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Four decades of change: The evolution of teaching styles in Nigerian science education (1983–2023)

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ABSTRACT

Over recent decades, science teaching in Nigeria has shifted alongside policy and curriculum reforms, yet empirical evidence on how classroom practices have evolved remains scarce. This study examines changes in teaching styles across four decades by comparing teacher data from 1983/1984 and 2023. Using multiple-group latent class analysis, we identified four profiles of instructional practice—ranging from traditional, teacher-led instruction to low-engagement routines, mixed/varied approaches, and student-centred, exploratory teaching—and assessed whether gender and teaching experience relate to profile membership. Data came from two samples of science teachers using seven indicators of instructional practice: the IEA Second International Science Study (1983/1984; N_1=261) and a 2023 sample from Nigerian schools (N_2=377). A four-class solution best fit the data. Measurement testing indicated that profile meanings differed across periods, implying that teaching styles evolved rather than remained directly comparable over time. Covariate analyses showed limited and largely non-significant associations for gender and experience; in 2023, any gender differences were small and not robust. Findings point to a broad shift away from uniform, teacher-led instruction toward more varied and student-centred approaches, while underscoring the need for contextually grounded teacher development policies that help translate reform messages into routine classroom practice.

1. Introduction

Instructional approaches are a core component of effective science teaching, shaping not only how teachers present content but also how students experience, understand, and respond to learning (Flanders, 1970; Grasha, 1996; OECD, 2019; Vermunt and Donche, 2017). According to Dallasheh (2024), teaching strategies that are student-centered and discussion-oriented encourage ethical reasoning, empathy, and critical thinking. Similarly, Urhievwejire et al. (2025) opined that teaching styles adopted by teachers are major determinants of effective learning. Over the decades, educational systems worldwide have undergone significant transformation, driven by pedagogical reforms, technological advancements, and changing societal expectations (Fullan and Gallagher, 2020; Schleicher, 2020). These shifts have prompted increased interest in understanding how teaching styles evolve over time, especially within diverse and dynamic educational contexts (Goodwin et al., 2021; Hattie, 2015). As noted by Vincent-Lancrin et al. (2019), change measured by comparing similar teaching practices at different points in time, i.e. longitudinally, is a good indicator of educational innovation. Yet, despite the global recognition of both the importance of teaching approaches and the relevance of innovation in education (Pietsch et al., 2023, 2024), research examining long-term changes in instructional patterns remains limited—particularly in developing countries such as Nigeria (Adedeji and Olaniyan, 2011; Unterhalter et al., 2014).

Nigeria's education system has navigated a complex historical trajectory shaped by colonial legacies, rapid population growth, persistent funding challenges, and efforts toward curriculum modernization (Adeyemi and Adeyinka, 2002). While reform efforts have called for more learner-centered instruction and innovative pedagogical practices (Ajayi and Ekundayo, 2010), the extent to which teachers have shifted their classroom strategies over time remains unclear. Previous research in the Nigerian context has tended to focus on isolated pedagogical interventions or cross-sectional analyses, offering little insight into how

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teaching styles may have evolved across generations of educators (Adeosun, 2010; Oloruntegbe, 2011).

Furthermore, research into the determinants of teaching styles—particularly the role of demographic characteristics such as gender and years of teaching experience—has produced inconsistent findings. Some studies suggest that more experienced teachers adopt flexible or student-centered approaches, contributing positively to student engagement and outcomes (Chetty et al., 2019; Ahmed et al., 2021), while others find minimal or no association between teaching experience and teaching styles (Driessen, 2007; Mullola et al., 2012). Similarly, gender has long been hypothesized to influence classroom behavior and instructional preferences, with some research indicating that male and female teachers differ in their use of motivation strategies, classroom management, and instructional emphasis (El-Emadi et al., 2019; Lingard et al., 2009; Singer, 1996), while others report negligible or no effect of teacher gender on student performance or teaching style (Carrington et al., 2008; Chudgar and Sankar, 2008; Oktan and Çağanağa, 2015). These discrepancies point to the need for more nuanced and longitudinal investigations into how such demographic variables interact with evolving pedagogical trends, particularly in under-researched contexts.

This study addresses these gaps by employing a multiple-group latent class analysis (GLCA) (Masyn, 2013; Muthén and Muthén, 2000) to investigate the evolution of teaching styles in Nigeria between 1983/1984 and 2023. Using survey data collected from teachers at both time points, we identified distinct teaching style profiles, test for measurement invariance across cohorts, and examine the influence of gender and teaching experience on class membership. In doing so, we aim to contribute to the literature on instructional change by offering a rare longitudinal perspective from a Global South context.

2. Literature review

Teaching styles are a cornerstone of classroom practice and play a critical role in shaping student learning, engagement, and academic success. A teacher’s approach to instruction—ranging from didactic lecture-based methods to more student-centered or experiential styles—can influence how students perceive the learning environment, how they interact with content, and ultimately how well they perform academically (Grasha, 1996; Flanders, 1970). Effective teaching styles not only enhance cognitive outcomes but also contribute to students’ motivation, self-efficacy, and emotional well-being (Borich, 2010). It has been found that teachers’ use of a motivating teaching style relates positively with student outcomes (Santana-Monagas et al., 2024). According to Vermote et al. (2024), students' learning outcomes are improved when teachers adopt a more inspiring teaching style that is marked by greater autonomy, support, and structure and less control and chaos. Perceived motivating teaching methods and students' need satisfaction are positively correlated (Wang et al., 2024). Vokić and Aleksić (2020) found that students who are more creative, activists, pragmatists, and particularly reflectors during their learning process do have a stronger preference for active teaching styles. Academic performance is strongly positively impacted by teacher teaching styles, demonstrating the critical significance that educators' methods and techniques play in helping students understand the course materials (Mudzakkir and Darmawan, 2024). According to Grecu et al. (2022), students' alienation from teachers and from learning, and ultimately from classroom engagement and social behavior, is influenced by teaching styles. It has been revealed that modern teaching styles have a significantly positive impact on secondary academic attainment (Qadir et al., 2024). According to Bhuttah et al. (2024), student engagement, critical thinking, and overall academic performance can be improved by Implementing active learning strategies and integrating technology in the classroom. As such, understanding the diversity and distribution of teaching styles within educational systems is essential for both research and policy-making.

Globally, teaching practices have undergone considerable transformation over recent decades, driven by technological innovation, educational policy shifts, and broader socio-cultural change. The field of teaching practices has experienced significant change over the past century as a result of changing educational philosophies, pedagogical research, technology breakthroughs, and societal changes (Shoimkulova and Yadigarova, 2024). Ummi et al. (2024) highlight the need for ongoing innovation and adaptation to satisfy the changing needs of contemporary education, directing teachers to design more dynamic and responsive learning environments. In earlier periods, teacher-centered methods such as lectures and rote memorization dominated classroom practice (Cuban, 1993). According to Abdullah et al. (2024), the traditional teaching practice known as one-size-fits-all method of instruction does not meet students' unique needs and preferences frequently and such can result in disengagement and poor academic achievement. Furthermore, students may become less interested in science-related courses as a result of the traditional teaching methods used in many secondary schools, which may not successfully engage and inspire them (Okunade, 2024).

However, increasing attention to constructivist theories and 21st-century skills has fostered a gradual shift toward more learner-centered approaches that emphasize collaboration, critical thinking, and real-world application (Voogt et al., 2013). The proliferation of digital tools and the integration of information and communication technologies (ICTs) have further reshaped instructional strategies, allowing for more interactive and multimodal learning experiences (Zhao and Frank, 2003). In order to ensure that instruction and assessment are not only successful but also interesting for a wider range of students, educators are increasingly investigating pedagogical strategies that accommodate different learning styles (Ballen, 2020; Ndikumana et al., 2024). The foundation of education is teaching strategies, which determine how information is communicated, absorbed, and kept by students (Shoimkulova and Yadigarova, 2024). It has been discovered through examining the teaching practices of many nations that creating curriculum objectives and essential competences with a variety of student options and media is essential to establishing agency for students' well-being (Jarrah, 2024). Despite these advancements, the pace and nature of pedagogical change vary significantly across countries, particularly between developed and developing contexts.

While the study of teaching styles remains a vibrant area of inquiry, several challenges persist. First, the literature lacks a universally accepted definition of “teaching style,” with overlapping constructs such as instructional strategies, pedagogical approaches, and teaching methods often used interchangeably (Conti, 2004). Second, there is a scarcity of longitudinal studies that examine how teaching styles evolve over time, limiting the field’s ability to identify trends or assess the impact of reforms. Third, most existing research is cross-sectional and context-specific, making generalisations difficult. Moreover, many studies rely on teacher self-reports, which may be subject to bias or misalignment with actual classroom practices. These limitations underscore the need for more methodologically robust and temporally sensitive studies that can capture the complexity of instructional change in science teaching styles.

Science teaching styles are the different methods teachers employ to present material and get learners interested in studying scientific ideas. These styles are frequently modified to accommodate various learning situations and requirements. The success, development, and growth of our students depend heavily on our ability to impart knowledge rather than create and withdraw it (Styles, 2012). Thus, by being consistent and proficient in our teaching methods, we can enable students to take charge of their education in a number of ways that promote efficient learning and advancement. Research on science teaching styles has shown an interplay between teachers' teaching styles and students' preferred methods of learning is revealed. Research shows that while students may favor kinesthetic and tactile learning styles, science teachers frequently use lecture-based, visual-auditory approaches

(Abu-Asba et al., 2014). According to research, teaching styles can vary depending on the subject taught, and matching teaching methods with learning styles can improve knowledge acquisition (Ventura, 2013). Understanding these dynamics can lead to better science teaching practices and more effective learning outcomes (Ventura, 2013; Ariem and Cabal, 2021).

The significance of matching teaching strategies to students' preferred learning styles is emphasized by research on science teaching styles. Research shows that pupils have a variety of learning styles, with visual being the most common in elementary schools. Other learning styles include auditory and kinesthetic (Anand and Rajendraprasad, 2016). Nonetheless, kinesthetic and tactile learning modalities are typically preferred by college scientific students (Abu-Asba et al., 2014). Education, expertise, and length of service are some of the characteristics that affect teachers' styles (Ariem and Cabal, 2021). Academic achievement and information acquisition can be enhanced by matching teaching and learning styles (Ariem and Cabal, 2021; Ventura, 2013). However, there is frequently a mismatch in science education, with students preferring kinesthetic methods and lecturers mostly employing visual and auditory approaches (Abu-Asba et al., 2014). Teachers should use a variety of teaching methods to accommodate different learning styles in order to improve science instruction (Anand and Rajendraprasad, 2016; Ventura, 2013).

2.1. Demographic factors and their role in teaching styles

Demographic characteristics such as gender and teaching experience are important yet often understudied variables in the analysis of teaching styles. Research has suggested that male and female teachers may exhibit different instructional tendencies, potentially shaped by cultural expectations or differences in professional socialization (Sadker and Zittleman, 2009). Similarly, novice and experienced teachers may adopt varying pedagogical approaches, with more experienced educators often perceived as more flexible or adaptive (Berliner, 2001). Years of experience, professional development, and educational background are some of the characteristics that affect teaching styles (Genc and Ogan-Bekiroglu, 2004). As Adams and Krockover (1999) stated, teachers in science education adopt a survival mode over time and return to teacher-centred teaching styles rather than student-centred styles throughout their careers. According to El-Emadi et al. (2019), gender had significant influence on teachers teaching styles. However, the authors found that while male teachers had better teaching styles during laboratory-based classes, female teachers delivered theory classes more effectively. Besides, Mofreh et al. (2021) found that the teaching and practices of the teachers were significantly impacted by demographic characteristics such as qualification, age, department, and status tenure. Also, Berhanu (2025) revealed that principals' pedagogical leadership styles were highly impacted by their age and length of service. Sebastian and Villa (2025) found that sex significantly influences teachers' teaching styles. In a related study, it was found that female medical practitioners were less likely to adopt expert and innovative teaching styles than males while suitable teaching styles were more strongly supported by individuals with formal education backgrounds than by those without (Moy, 2025).

On the contrary, findings showed that the demographic factors and instructional strategies did not significantly correlate (Rao, 2016). Additionally, studies have shown that demographic factors—such as gender, region, experience, age, and qualification—have no significant impact on instructional behavior (Ahmad et al., 2022). Similarly, Berhanu (2025) found that gender had no significant influence on teachers' pedagogical practices. Besides, it has been revealed that there was no significant difference in the use of teaching styles by gender (Espada et al., 2025). In the same vein, Bayirli (2025) found that the teachers' teaching styles are not affected by their gender, age, and teaching experience. Corroborating the above findings, Urhievwejire et al. (2025) found that sex has no significant influence on the teaching styles adopted by teachers.

However, findings on these relationships remain mixed, and few studies have systematically examined how demographic factors influence classifiable patterns of teaching behavior. Investigating these dynamics can provide critical insights into the professional development needs of different teacher groups.

2.2. Focus on the Nigerian educational context

Nigeria presents a compelling context for studying the evolution of teaching styles, given its complex educational landscape, historical legacies, and ongoing reforms. As one of Africa's most populous countries, Nigeria has long grappled with challenges related to teacher preparation, infrastructural disparities, and uneven access to quality education (Ajayi and Ekundayo, 2010). Furthermore, Okunade (2024) noted that the traditional teaching methods used in many Nigerian secondary schools might not engage and inspire students as well, which could lead to a drop in their interest in science-related courses. Okunade further stated that the scarcity of modern teaching resources and tools exacerbates these issues, calling for creative solutions that could revolutionize science education. Educational practices in Nigeria have historically leaned toward authoritarian and examination-driven models, though recent policy initiatives have promoted learner-centered reforms and competency-based curricula.

Since the 1990s, Nigeria has seen substantial changes to its curriculum and policies on science education, marked by lofty objectives but enduring difficulties in putting them into practice. The Universal Basic Education (UBE) Program, which was first implemented in 1998 and underwent significant curriculum revisions in 2008 and 2012, is one of the major developments (Igbokwe, 2015). In order to produce scientists for the advancement of the country, the changes sought to make scientific education more applicable and relevant (Adolphus, 2019). But there have been issues with implementation. Research shows that official curriculum goals and classroom practices differ significantly. Oloruntegbe (2011). Lack of financing, ill-equipped laboratories, little teacher participation in curriculum planning, and restricted technological integration are some of the ongoing issues (Matthew, 2013). The data points to continued reform initiatives, but there is still much space for improvement in terms of converting policy into successful science instruction. Besides, implementation remains uneven across regions and school types. The issues highlighted above have significant impact on classroom practices and that informed the choice of 1983/84–2023 science teaching comparison.

As summarized in Table 1, the seven instructional indicators map onto a continuum from teacher-led to student-centered practice. This mapping aligns QUESTION, LECTURE, and ASSIGN with teacher-centered/direct instruction; GROUPS and FIELD with collaborative/inquiry-based pedagogy; and INDIV and AUDIOVIS with differentiated/technology-supported approaches. Consistent with prior research (e.g., Flanders, 1970; Grasha, 1996; Keeves, 1992), we therefore anticipated distinct teaching profiles reflecting varying degrees of structure, collaboration, and student autonomy.

Table 1
Conceptual mapping of instructional indicators to pedagogical dimensions and expected teaching profiles.

Indicator	Pedagogical Dimension	Expected Teaching Style Profile
QUESTION, LECTURE, ASSIGN	Teacher-centered / Direct instruction	Traditional or Structured Teaching
GROUPS, FIELD	Collaborative / Inquiry-based	Student-centered Teaching
INDIV, AUDIOVIS	Differentiated / Technology-supported	Mixed or Innovative Teaching

2.3. The current study

Teachers in Nigerian secondary schools are more conscious of the impact of high-stakes examinations on their teaching styles than the learners (Abdallah et al., 2022). Although there is potential for integrating A New Kind of Science (NKS) and information and communication technologies (ICT) into science education, there are obstacles because of a lack of resources and teachers' lack of computer confidence (Aladejana, 2009). In Nigeria, there are several barriers to sustainable growth through science education, such as insufficient research tools and low teacher pay (Obianuju et al., 2013). According to research, classroom management has a big impact on teaching methods, and teachers are more aware of this than students are (Taiwo et al., 2021). Available literature shows that there is dearth of research on how science teaching styles is changing in Nigeria and this is a big gap that we tried to fill in this research. Thus, studying how teaching styles have evolved in Nigeria over time can yield important lessons for both national reform efforts and broader theories of instructional change in low- and middle-income countries. Hence, this research explored the evolution of teaching styles in Nigeria across a forty-year span, comparing data from 1983/1984 and 2023 using Multiple-Group Latent Class Analysis. Specifically, the research provided answers to the following questions:

1. In what ways have the teaching styles adopted by teachers in Nigeria evolved between 1983/1984 and 2023?
2. Are demographic factors, such as gender and years of experience, related to the teaching styles of teachers in Nigeria across the two-time points of 1983/1984 and 2023?

By addressing these questions, this study offers critical insights into how pedagogical practices shift over time and how teacher characteristics may shape instructional behavior in an evolving educational landscape.

3. Methodology

3.1. Data

Data for this research stem from two separate studies conducted in Nigeria in the years 1983/1984 and 2023. The data from 1983/1984 originate from the Second International Science Study (SISS), which was conducted by the International Association for the Evaluation of Educational Achievement (IEA; Keeves, 1992). This is the last International Large Scale Assessment (ILSA) study focusing on science education in which Nigeria has participated (Howie, 2011). SISS took place in 23 countries around the world. In Nigeria, a total of 176 schools in the states of Anambra, Bauchi, Bendel, Cross River, Gongola, Kano, Kwara, Lagos, Niger, Oyo and Plateau participated in the survey (Mordi, 1993). Data sets for population 1 (grade 5) and 2 (grade 9) are publicly available on the homepage of the Gothenburg Centre for Comparative Analysis of Educational Achievement (COMPEAT; https://www.gu.se/en/center-for-comparative-analysis-of-educational-achievement-compeat). With regard to teacher data, however, only data for population 2 is available, comprising N = 261 science teachers from 108 schools.

The data from the second study form part of an international comparative study being conducted in Chile, China, Germany, Kyrgyzstan, Malaysia, Switzerland, Turkey, Ukraine and Uganda, in addition to a number of other countries. The data from 2023 were collected in the Nigerian states of Abuja, Akwa Ibom, Anambra, Benue, Delta, Ebonyi, Enugu, Kogi, and the Federal Capital Territory following a purposive sampling technique and utilising paper-and-pencil surveys. Purposive sampling was chosen to ensure researchers avoided security risks, as Nigeria faces ongoing threats, i.e. kidnapping, human trafficking, armed robberies and urban violence (Ugwuanyi and Pietsch, 2024). A total of N = 1406 Nigerian teachers nested in 146 schools participated in this cross-sectional study. Of these, N = 377 were science teachers, teaching in secondary education.

The two datasets were selected based on their direct relevance to Nigerian science education and the comparability of their teacher-level instructional practice measures. The 1983/1984 data were drawn from the IEA's Second International Science Study (SISS), which represents the most recent international science assessment including Nigeria. The 2023 dataset was obtained from a broader international comparative study on teaching practices coordinated by the research team.

In SISS 1984, only 11 of the 21 Nigerian states at the time participated (Mordi, 1993). These states were grouped into clusters: South-West (Bendel, Oyo, Lagos), South-East (Anambra, Cross River), Central (Kwara, Plateau), North-West (Sokoto, Niger), and North-East (Sokoto, Niger). The 2023 sample followed this clustering approach. However, due to security concerns in northern Nigeria, states from the North-West and North-East clusters could not be included. As a result, the 2023 sample focused on schools from the South-West, South-East, and Central clusters.

The historical clusters, however, do not fully correspond to today's geopolitical zones. For instance, Bendel, originally part of the South-West cluster, was divided in 1991 into Delta and Edo. Akwa Ibom was originally part of the Cross River region (historical South-East). The Federal Capital Territory, in turn, was created in 1991 from parts of Kwara, Niger, and Kogi states, which were historically part of the Central cluster. For the purposes of the 2023 sample, the historical clusters can be approximated as follows: South-West (Ogun, Delta), South-East (Enugu, Anambra, Ebonyi, Akwa Ibom), and Central (Kogi, Benue, Federal Capital Territory).

The final sample sizes (N = 261 for 1983/1984 and N = 377 for 2023) include all science teachers who provided complete responses to the instructional practice items at the secondary level. The ratio of teachers per school is approximately the same in both samples, with an average of about 2.5 science teachers per school (1983/1984: 2.42; 2023: 2.58).

3.2. Ethical approval statement

The Declaration of Helsinki's ethical guidelines were followed when conducting the study. The Institutional Review Board granted ethical approval (REC/FOE/2023/00108) for the 2023 data collection. All participants gave their informed consent, participation was entirely voluntary, and confidentiality and anonymity were guaranteed.

3.3. Measure

We aimed to explore how science teaching in Nigerian secondary education has changed over the past 40 years. In order to achieve this objective, the 2023 survey utilised the same instruments for measuring teaching practices as the 1983/1984 SISS study. The instrument enables cross-national comparisons of science teaching, with its validity assessed by the science staff of the International Association for the Evaluation of Educational Achievement (IEA) (Rosier and Couper, 1981).

In the context of SISS, science teaching was modelled following a three-dimensional approach, comprising (1) instruction, where teaching is focused on knowledge transmission, (2) participation, which prioritises student involvement, and (3) investigation, emphasising inquiry-based learning (Keeves, 1992). As Young (1995) noted, these three dimensions correspond to passive, shared, and active learning environments. The main question was: *How often do you use each of the following types of instructional method for teaching science*?

Teachers were presented with seven distinct instructional methods, each of which was to be answered on a four-point Likert-type scale, ranging from 1 = frequently to 4 = never (see Table 2). As reported by Wolf (1992), the analysis of the SISS data set has revealed that in upper secondary schools (population 2), teaching, conceptualised as a singular

Table 2
Studies sample.

Study	*n*
Study 1983/1984 (SISS)	261
Study 2023	377

scale score, accounts for approximately 3 % of the observed variation in student achievement between schools. Specifically, active experiential learning, practical work, field trips, and the utilisation of audiovisuals, exhibited a positive correlation with student achievement.

We have recoded the original teaching practice variables so that higher values indicate more frequent use of the instructional approach. Specifically, the response categories were reversed: *1* = *never*, *2* = *rarely*, *3* = *occasionally*, and *4* = *frequently*. This recoding ensures consistency in interpretation across all analyses, where higher scores reflect greater instructional frequency.

3.4. Covariates

The covariates included in the current study were gender (where 1 indicates male) and years of teaching experience, with higher scores reflecting a greater number of years in the profession. Male teachers were coded as 1 (reference category) to ensure consistency with the 1983/1984 SISS dataset and common practice in comparative analyses. This coding convention allows coefficients to be interpreted relative to male teachers, without implying analytical emphasis on that group.

3.5. Analytical strategy

The analytical strategy for this study comprised three essential steps, conducted using the glca package in R, designed for multiple-group latent class analysis (Kim et al., 2022).

Initially, we performed a latent class analysis (LCA) to explore patterns in teaching styles among various study groups (Geiser, 2012.; Masyn, 2013). This analysis spanned a range of model specifications, varying the number of latent classes from 2 to 7. By comparing fit indices such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), we determined the optimal number of classes that best represented the underlying data structure (Muthén and Muthén, 2000). This initial step was crucial in identifying distinct profiles of teaching styles within the sample.

Following the identification of the optimal number of classes, we conducted a measurement invariance test to evaluate whether the latent class structure remained consistent across the different study groups. This step is vital for ensuring that the interpretations of the latent classes are valid and comparable across the groups, thereby enhancing the robustness of the findings (Muthén, 1998).

Lastly, we examined the influence of demographic covariates, specifically gender (coded as 1 for male) and years of teaching experience, on class membership. This analysis assessed how these variables affected the likelihood of belonging to specific latent classes, providing insights into the relationship between teacher characteristics and teaching styles (Lanza et al., 2007). These analyses were carried out using the glca package, developed by Youngsun Kim et al. (2022).

Overall, this analytical framework is particularly appropriate for the present study because Multiple-Group Latent Class Analysis (GLCA) allows for the identification of unobserved subpopulations (i.e., teaching style profiles) based on categorical indicators while simultaneously testing whether these latent structures are comparable across groups (in this case, time points). Unlike traditional variable-centered methods, GLCA captures the heterogeneity of instructional behaviors within and between cohorts, making it well suited for investigating how teaching styles evolve over time and differ across teacher groups.

4. Results

4.1. Descriptive statistics

In 2023, the proportion of male teachers declined notably compared to 1983/1984 (29.65 % vs. 61.43 %), and there was a slight increase in less experienced teachers. While average experience remained similar across both years, teaching styles showed small but consistent increases in mean scores, indicating more frequent use of various instructional approaches. Notably, dimensions like individual and audiovisual methods saw marked growth, suggesting a shift toward more student-centered practices (Table 3).

4.1.1. The results of latent class analysis

The results of the Latent Class Analysis (LCA) revealed the fit indices for models with varying numbers of latent classes, ranging from 2 to 7 classes (Table 4). The log-likelihood values, number of parameters (npar), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), entropy values, degrees of freedom (df), G-squared values, and bootstrapped p-values were assessed for each model.

The model fit statistics showed that increasing the number of latent classes improved fit in terms of log-likelihood and (to a lesser extent) AIC; however, the BIC reached its minimum at the four-class solution and increased thereafter, indicating that additional classes did not offer a better balance of fit and parsimony. The four-class model (AIC = 10,252.87; BIC = 10,640.34) also yielded high entropy (0.83), reflecting clear class separation. Taken together—minimum BIC, competitive AIC, and strong entropy—these indices support the four-class solution as the optimal and substantively interpretable model.

Fig. 1 presents the item-response probabilities for the highest response category (Y = 4; “frequently”) across seven instructional practice items and the four latent classes identified through latent class analysis. Because the variables were recoded so that higher values reflect more frequent use of teaching methods (i.e., 4 = frequently, 1 = never), the graph illustrates the probability that teachers in each class frequently use each instructional strategy.

The four classes reveal clearly differentiated teaching profiles. Class 1 is characterized by moderate use of traditional instructional methods such as lectures and question-and-answer sessions, with moderate probabilities across most items. This suggests that teachers in Class 1 use a relatively balanced mix of methods, particularly leaning toward conventional whole-class formats.

Table 3
Items, descriptions and response categories.

Item	Description	Response Category
QUESTION	Question-and-answer methods for presenting information to the whole class	1.frequently, 2. occasionally, 3. rarely, 4. never
LECTURE	Lecture to the whole class followed by questions from students	1.frequently, 2. occasionally, 3. rarely, 4. never
ASSIGN	All students do the same assignment, working from their textbooks or other printed materials	1.frequently, 2. occasionally, 3. rarely, 4. never
GROUPS	The class is divided into small groups of students who work together on the same assignments, or different including practical/laboratory work	1.frequently, 2. occasionally, 3. rarely, 4. never
INDIV	Students follow individualized programs, which may include individual printed materials and laboratory work	1.frequently, 2. occasionally, 3. rarely, 4. never
AUDIOVIS	Presentation of audio-visual materials to the whole class: for example, slides, films, TV	1.frequently, 2. occasionally, 3. rarely, 4. never
FIELD	The whole class goes on field trips or excursions in connection with the science program	1.frequently, 2. occasionally, 3. rarely, 4. never

Table 4
Descriptive statistics of teacher characteristics and instructional practices by year (1983/1984 vs. 2023).

	Year	
Variable	1983/1984	2023
Male (%)	61.43	29.65
Experience (Mean)	2.65 (0.94)	2.63 (1.13)
0–5 yrs (%)	23.57	30.96
6–10 yrs (%)	20	12.17
11–20 yrs (%)	35.71	35.65
21–30 yrs (%)	16.43	15.65
30 + yrs (%)	4.29	5.57
QUESTION (Mean)	2.78 (0.84)	3.09 (0.77)
LECTURE (Mean)	3.03 (0.92)	3.15 (0.9)
ASSIGN (Mean)	2.77 (0.88)	2.83 (0.91)
GROUPS (Mean)	2.57 (0.87)	2.75 (0.88)
INDIV (Mean)	2.78 (0.93)	3.1 (0.94)
AUDIOVIS (Mean)	2.71 (0.93)	2.89 (0.92)
FIELD (Mean)	2.61 (0.95)	2.87 (0.97)

Standard Deviations are in the parentheses.

Class 2 displays consistently low probabilities across all instructional practices, indicating that these teachers rarely or never use the listed teaching strategies. The profile reflects a minimal engagement with both traditional and student-centered methods.

Class 3 demonstrates the highest overall probabilities of frequent usage across almost all items, especially for traditional methods (LECTURE, ASSIGN, QUESTION) and individualized learning (INDIV). This suggests that Class 3 represents the most instructionally active group, frequently incorporating a broad variety of approaches.

Class 4 shows particularly high probabilities for traditional methods like lectures and question-and-answer sessions, but much lower probabilities for student-centered or active learning strategies such as group work or audiovisual materials. This pattern indicates a preference for more structured, teacher-led instruction, with less emphasis on exploratory or collaborative techniques.

These distinct patterns support the selection of the 4-class solution as an optimal balance between interpretability and statistical fit. The prevalence of Class 3 (50.9 %) suggests that it represents the dominant teaching style in the sample, characterized by frequent use of diverse instructional methods. Class 1 accounts for about 20.6 % of the sample, while Classes 2 and 4 represent smaller but meaningful subsets, comprising 13.8 % and 14.7 % of the sample, respectively. Together, these results provide insight into the variation and prevalence of teaching strategies across science classrooms.

Based on these findings, the majority of teachers in the sample (Class 3) appear to adopt a highly active and diverse instructional approach, frequently using both traditional and individualized strategies. The existence of Class 2, comprising teachers who seldom use any of the listed methods, highlights a group with limited instructional engagement that may warrant further investigation or support. Meanwhile, Classes 1 and 4 reflect more moderate or traditional teaching profiles, pointing to variability in pedagogical preferences. Overall, the 4-class solution captures meaningful distinctions in instructional practice that can inform targeted professional development and policy interventions.

Fig. 2 illustrates the item response probabilities for each of the four identified classes, showcasing the likelihood of selecting various response categories for the manifest items. This visualization reveals distinct patterns among the classes, highlighting how different teaching styles relate to the evaluated items.

4.1.2. *Measurement invariance between time points*

In our analysis, we next aimed to understand how the latent class structure differed between 1983/1984 and 2023. To achieve this, we conducted a series of models to test for measurement invariance among the classes identified in the data. This approach allowed us to evaluate whether the latent constructs measured were consistent across the two distinct time periods, ensuring the validity of our comparisons between the teaching styles in these years. We fitted three models for comparison (Table 5).

Model 1 served as the baseline model, estimating item response patterns across the full sample without including the grouping variable (STUDY). This model specified four latent classes and yielded a log-likelihood of −5039.44, with an AIC of 10252.87 and a BIC of 10640.34. The entropy value of 0.83 indicates relatively clear class separation, though this model does not account for potential group-level differences in item functioning.

Model 2 introduced the grouping variable (STUDY: 1983/1984 vs. 2023), while assuming measurement invariance across groups. This model showed improved fit statistics compared to Model 1, with a log-likelihood of −4939.36, an AIC of 10058.73, and a BIC of 10459.55.

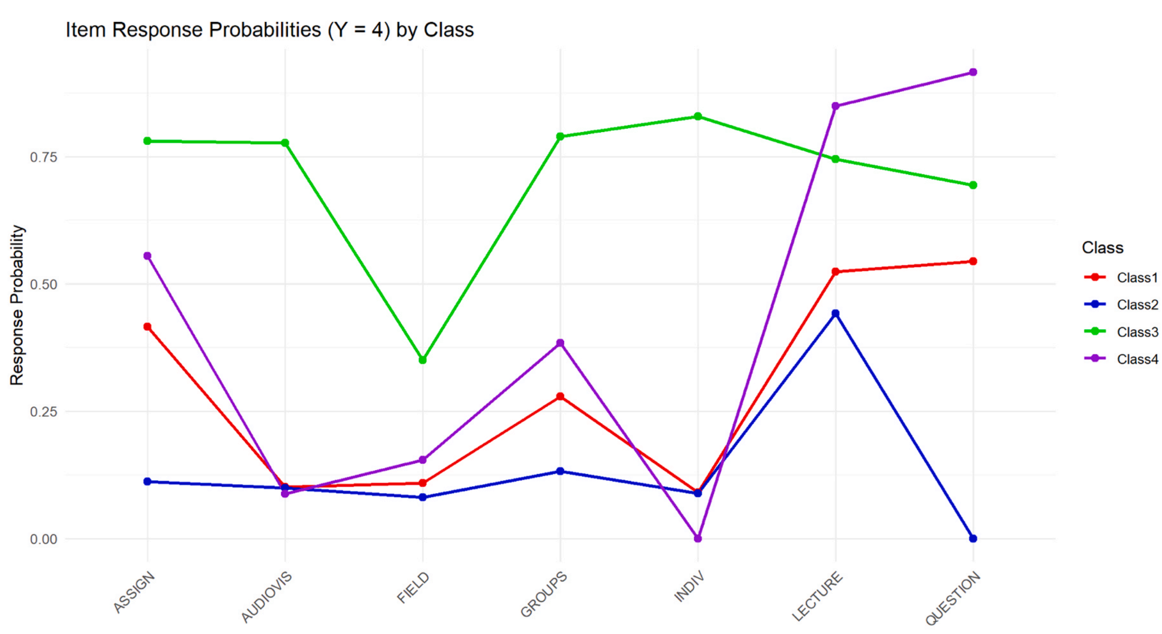

Fig. 1. Response pattern of the 4-class solution.

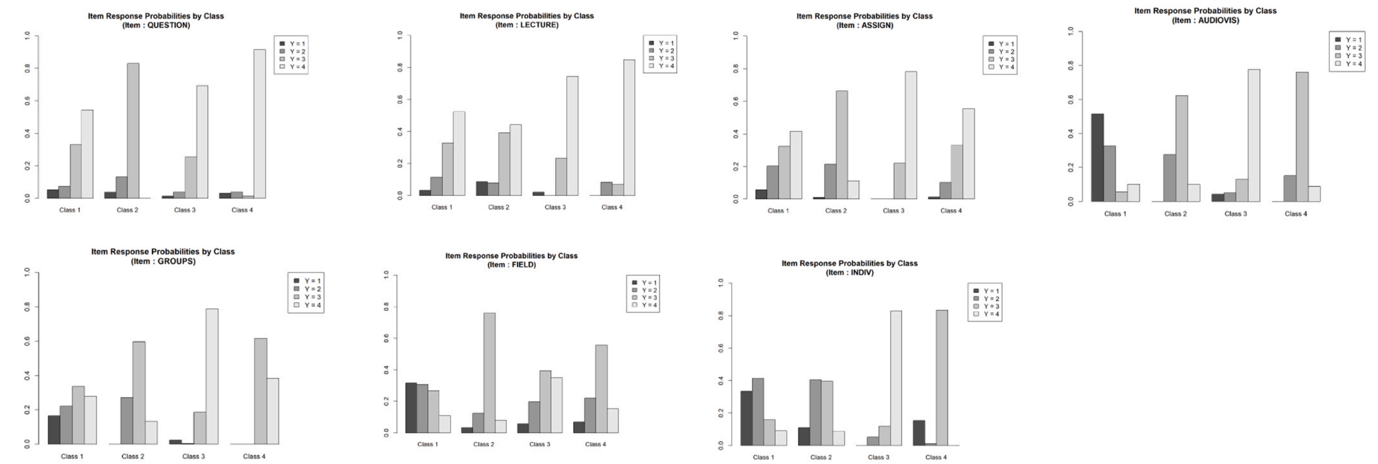

Fig. 2. Item Response Probabilities by Class.

Table 5
Summary of fit results.

N° Classes	Loglik	npar	AIC	BIC	Entropy	df	Gsq	Boot p-value
2	-5206.97	43	10499.94	10691.45	0.76	591	3236.23	0
3	-5101.81	65	10333.63	10623.11	0.73	569	3025.92	0
4	-5039.44	87	10252.87	10640.34	0.83	547	2901.16	0
5	-4983.56	109	10185.12	10670.56	0.84	525	2789.41	0
6	-4926.4	131	10114.8	10698.23	0.84	503	2675.09	0
7	-4892.05	153	10090.1	10771.5	0.86	481	2606.39	0

The entropy also improved to 0.86, suggesting clearer latent class distinctions. However, the strict assumption of measurement invariance may still obscure meaningful differences between groups.

Model 3 relaxed the assumption of measurement invariance and allowed the item parameters to vary across the two groups. This model produced the best fit, with the lowest AIC (9860.67) and BIC (10635.60), and a log-likelihood of −4756.34. Although the entropy slightly decreased to 0.81, the improved model fit indicates that accommodating measurement non-invariance yields a more accurate representation of the data.

To statistically assess improvements in model fit, we conducted deviance comparisons. Comparing Model 2 to Model 1 showed a deviance of 200.15 ($p < .001$), confirming the value of including group membership. More critically, the comparison between Model 3 and Model 2 yielded a deviance of 366.05 ($p < .001$), providing strong evidence that measurement invariance does not hold across the two time points. These results suggest that item response patterns—and thus the interpretation of the latent classes—differ significantly between the 1983/1984 and 2023 cohorts.

Therefore, Model 3 is preferred for subsequent analysis. By relaxing the assumption of measurement invariance, it accounts for the variability in how constructs are understood and expressed across different historical contexts, thereby enhancing the validity and comparability of the latent class interpretation.

Fig. 3 illustrates the overall (marginal) prevalence of the four latent teaching style classes across the full sample. Class 1 is the most prevalent overall, indicating a substantial portion of the sample adopts a teaching style characterized by more traditional instructional practices. Fig. 4 and Table 6 break down class membership by cohort, comparing 1983/1984 and 2023. The results reveal a dramatic shift in teaching styles over time. In 1983/1984, nearly all teachers (94.9 %) belonged to Class 1, reflecting widespread reliance on lectures and question-and-answer methods. In contrast, the 2023 cohort shows much greater diversity in teaching approaches: only 3.5 % fall into Class 1, while 24.1 % and 25.6 % are members of Classes 2 and 3, respectively. Most notably, nearly half of the 2023 teachers (46.7 %) belong to Class 4, suggesting a shift toward more varied and student-centered practices. These findings underscore a significant pedagogical transformation in science education in Nigeria over the past four decades.

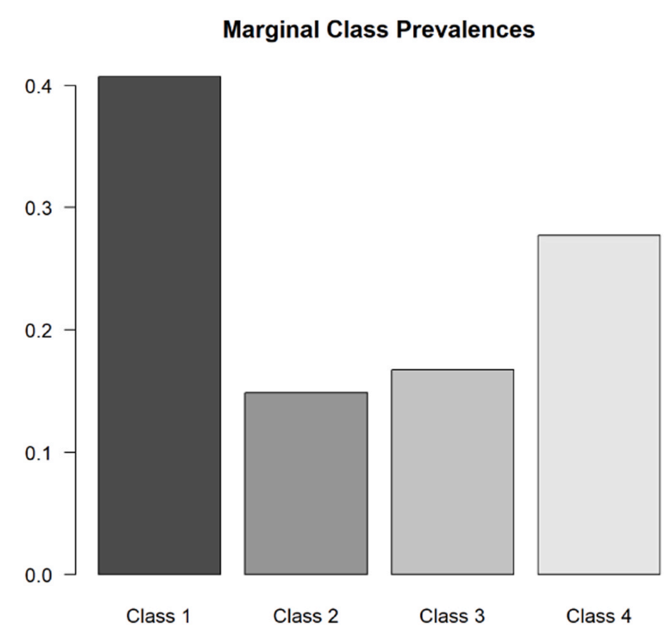

Fig. 3. Marginal Class Prevalences.

These results suggest that item response patterns—and thus the interpretation of the latent classes—differ significantly between the 1983/1984 and 2023 cohorts. As shown in Fig. 5, the response probability profiles for each class differ markedly between the two cohorts. This visual divergence corroborates the finding of measurement non-invariance and reinforces that the latent classes represent cohort-

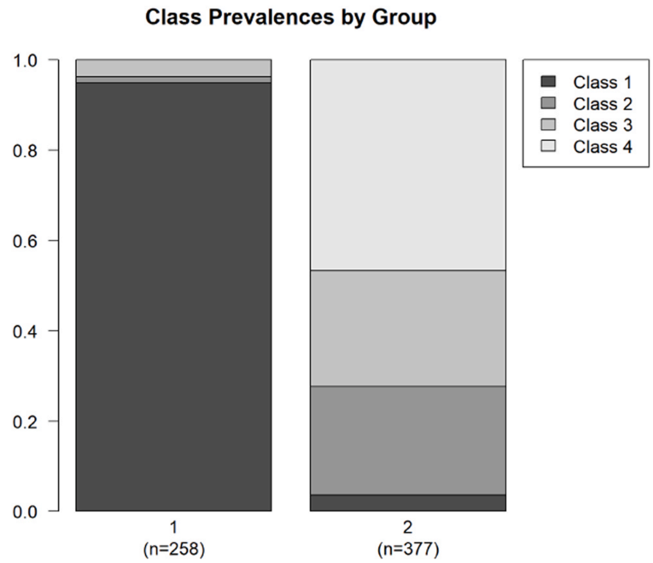

Fig. 4. Class Prevalences by Group.

specific teaching style configurations rather than directly comparable categories.

The cohort-specific item–response probability plots further illustrate that the meaning and configuration of the latent classes differ between 1983/84 and 2023. In the 1983/84 cohort, *Class 4* shows high probabilities for lecture and question-based instruction but very low engagement with group work or audiovisual methods, indicating a predominantly **teacher-led/traditional** profile. In contrast, *Class 4* in 2023 displays higher probabilities for collaborative and individualized practices, marking a **more varied and student-centered** approach. These visual differences align with the test of measurement non-invariance and suggest that each cohort's classes should be interpreted **within their respective contexts**, rather than as directly equivalent categories across time.

4.1.3. *Sex and teaching years effect on latent teaching classes*

Finally, we examined whether teacher characteristics—specifically gender (coded as 1 = male)—were associated with different teaching style classifications in Nigerian secondary education and how these associations have changed over the past four decades. Table 7 presents the results of multinomial logistic regressions conducted separately for the 1983/1984 and 2023 samples, using Class 2 as the reference category.

In 2023, male teachers were less likely than females to belong to Class 1 relative to Class 2 (OR = 0.59, p = .18), indicating a modest but non-significant gender gap. Compared to 1983/84, gender differences appear attenuated, suggesting convergence in teaching style preferences over time.

Using Class 2 as the reference category, no statistically significant gender differences in class membership emerged for the 1983/1984 cohort. Relative to Class 2, the odds for males (vs. females) were higher for Class 1 (OR = 1.30, p = .61) and Class 3 (OR = 2.36, p = .38), and lower for Class 4 (OR = 0.83, p = .74), but none of these estimates

Table 7
Class prevalences by group.

Group	Class 1	Class 2	Class 3	Class 4
Group 1 (1983/1984)	0.94939	0.01315	0.03746	0
Group 2 (2023)	0.03554	0.24128	0.25642	0.46675

Table 6
The goodness-of-fit statistics and the analysis of deviance for each model.

Model	Description	loglik	AIC	BIC	Entropy	df	Gsq	npar	Deviance	Pr (>Chi)
Model 1	Item response patterns without grouping (nclass: 4)	-5039.44	10252.87	10640.34	0.83	547	2901.16	87		
Model 2	Grouping variable (STUDY), measurement invariant (nclass: 4)	-4939.36	10058.73	10459.55	0.86	544	3500.06	90	200.15	0
Model 3	Grouping variable (STUDY), measurement not invariant (nclass: 4)	-4756.34	9860.67	10635.6	0.81	460	3134	174	366.05	0

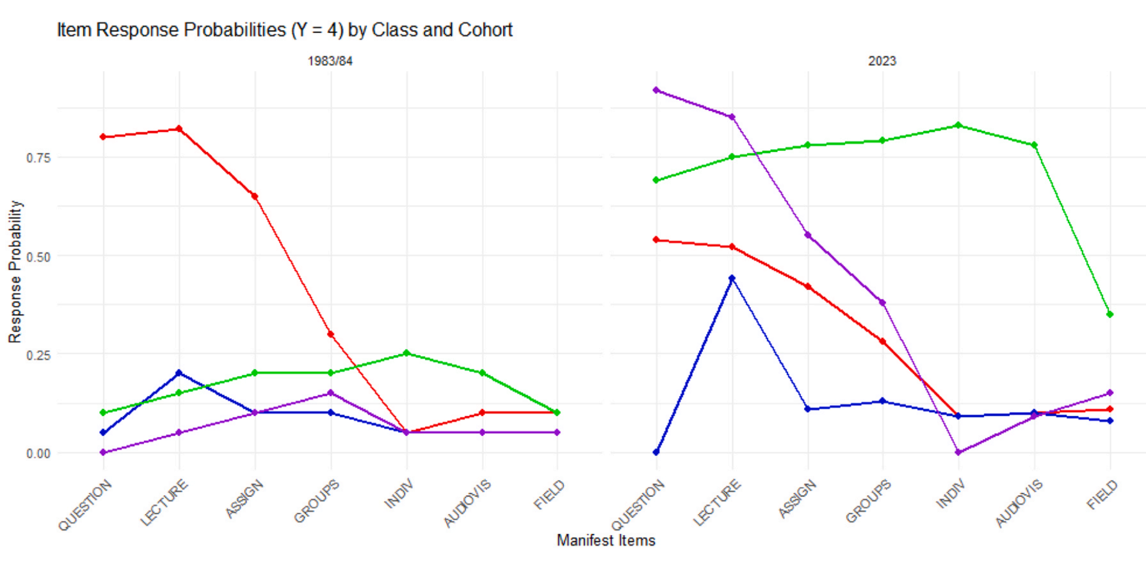

Fig. 5. Item response probabilities (Y = 4, "frequently") by class and cohort (1983/84 vs. 2023).

reached significance, indicating no reliable gender patterning in the earlier cohort (Table 7). In 2023, gender effects remained small and predominantly non-significant relative to Class 2. Males showed lower odds of membership in Class 1 versus Class 2 (OR = 0.59, p = .18) and virtually no difference for Class 3 versus Class 2 (OR = 0.98, p = .96). There was a marginal tendency for higher odds among males for Class 4 versus Class 2 (OR = 2.13, p = .068), which did not meet conventional significance thresholds. Overall, the results suggest limited and non-robust gender differences in latent class membership across cohorts when comparisons are made to Class 2 (Table 7).

Tables 8 and 9 presents the results of logistic regression analyses examining the influence of teaching experience on latent class membership, with Class 2 serving as the reference category.

Teaching experience showed a significant negative association with membership in Class 4 compared to Class 2 in 1983/84 (OR = 0.18, p < .001), suggesting that less experienced teachers were over-represented in traditional styles. By 2023, the influence of experience diminished considerably, indicating a more uniform distribution of teaching styles across experience levels.

Using Class 2 as the reference category, teaching experience exhibited a limited association with class membership overall (Table 8). In 1983/1984, more experience was significantly associated with lower odds of membership in Class 4 relative to Class 2 (OR = 0.18, p < .001), whereas the contrasts for Class 1 (OR = 1.10, p = .82) and Class 3 (OR = 0.62, p = .51) were small and not statistically significant. In 2023, none of the experience effects reached conventional significance: the odds for Class 1 versus Class 2 were slightly lower (OR = 0.74, p = .50), for Class 3 were near unity (OR = 0.91, p = .84), and for Class 4 were modestly higher (OR = 1.74, p = .16). Taken together, these results suggest that while more experienced teachers in 1983/1984 were less likely to be in Class 4 (relative to Class 2), experience-related differentiation in teaching style membership was largely attenuated by 2023.

5. Discussion

This study examined the evolution of teaching styles in Nigerian Science Education over four decades (1983/1984–2023) and explored how teacher demographics—specifically gender and teaching experience—are associated with different instructional profiles. Through multiple-group latent class analysis (LCA), we identified four distinct teaching profiles and revealed substantial shifts in instructional practices over time.

5.1. Four distinct teaching profiles

The 4-class model provided optimal statistical fit and conceptual clarity, revealing four differentiated teaching styles. Class 1 was characterized by strong adherence to traditional instructional methods, particularly lectures and question-and-answer sessions. Buttressing this finding, it has been revealed by researchers that teacher-centered pedagogies, which reduce students to note-takers and passive listeners rather than critical thinkers and problem-solvers, dominate modern teaching practices and active learning techniques are overlooked, which prevents teachers from fostering thinking classroom communities. In specific term, Benson et al. (2020) highlighted that over the years have seen a reduction in students' interest in and attitudes toward scientific and math-related courses, which has been linked to the teachers' traditional instructional methodologies. Similarly, learners' poor performance in Basic Science has been linked to teachers' employment of traditional teaching methods (Ugwuanyi, 2022). In the same vein, Mbonu-Adigwe et al. (2024) discovered that Nigerian students' consistently low academic performance in Basic Science has been attributed to teachers' use of inadequate teaching strategies. It was also found that the main cause of low achievement is teachers' use of teaching strategies that do not put the students at the center of the learning process (Attah and Nwagbo, 2024).

Class 2 reflected low engagement across all instructional strategies, suggesting a minimalist or disengaged teaching approach. However, Class 3 represented a diverse and active teaching profile, with frequent use of both traditional and individualized techniques. This finding aligns with the findings of Ballen (2020). The authors found that in order to ensure that instruction and assessment are not only successful but also interesting for a wider range of students, adopting pedagogical strategies that accommodate different learning styles are strongly recommended (Ballen, 2020; Ndikumana et al., 2024). Besides, the foundation of education is interactive teaching strategies, which determine how information is communicated, absorbed, and kept by students of varying needs (Shoimkulova and Yadigarova, 2024). In a similar study, it has been found through examining the teaching practices of many nations that creating curriculum objectives and essential competences with a variety of student options and media is essential to establishing agency for students' well-being (Jarrah, 2024). Finally, Class 4 demonstrated selective but frequent use of strategies like group work, audiovisual tools, and field trips, reflecting a more student-centered, exploratory teaching approach. In line with this finding, Anand and Rajendraprasad (2016) revealed that pupils have a variety of learning styles, with visual being the most common in elementary schools while other learning styles include auditory and kinesthetic. Nonetheless, kinesthetic and tactile learning modalities are typically preferred by college science students (Abu-Asba et al., 2014). Thus, incorporating group work, audiovisual technologies, and field trips can greatly boost student engagement and performance. In line with that, Barraket (2005) discovered that combining student-centered strategies with conventional teaching methods had a favorable impact on learning experiences and student performance. Also, the advantages of having students create peer-based audiovisual learning resources for direct practice courses were highlighted by Harrison et al. (2011). According to Todd and Goeke (2012), incorporating learner-centered teaching and student-led

Table 8
Logistic regression coefficients by sex (Reference = Class 2).

Group	Class	Odds Ratio	Coefficient	Std. Error	p-value
Group 1 (1983/1984)	Class 1/2	1.30	0.262	0.512	0.61
	Class 3/2	2.36	0.859	0.991	0.38
	Class 4/2	0.83	-0.186	0.577	0.74
Group 2 (2023)	Class 1/2	0.59	-0.527	0.398	0.18
	Class 3/2	0.98	-0.019	0.437	0.96
	Class 4/2	2.13	0.757	0.411	0.068

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 9
Logistic Regression Coefficients by Teaching Experience (Reference = Class 2).

Group	Class	Odds Ratio	Coefficient	Std. Error	p-value
Group 1 (1983/1984)	Class 1/2	1.10	0.095	0.432	0.82
	Class 3/2	0.62	-0.476	0.702	0.51
	Class 4/2	0.18	-1.71	0.298	< .001***
Group 2 (2023)	Class 1/2	0.74	-0.30	0.443	0.50
	Class 3/2	0.91	-0.094	0.481	0.84
	Class 4/2	1.74	0.554	0.392	0.16

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

field trips into a science course, enhanced students' content knowledge, communication abilities, and sense of community.

5.2. Temporal shifts in teaching styles

A major contribution of this study lies in its longitudinal, or more precisely: trend analysis. Measurement invariance testing indicated that the structure and meaning of teaching profiles significantly differed between 1983/1984 and 2023. The model allowing for measurement non-invariance yielded the best fit, suggesting that the latent constructs underlying teaching practices have evolved over time—likely influenced by reforms in teacher education, curricular policies, and broader educational discourse in Nigeria.

The distribution of teaching profiles changed dramatically over time. In 1983/1984, nearly all teachers (94.9 %) belonged to Class 1, relying heavily on traditional, teacher-led instruction. By contrast, in 2023, only 3.6 % of teachers belonged to this group. The most prevalent teaching style in 2023 was Class 4 (46.7 %), marked by more varied, student-centered strategies. The emergence and rise of Classes 2 and 3 in 2023 further reflect a broader diversification of instructional practices. These findings point to a clear pedagogical transformation—away from conventional, homogeneous methods toward a richer array of differentiated, learner-oriented approaches.

Nigeria has been creating novel approaches in the twenty-first century, mostly through sectoral and educational changes spurred by technology, yet execution has proven to be extremely difficult. Buttressing these findings, Hasrat (2024) found that given the constantly changing technological world, globalization, and a dynamic labor market, traditional educational paradigms that place a premium on standardized testing and rote memorization are no longer adequate. Ugwuanyi et al. (2025) demonstrated that teacher ambidexterity and a paradox mindset have significant direct effects on their creativity in the classroom. Besides, Ajadi (2024) cited the use of technology pedagogies such as student-centered approaches, collaborative learning, and gamification in education. Also, Hassan and Salihu (2020) suggested creative teaching strategies for chemistry education, such as cooperative learning and peer instruction. However, there are significant obstacles to these breakthroughs, such as limited finance, opposition to change, and limits in the technology infrastructure (Ajadi, 2024). The data points to a good future for innovation, but there are major structural obstacles to its broad adoption in Nigerian industries.

Therefore, in order to encourage the development of 21st century skills, teacher education institutions must reorient their structures and strategies (Gómez and Gómez, 2024). In a related study, it has been found that as a result of the new student-centered educational paradigm, the classroom environment and teaching methods have been redesigned to allow students to learn independently (Patiño et al., 2023). Furthermore, Patiño et al. (2023) stated that open education is associated with cooperative teaching methods in learning communities that support students' active learning and the growth of an exchange culture. As a result, a broader range of skills are required to study, communicate, collaborate, and solve problems in digital contexts or the twenty-first century (González-Salamanca, et al., 2020). Thus, Sarigöz (2024) asserted that a cycle of technology preservation, problem-solving, communication, critical thinking, teamwork, and creative teaching techniques is responsible for success in the twenty-first century.

Although there have been improvements in teaching methods and curriculum development (Bunmi et al., 2024), the Nigerian government has formed partnerships and federal universities of science and technology to improve STEM education (Agboola, 2021). STEM education in Nigeria has helped the country develop in areas such as health, agriculture, and telecommunications (Aina, 2022). However, it faces significant challenges, such as inadequate funding, lack of creativity and employability skills, poor teacher quality, and low research output (Aina, 2022). To address these challenges, stakeholders must concentrate on improving teacher training, updating curricula, integrating modern technologies, and fostering gender equity in STEM education (Bunmi et al., 2024; Agboola, 2021). These efforts are essential for bringing Nigerian STEM education into line with international standards and advancing national development. Thus, our current findings have implicated policy framework on the adequate training of teachers on the use of various innovative teaching strategies to meet the demands of the twenty-first centrury skills.

5.3. Demographic predictors of teaching style

The role of teacher demographics in shaping instructional styles yielded nuanced insights. Teaching experience was not consistently associated with class membership in either time period. However, in the 2023 sample, gender did not robustly predict teaching style. Male teachers showed at most a weak tendency regarding membership in the student-centered profile, and overall patterns were not statistically reliable, suggesting they may not systematically rely more on conventional instructional approaches than their counterparts. These findings align with literature indicating mixed or limited gender-based differences in teaching behaviors, potentially shaped by access to professional development, pedagogical beliefs, or structural biases within the education system (El-Emadi et al., 2019; Ahmed et al., 2021). Besides, Mofreh et al. (2021) found that teachers' practices were significantly impacted by demographic characteristics such as qualification, age, department, and tenure status. Also, Berhanu (2025) revealed that principals' pedagogical leadership styles were strongly associated with their age and length of service. Sebastian and Villa (2025) found that sex significantly influences teachers' teaching styles. In a related study, it was found that female medical practitioners were less likely to adopt expert and innovative teaching styles than males, while suitable teaching styles were more strongly supported by individuals with formal education backgrounds than by those without (Moy, 2025). Our current finding on gender differences in the adoption of teaching styles by science teachers aligns with the view of Bunmi et al. (2024), who found that persistent issues like gender disparities, resource inadequacies, and deficiencies in teacher training still persist among STEM educators.

In 1983/1984, however, no significant gender effects were found, possibly due to the lack of variation in instructional practice at that time. This finding is consistent with the work of Rao (2016), Ahmad et al. (2022), Berhanu (2025), Espada et al. (2025), and Bayirli (2025). Rao (2016) reported that demographic factors and instructional strategies did not significantly correlate. Additionally, Ahmad et al. (2022) showed that demographic factors—such as gender, region, experience, age, and qualification—had no significant impact on instructional behaviour. Similarly, Berhanu (2025) found that gender had no significant influence on teachers' pedagogical practices. It has also been reported that there was no significant difference in the use of teaching styles by gender (Espada et al., 2025; Bayirli, 2025). Corroborating these findings, Urhievwejire et al. (2025) found that gender has no significant influence on the teaching styles adopted by teachers.

5.4. Implications for practice and policy

The shift toward more varied and student-centred teaching in Nigeria is encouraging, particularly given policy emphases on twenty-first-century skills. At the same time, the persistence of a low-engagement profile suggests the need for sustained, system-level support to broaden pedagogical repertoires. Priority should be given to school-embedded professional learning—collaborative planning, coaching, and mentoring—that helps teachers translate reform messages into day-to-day practice. Because demographic effects were small and inconsistent, capacity-building should be offered broadly rather than targeted narrowly by gender or experience. Attention to material and organisational conditions (time, resources, leadership) remains essential for durable change.

5.5. Limitations and directions for future research

This study has several limitations that bound inference and external validity. Sampling in 2023. The 2023 data were collected under purposive, security-driven conditions. As such, the sample should not be treated as nationally representative of all Nigerian science teachers. Generalisations from the 2023 cohort should be made cautiously and with attention to potential coverage and selection constraints.

Cross-time comparability and non-invariance. Multiple-group LCA indicated that the latent profiles were not strictly invariant across periods. Profiles therefore index context-specific constellations of practice rather than identical constructs through time. Cross-time contrasts should be interpreted as trends in the configuration of practices rather than precise like-for-like changes in the same latent classes.

Reference category in multinomial models. The original regressions used a sparse reference class for the earlier cohort; all models were re-estimated using a non-empty class as the reference to improve stability and interpretability. While this correction strengthens within-cohort comparisons, direct comparison of regression contrasts across periods should be treated cautiously because estimates are conditioned on cohort-specific class structures.

External validity. Findings pertain to science education in Nigeria under the study's sampling and measurement conditions and may not generalise to other subjects, phases, or countries. In addition, all indicators are self-reported frequencies of practice, which may not fully capture instructional depth or quality, and the design spans two time points rather than a continuous panel.

Future work should combine probability-based sampling where feasible with classroom observations and mixed-methods designs; incorporate design-based or Bayesian approaches for sparse categories; strengthen longitudinal comparability via anchoring strategies and rigorous invariance testing; and examine how organisational supports (resources, leadership, professional learning) enable teachers to sustain student-centred practice at scale.

Despite these limitations, the study provides rare evidence on how instructional practice has evolved and where support is most needed, offering actionable guidance for policymakers and teacher-education providers seeking to consolidate Nigeria's pedagogical transition.

CRediT authorship contribution statement

Ugwuanyi Christian: Writing – review & editing, Writing – original draft, Validation, Project administration, Investigation, Funding acquisition, Data curation. **Eryılmaz Nurullah:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Marcus Pietsch:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Informed consent statement

Before the commencement of the data collection, all the participants were served with written informed consent forms dated 1st September 2023. These consent forms were written by the researchers. The participants were requested to read and sign the consent forms to ensure that they consented to full participation in the research. The scope of the consent covered the participation of the participants, data usage and consent to publish. All the participants were fully informed that their anonymity was assured, why the research is being conducted, how their data would be utilised, and if there were any risks to them of participating in the research.

Ethical approval statement

The Faculty of Education, University of Nigeria, Research Committee on Ethics granted ethical approval for the conduct of this research. We confirm that every aspect of this research was done in accordance with the University of Nigeria guidelines on research involving human participants. The ethical approval number for this research is REC/FOE/2024/00053, which was issued on 23rd August 2023. The scope of the approval covered research on school leadership of principals and teachers' teaching practices.

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Declaration of Competing Interest

We do not have any competing interest.

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