. This suggests that longer exposure to the flipped-classroom strategy may be necessary for substantial attitudinal changes to occur.

The absence of a statistically significant improvement should therefore not be interpreted as evidence that the flipped-classroom strategy is ineffective in promoting positive attitude. Rather, it suggests that changes in students' affective dispositions are likely to occur progressively as learners become more familiar with independent learning, collaborative classroom activities, and the effective use of multimedia instructional resources. This interpretation reinforces the view that instructional innovations often require sustained implementation before their full educational benefits become evident.

From a practical perspective, the finding suggests that Chemistry teachers should regard the flipped-classroom strategy as a long-term instructional approach rather than expecting immediate improvements in students' attitude. Consistent implementation, coupled with meaningful classroom interaction, effective teacher facilitation, and active engagement with pre-class learning materials, may be required to realise its full affective benefits. Educational administrators and curriculum planners should also support the effective implementation of flipped-classroom instruction by providing adequate technological infrastructure, teacher professional development, and access to quality digital learning resources capable of enhancing students' learning experiences.

The study further revealed that there was no significant difference between the attitude of male and female students taught using the flipped-classroom strategy. This finding agrees with Abubakar (2024), who similarly found no significant gender difference in students' attitude under a flipped learning approach. However, it differs from Almasri et al. (2021), who reported gender-related variations in students' attitude within collaborative learning environments. The difference between the studies may be attributed to variations in instructional design, learning environment, participant characteristics, and the nature of classroom implementation. It is also possible that the collaborative and learner-centred nature of the flipped-classroom strategy provides relatively equal opportunities for both male and female students to participate actively in learning activities, thereby minimising gender-related differences in attitude. The absence of a statistically significant gender difference was further supported by the 95% confidence interval for the mean difference, which included zero, indicating that any observed difference between male and female students could reasonably be attributed to sampling variability rather than a true difference in attitude. The present finding therefore suggests that the flipped-classroom strategy provides comparable opportunities for both male and female students to develop positive attitude towards Inorganic Chemistry. The six-week duration of the intervention and the inclusion of only two public secondary schools in Makurdi Metropolis may have limited the extent to which changes in students' attitude could be observed and may also restrict the generalisability of the findings. Furthermore, variations in students' access to digital learning resources outside the school environment may have influenced their level of engagement with the pre-class instructional materials, thereby affecting the magnitude of the attitudinal changes observed. Future studies should investigate the effect of the flipped-classroom strategy over longer intervention periods and across a larger number of schools. Further research may also examine how students' access to digital resources, teacher preparedness, and students' level of engagement with pre-class learning materials influence attitude towards Inorganic Chemistry.

6 Conclusion

This study investigated the effect of the flipped-classroom strategy on students' attitude towards Inorganic Chemistry and examined whether gender influenced students' attitude under the instructional approach. The findings showed that the flipped-classroom strategy did not produce a statistically significant improvement in students' attitude towards Inorganic Chemistry when compared with the conventional teaching method. Similarly, no significant difference was found between the attitude of male and female students taught using the flipped-classroom strategy. These findings indicate that, within the context of the present study, the strategy provided comparable attitudinal experiences for both genders but did not produce measurable improvements in students' attitude during the six-week intervention period. The study contributes to the growing body of evidence suggesting that the effect of the flipped-classroom strategy on students' attitude is context-dependent and may vary according to the duration of implementation, instructional environment, and students' engagement with pre-class learning activities. The findings also support the view that the strategy can be implemented without disadvantaging either male or female students. Future studies should examine the long-term implementation of the flipped-classroom strategy across a wider range of schools to determine whether sustained exposure produces greater improvements in students' attitude towards Inorganic Chemistry.

7 Declarations

Ethical statements: An introductory letter was obtained from the Department of Science Education, Ahmadu Bello University, Zaria, and presented to the authorities of the participating secondary schools. Permission to conduct the study was granted by the respective school authorities before data collection commenced. Participation in the study was voluntary, and the students were informed of the purpose of the research. Responses were treated confidentially, used solely for research purposes, and reported anonymously to protect participants' identities.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: O. A. Onehi: Conceptualization, methodology, study design, formal analysis, data curation, and writing of the original draft. R. E. Umahaba: Conceptualization, methodology, theoretical framework development, manuscript review, supervision and editing. S. Joseph: Conceptualization, manuscript review, and editing.

Funding: This research received no external funding.

Acknowledgments: The authors appreciate the management, principals, Chemistry teachers, and students of the participating secondary schools in Makurdi Metropolis for granting permission and providing the necessary cooperation during data collection. The authors also acknowledge the Department of Science Education, Ahmadu Bello University, Zaria, for providing the introductory letter that facilitated access to the participating schools.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

8 Reference

Abubakar, S. A. (2024). Impact of cooperative, flipped digitalized classroom on the attitude of male and female undergraduate biology education students. *Ilorin Journal of Education*, *44*(1), 13-20.

Ajzen, I. (2020). The theory of planned behavior: Frequently asked questions. *Human Behavior and Emerging Technologies, 2*(4), 314–324. https://doi.org/10.1002/hbe2.195

Almasri, F., Hewapathirana, G. I., Ghaddar, F., Lee, N., & Ibrahim, B. (2021). Measuring attitudes towards biology major and non-major: Effect of students' gender, group composition, and learning environment. *PLOS ONE, 16*(5), Article e0251453. https://doi.org/10.1371/journal.pone.0251453

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA Press.

Flaherty, A. A. (2020). A review of affective chemistry education research and its implications for future research. *Chemistry Education Research and Practice*, *21*(3), 698-713.

George, D., & Mallery, P. (2024). *IBM SPSS Statistics 29 step by step*: *A simple guide and reference* (18th ed.). Routledge.

George, P. C., & Osuafor, A. M. (2023). Effect of flipped classroom instruction via Google Classroom on secondary school students' academic attitude towards chemistry in Onitsha Education Zone of Anambra State of Nigeria. *International Journal of Research and Innovation in Social Science*, *7*(6), 45-59.

Kefalis, C., Skordoulis, C., & Drigas, A. (2025). Digital simulations in STEM education: Insights from recent empirical studies, a systematic review. *Encyclopedia, 5*(1), 10. https://doi.org/10.3390/encyclopedia5010010

Liday, D. (2025). Making sense of students' attitude towards college general chemistry: A partial least squares structural equation modeling (PLS-SEM) approach. *Journal of Technology and Science Education, 15*(2), 380–398. https://doi.org/10.3926/jotse.2971

Lo, C. K., & Hew, K. F. (2017). A critical review of flipped classroom challenges in K–12 education: Possible solutions and recommendations for future research. *Research and Practice in Technology Enhanced Learning, 12*(1), Article 4. https://doi.org/10.1186/s41039-016-0044-2

Mahaffy, P. G., Ho, F. M., Haack, J. A., & Brush, E. J. (2019). Can chemistry be a central science without systems thinking? *Journal of Chemical Education, 96*(12), 2679–2681. https://doi.org/10.1021/acs.jchemed.9b00991

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.

Nja, C. O., Ukwetang, J. O., Orim, R. E., Neji, H. A., Edu, G. O., Ukah, J. U., & Olofu, M. A. (2022a). Cultural resources, academic self-concept, and achievement of chemistry students in senior secondary schools of Calabar Municipality, Cross River State, Nigeria. *Frontiers in Education, 7*, Article 896833. https://doi.org/10.3389/feduc.2022.896833

Nja, C. O., Orim, R. E., Neji, H. A., Ukwetang, J. O., Uwe, U. E., & Ideba, M. A. (2022b). Students' attitude and academic achievement in a flipped classroom. *Heliyon, 8*(1), Article e08792. https://doi.org/10.1016/j.heliyon.2022.e08792

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Olatunji, S. O., & Akinsulire, Y. P. (2022). Awareness of and attitude to learning management system among undergraduates in University of Ibadan, Nigeria. *Benin Journal of Educational Studies, 28*(1), 134–143.

Onyi, I. E., Njoku, Z. C., & Nwafor, S. C. (2022). Efficacy of problem based learning in promoting high achievement of students in chemistry. *Journal of Critical Reviews*, *9*(01), 49-57.

Pongsophon, P. (2024). Deciphering the dynamics of achievement in the chemical basis of life: Attitude as a mediator and gender as a nonmoderator. *Journal of Chemical Education, 101*(6), 2257–2265. https://doi.org/10.1021/acs.jchemed.3c01338

Sağlam, D., & Arslan, A. (2018). The effect of flipped classroom on the academic achievement and attitude of higher education students. *World Journal of Education, 8*(4), 170–176. https://doi.org/10.5430/wje.v8n4p170

Tan, C. K., Ramasamy, T., Tan, C. P., & Koo, A. C. (2025). Influence of conversational agent on students' attitude toward mathematics. *Journal of Research in Innovative Teaching & Learning*. https://doi.org/10.1108/JRIT-09-2024-0234

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000379707

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press

Publisher's Note