




Research Article

The impact of COVID-19 pandemic on the learning preferences of public universities' undergraduates: The case of Nigeria

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The COVID-19 pandemic prompted the introduction of two new learning modes—remote and blended—within Nigerian higher education, which have important implications for pedagogical practices, particularly in the delivery of technical subjects such as mathematics. This study critically evaluates the influence of these emergent learning modes on the preferences of undergraduates in Nigerian public universities, with a specific focus on mathematics instruction. Employing a case study methodology, one of Nigeria's oldest and largest public universities, which adopted remote and blended modes alongside the traditional face-to-face approach, was examined. A structured survey, administered to 314 respondents was analyzed using the Borda count technique. The empirical findings reveal a discernible shift in learning preferences, with the blended mode emerging as the most favoured, superseding face-to-face learning, while the remote mode was the least preferred. These results underscore the evolving nature of educational preferences among Nigerian undergraduates, particularly the growing appeal of hybrid learning environments. Furthermore, the study reaffirms the indispensable role of face-to-face interaction in the comprehension of mathematics. The findings suggest that future educational policy frameworks should prioritize the integration of both online and traditional learning modalities to optimize the delivery of mathematics education in public universities.

Keywords: Africa, blended learning, borda count, face-to-face learning, remote learning

1. Introduction

The outbreak of COVID-19 pandemic and its containment measures such as school closure caused a wide-scale disruptions and learning losses in educational sectors. The case of Africa is peculiar and worth investigating for several reasons.

First, pre-COVID, developed countries had incorporated various forms of remote learning in their education delivery system; hence it was relatively easier for them to adjust and transit to remote learning during the outbreak (Ogenyi, 2022). Africa, on the other hand, was characterized by inadequate infrastructure prior to the outbreak (Ogunyinka et al., 2015), it therefore lacks basic sophisticated digital tools for education delivery. In addition, most lecturers were ill-prepared, in terms of the pedagogy and the mastery of digital tools required for remote learning (Bouhnik & Deshen, 2014); hence the challenges of transition were greater in Africa and so were the levels of disruption to its educational sectors. In Nigeria, the most populous African country, for instance, a national longitudinal phone survey was conducted in April 2020 by the National Bureau of Statistics. It involved a sample of 1,950 households. The survey showed that from March 2020 when schools were closed, most students were disconnected from the school system and about 38% of them did not participate in any educational activities. It took six months for public universities to resume learning remotely during the outbreak.

Second, in contrast to the advanced countries, the modes of learning that were adopted in African universities were limited due to inadequate education and technology infrastructure. In the first instance, only one mode was available to every student taking a particular course as opposed to advanced countries where students could choose among face-to-face [F2F], remote and

blended modes (Maphosa et al., 2020). In the second instance, learning platforms were restricted to those which were easy to use and consumed low data. The Whatsapp social networking platform, in particular, became the popular choice due to its low data consumption and ease of use (Yeboah & Dominic, 2014). With little or no training, lecturers could deliver voice notes that were accessed by the students at their convenience without geographical boundaries (Bouhnik & Deshen, 2014). Free remote learning platforms such as Google classroom were also adopted in some cases. Live sessions on such platforms were restricted to classes of less than 100 students per lecture; lecturers of large classes would usually make videos to post on the Google classroom (Maphosa et al., 2020). This was in contrast to the advanced countries which were already experimenting with pen-based technologies prior to the outbreak (Karal et al., 2015).

Lastly, previous studies on similar subject were mostly concentrated in advanced countries (Betthausen et al., 2023), and little or nothing was known about the developing countries. Some studies conducted in Asia (e.g. Asio et al., 2021; Asio & Bayucca, 2021; Gadia et al., 2021; Paguio et al., 2021). Birkelund and Karlson (2023) stressed the need to obtain evidences from other countries because these disruptions and losses may vary by country. These variations may arise from disparities in educational structure and technology advancement level in each country. It is therefore important to obtain additional information from other countries to gain comprehensive understanding of the impact of the pandemic on education. Such information is also important for policy makers in each country to provide country-specific solutions tailored towards their peculiar needs.

The fourth sustainable development goal of the United Nations released in 2015 stipulated that quality education should be accessible to all, regardless of geographical locations. In order to achieve this in technologically-lagging countries, studies investigating COVID effect under the afore-mentioned peculiarities and challenges must be encouraged because they could provide new insights on education and its delivery. Knowledge on the learning preference of students pre- and post-COVID could also assist policy makers to make evidence-based decisions on future directions in education delivery. Our extensive search however revealed that there were no such studies yet in Africa.

This study therefore examined the effect of the pandemic on the learning preferences of undergraduates in public universities in Nigeria. In particular, we investigated whether or not students now prefer the new learning modes introduced during COVID to the conventional face-to-face which was in use prior to the pandemic for learning mathematics. In other words, the study attempted to answer the question, did the new learning modes introduced during COVID change learning preferences of undergraduates for learning mathematics in public universities in Nigeria?

This all-important question was answered in the framework of preference aggregation and voting theory. We imported Borda count [BC] technique from the decision-theoretic literature to provide a consensus mode of learning. Saari (2023) assured that, among all social choice rules, only the Borda count preference aggregation method could produce an outcome that would accurately reflect the wish of the respondents. BC had been effectively applied in real-life collective decision-making scenarios such as sports (Mukadi, 2023). In the twentieth century, it was incorporated in artificial intelligence (Arrow et al., 2002) and also in sentiment analysis to enhance accurate extraction of opinions and views from textual expressions (Grandi et al., 2016).

Our study has important implications for education and political science literature. In the educational sector, it would provide comprehensive understanding on the evolution of education in Africa, which would assist in policy making on education delivery in future. In political science, our study provided an avenue and a pioneer attempt to demonstrate the appropriateness and wide applicability of the Saari's (1994) geometric approach to collective decision-making in education.

2. The Concept of Remote Learning and Online Learning of Mathematics

According to Singh and Thurman (2019), the concept of remote learning allowed students to learn and interact with their lecturers using technology and internet regardless of their geographical

location. Remote learning was sometimes used interchangeably with online learning (Haser et al., 2022). It was also similar to distance learning except that online platforms were used (Oblinger & Oblinger, 2005). Learning could be in synchronous or asynchronous setting. The synchronous setting consisted in live and real-time interactions between students and lecturers whereas in asynchronous setting students accessed lecture materials and provided feedbacks at their convenience (Dhawan, 2020). A mix of face-to-face (F2F) and remote learning approaches was termed blended learning (Gadia et al., 2021).

The notion of remote learning should not be confused with electronic learning (e-learning); the latter involved learning through technology and digital tools in F2F setting or remotely (Eze et al., 2018). Electronic learning provided the benefit of virtual teaching, online learning, remote learning and mobile learning (Maheshwari & Thomas, 2017). In essence, online learning takes place at one's convenience, overcoming all geographical difficulties.

Studies had shown that students preferred to learn through social networking sites than face-to-face in classrooms as they enjoyed the collaboration and the continuous learning offered through technology (Ali Ta'amneh, 2017; Amry, 2014). However, the extant literature was also aware of the relative difficulty inherent in online teaching of mathematics compared to other non-technical subjects. Unlike online learning, face-to-face setting offered the benefit of full interaction between teacher and student; in addition, a student sees mathematical symbols and concepts displayed in teacher's handwriting; these are also well-explained by the teacher in a fully interactive atmosphere (Jin, 2023). Developed countries had tried to overcome this difficulty by infusing pen-based technologies in online learning to enhance sufficient interaction between teacher and students (Karal et al., 2015). The COVID-19 experience was a reminder to every country that, regardless of their level of technology infrastructure, learning should be allowed to evolve continuously in order to make it attractive and accessible to students regardless of their orientation and geographical location.

2.1. Remote Learning and COVID-19

Previous studies had focused on the readiness for online learning and challenges faced as a result of the emergency transitioning to remote and blended learning during the coronavirus pandemic. To our knowledge, all of these studies were concentrated in continents outside Africa and were reviewed in what follows.

At the first wave of the pandemic there were concerns that teachers of technical courses such as mathematics may not be able to teach effectively as they would in face-to-face setting given the symbols and formulas inherent in them (Cassibba et al., 2021). There were also concerns that most lecturers were ill-prepared, in terms of the pedagogy and the mastery of digital tools required for online learning. However, using both quantitative and qualitative approaches, Cassibba et al. (2021) found that Mathematics lecturers at the Sicilian State University adapted well during the period as they were able to effectively utilize digital tools which provided an almost equivalent experience as their blackboards in the F2F mode.

From students' perspectives, Vishnu et al. (2022) also examined the digital literacy level of 833 students offering undergraduate and postgraduate programmes in an agricultural university during the pandemic in readiness for digital learning. The study found that most of them had satisfactory level of competence to effectively participate in online learning. In addition, most of them accessed learning materials through their smartphones. A similar submission was given in Asio et al. (2021) which assessed the availability of internet connections and learning devices among college students in Central Luzon, Philippines. Their study, which surveyed 2,894 students, found that 70% had internet access and that smartphones were the primary learning device. Kamalipour and Peimani (2022) however opined that more attention should be given to teaching pedagogy than digital competence. Students' preferences of learning mode and vaccination status were the major point of investigation in Gadia et al. (2021). The study was conducted at a tertiary institution in Olongapo City, Philippines. Though the findings revealed that 94.7% of students preferred online learning, their preferences were however significantly unrelated to their

vaccination status. The study stressed the need to continue and enhance flexible learning options beyond the pandemic era.

The broader impact of the pandemic on institutions was explored by Paguio et al. (2021), who examine the challenges and opportunities faced by a local college. The study, which includes input from both teaching and non-teaching staff, emphasizes the need for well-structured transition plans to maintain educational quality. The findings suggest that while the pandemic has posed significant challenges, it has also presented opportunities for innovation in educational practices. Asio and Bayucca (2021) also conducted a study involving 36 administrators from a school division in Bulacan, Philippines, to evaluate the digital competence of school administrators and the overall readiness of educational institutions. Their findings revealed varied levels of digital competence among administrators and indicated that schools were generally unprepared for distance learning. Internet connectivity was identified as a major challenge, alongside issues related to preparation, funding, and devices.

Studies measuring challenges faced due to emergency transitioning also involved teachers' and students' perspectives. From the teachers' view, Colclasure et al. (2021) surveyed 14 faculty members of certain undergraduate institutions in United States and identified two major challenges; these include ease of access to technology and mental health. On the other hand, Aljedaani et al. (2021) investigated the online learning experiences of deaf students in the college of the Technical and Vocational Training Corporation in Saudi Arabia. The study identified inadequate internet access and online learning support as major challenges encountered by this group of students.

2.2. Remote Learning of Mathematics in Nigeria pre- and during COVID

Up until the coronavirus pandemic in 2020, college mathematics was taught in F2F setting in most African countries, including Nigeria (Eze et al., 2018). Though most public tertiary institutions had information and communication technologies [ICT] units, majority of them were used as web centres for administrative purposes and entrance examinations (Salawudeen, 2006); not many of them served to promote e-learning in the institutions. Despite various interventions by the World Bank and other international bodies, e-learning facilities in Nigeria were still grossly inadequate for public universities to incorporate e-learning in their education systems.

In its study, Chiaha et al. (2013) found that only approximately 43% of the students surveyed could access e-learning facilities; and most of those who accessed the facilities only had access to email accounts. Atsumbe et al. (2012) also reported that most students in a Nigerian institution who had computers and internet access did not use them for learning purposes. Lecturers, on the other hand, use theirs mainly for research. The inadequacy of learning materials also extended to distance learning institutions. Aboderin (2015) in a study of the availability, utilization and prospects of e-learning facilities in the National Open University of Nigeria reported that the institution lacked adequate digital tools, internet access and power supply to promote quality e-learning. The study however, admitted that e-learning promotes digital competence among the students.

Despite numerous infrastructural challenges facing public universities in Nigeria, the country took the initiative to adopt remote learning during COVID. Students were exposed to two more learning approaches - remote and blended - in addition to the F2F that had been. Due to its low level of data consumption, the Whatsapp social networking platform was mostly adopted in classes of 100 and more. Lectures were also delivered live to classes of 100 and less through free platforms such as the Google Classroom. In other cases, lecturers made videos and voice notes and share them asynchronously by Whatsapp and Google platforms. In addition, practicals and tutorials were conducted face-to-face. Thus a course with lecture and tutorial components, and one with lecture and practical components would be taught in blended mode whereas one with only lecture component was taught in remote mode. Students of a particular course were only allowed one mode of learning.

3. Method

3.1. Research Design

This paper adopted a case study approach. Timmons and Cairns (2010) emphasized the significance of case study approach in educational research: it equips teachers with various experiences to enable them cope effectively with various educational scenarios, thereby improving their teaching skills and also promoting high quality of education in their students. A case study approach was appropriate in this context because the learning pattern in public universities were similar as they were being regulated by a central body; that is, the Federal Ministry of Education through the National Universities Commission. In addition, the admission procedure practiced in Nigeria was such that each federal university was a cluster of all categories of students that could be found in the country. Insights gained from this study could therefore be easily extended to other public institutions.

3.2. Participants

The study area was one of the oldest and largest public universities in Nigeria situated in the South-West region. Prior to the pandemic outbreak in 2020, the selected institution, just like every other public university, operated a face-to-face mode of learning for all courses, including mathematics. The total population involved one thousand, six hundred and seventy-seven (1,677) students who had been exposed to the three modes of learning. The finite population correction formula was used to obtain a sample size of 314. The chosen error margin was 0.05; giving a z value of 1.96. Proportion was fixed at 50%.

Demographic characteristics of the respondents were displayed in Table 1. We observed that all possible categories in the population were represented in the data collection process. The sampling therefore truly represented all members of the target population. In addition, it was no surprise that most of the students fell within the age range of 18 - 30 years: The 6-3-3-4 system of education adopted in Nigeria was such that a child would spend 6 years in the primary; 3 in the junior secondary; 3 in the senior secondary and 4 in the tertiary institution, on the average. The original level of education of the target population was 300 levels. A student at this level of education was expected to fall within 18 - 30 years.

Table 1
Distribution of respondents by categories

<i>Category</i>	<i>f</i>	<i>%</i>
Gender		
Male	159	50.6
Female	155	49.4
Age		
Below 18	4	1.3
18-30	290	92.4
Above 30	20	6.4
Leves		
300L	187	59.6
400L	127	40.4

3.3. Data Collection

A questionnaire was developed based on the study objectives and divided into two sections: Section A contained three questions on the demographic characteristics of the respondents such as gender, age and level of study; Section B required the students to rank the three modes of learning - face-to-face, remote and blended - in order of their preferences.

The instrument was face-validated by an expert who was a professor of Statistics and holds almost two decades of teaching and research experience in the field. All suggestions given by the expert were incorporated before the questionnaires were administered. The revised version was

presented in Google forms (an application developed for remote surveys) and the link was sent out to the forums of relevant students through WhatsApp. The process was discontinued after a total of 314 valid responses were received. The time stamp for the responses was between April 10, 2023 and May 15, 2023. For ethical considerations, all respondents were willing participants and were given assurances of the confidentiality of the information they supplied before they filled the forms.

3.4. Data Analysis

The major objective of this research was to determine the most preferred order of preference among the three modes of learning (face-to-face; and the two newly-introduced modes - remote and blended) in public universities in Nigeria. It is very important to ensure that the outcome effectively reflected the intent of the respondents and enable them to choose a consensus option from the three alternatives (Saari, 2023). We therefore adopt the voting rule from the decision theory literature. Voting was a social choice rule which had been applied in a wide range of decision-making contexts such as in sports (Mukadi, 2023), artificial intelligence (Arrow et al., 2002), sentiment analysis (Grandi et al., 2016) and politics (Tabarrok & Spector, 1999).

The study survey involved 314 respondents, R who expressed preferences on a set of alternatives,

$$A = \{F, R, B\}. \quad (1)$$

where $F = Face - to - face$, $R = Remote$, and $B = Blended$.

A rule V was applied on the preferences and the alternatives to determine a consensus option. The most common approach in decision theory was to specify preference as a linear order over A ; that is, a binary, anti-symmetric and transitive relation over A (Grandi et al., 2016).

The choice of each of the 314 respondents was represented in a preference relation $<_i$ in a profile of preferences

$$P = (<_1, <_2, \dots, <_{314}) \quad (2)$$

where $a <_i b$ denoted that respondent i preferred option b to option a in P . For instance, suppose the second respondent filled out his preference ballot as follows:

$$F <_2 R <_2 B, \quad (3)$$

this implied that Respondent 2 preferred Blended as his first choice; Remote as his second choice; and Face-to-face as his third choice. Each student was asked to rank the three options in Equation (1) in his order of preference (as in (3)), and the 314 preference orders were collected in P as shown in Equation (2). A Preference schedule was then constructed from the orders in P . A preference schedule is a table used to organize the preference ballot filled out by each of the respondents (Reilly, 2002). V associated a non-empty subset of preferred candidates $V(P) \in 2^A \setminus \emptyset$ with every profile P (Grandi et al., 2016).

Various decision rules had been introduced in decision-theoretic literature, (see for instance, Brams and Fishburn (2002) for a comprehensive list). The most widely used in real-life applications was the Borda count rule proposed by Jean-Charles de Borda (Mukadi, 2023). In this context, it allowed a respondent to make observations on all alternatives, and utilized all the given information to assign an option with best average ranking (Saari, 2023). The decision rule was defined as follows:

Given a linear order $<_i$, for each $r \in R$, the Borda count rule associated with each alternative $a \in A$ one and only one point for each alternative that is ranked below a in $<_i$. These points were then aggregated over all respondents. The alternative(s) with the highest overall score was (were) declared the best (Grandi et al., 2016).

Borda count rule was a widely studied method which had been applied to different preference aggregation scenarios such as preference order involving ties (Fagin et al., 2003) and partial orders (Fagin et al., 2006). A major criticism against Borda count was advanced by Marquis de Condorcet (Saari, 2023). The Condorcet approach involved an exhaustive pairwise comparison between the given candidates. While Borda count method would always lead to a definite winner, the probability of getting a "Condorcet winner" decreases as the competing candidates increases

(Reilly, 2002). There also was the Arrow's (1963) impossibility theorem which stated that with three or more alternatives, no decision rule could satisfy all fairness criteria. Saari (2023), in a recent study, showed that this statement was "not accurate".

4. Results

The preference schedule generated from the students' responses to section B of the questionnaire was placed in Table 1.

Table 1

Preference schedule for different modes of learning

No. of votes	52	59	47	43	58	55
1 st choice	F	F	R	R	B	B
2 nd choice	R	B	F	B	F	R
3 rd choice	B	R	B	F	R	F

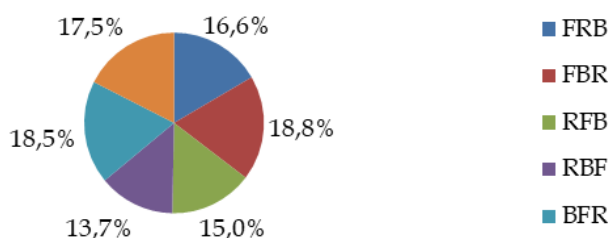
Note. F=Face-to-face, R=Remote, B=Blended.

Column 2 of Table 1 indicated that 52 out of 314 students who participated in the survey filled their preference ballot as $B < R < F$; that is, $16.6\% \left(= \frac{52}{314} \right)$ of the respondents preferred Face-to-face (F) followed by Remote (R) and then Blended (B) mode of learning. Similarly, Column 6 of Table 1 showed that the highest percentage, $18.8\% \left(= \frac{58}{314} \right)$ filled preference order $R < F < B$. And finally, Column 5 of Table 1 showed that the least percentage, $13.7\% \left(= \frac{43}{314} \right)$ preferred the order $F < B < R$.

The information provided in Table 1 was displayed in a pie chart in Figure 1.

Figure 1

Chart illustrating the preference schedule



Following the geometric approach discussed in Saari (1994), we observed that the ranking displayed in Table 1 uncovered some interesting patterns: If there were just two modes of learning then the option with more than 50% of the votes would clearly be more preferred. But in this case of three options, the decision was not a straight-forward one. As shown in **Hata! Başvuru kaynağı bulunamadı.**, on the first look, R was ranked first by 90 (= 47 + 43) students, B was ranked first by 113 (= 58 + 55) students and F by

Table 3

Analysis of Table 2

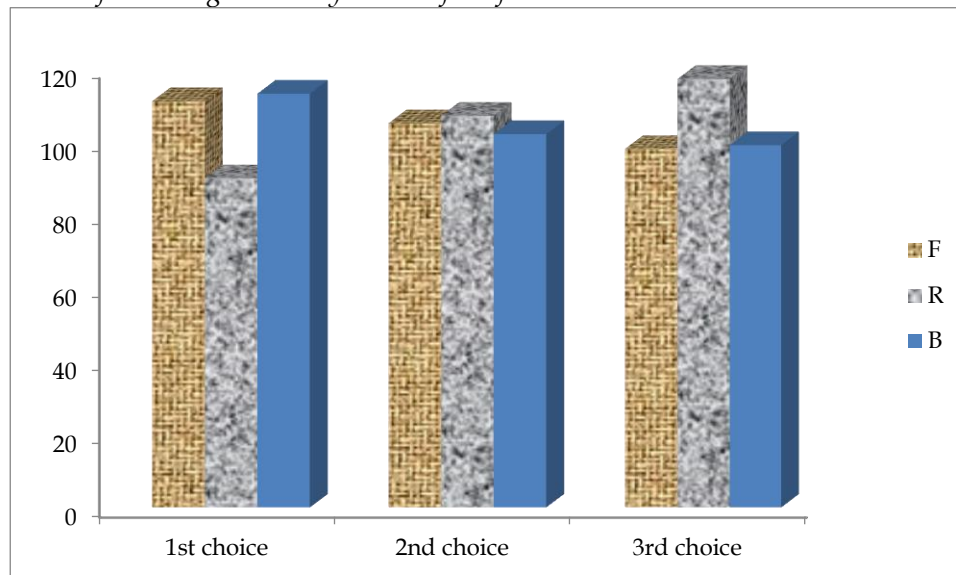
	Modes		
	F	R	B
1 st choice	52	47	58
	59	43	55
2 nd choice	47	52	59
	58	55	43
3 rd choice	43	59	52
	55	58	47

Note. F=Face-to-face, R=Remote, B=Blended.

111 (= 52 + 59) students. Thus, *B* appeared to be the most preferred choice as it was ranked first by most students. However, **Hata! Başvuru kaynağı bulunamadı.** also showed that *B* received the lowest votes in the 2nd choice. Further, while most respondents ranked *B* first, more than one-third of them ranked *R* last; *R* therefore did not appear to be a popular option. However, *R* also had the highest votes in the 2nd choice. See a pictorial representation of the analysis in Figure 2.

Figure 2

Chart of Learning Modes by Order of Preference



Further, comparing each of these three modes in a pair wise manner also showed an interesting pattern. Saari (2023) showed that all of these were taken into consideration in the Borda count method.

4.1. Computation of Borda Scores

From **Hata! Başvuru kaynağı bulunamadı.**, the Borda score (BS) for Face-to-face mode, *F* was computed as follows:

111 respondents selected *F* in the 1st choice;
 105 respondents selected *F* in the 2nd choice;
 98 respondents selected *F* in the 3rd choice.

Award first choice 2 points; second choice 1 point; and third choice 0 point; so that *F* had a Borda Score (BS) of;

$$BS(F) = (111 \times 2) + (105 \times 1) + (98 \times 0) = 327 \text{ votes,}$$

Similarly, Remote mode, *R* had;

$$BS(R) = (90 \times 2) + (107 \times 1) + (117 \times 0) = 287 \text{ votes,}$$

and Blended mode, *B* had;

$$BS(B) = (113 \times 2) + (102 \times 1) + (99 \times 0) = 328 \text{ votes.}$$

The Blended mode, having the highest Borda score of 328 votes was therefore declared the most preferred choice by the respondents; however it is noteworthy that the F2F mode fell short of being the most preferred by just 1 vote. In addition, Borda score for Remote mode also showed that it trailed the two other options by at least 40 votes. It was clearly the least preferred. In summary, the preference outcome chosen by Borda count was:

$$R < F < B$$

4.2. Analysis of Preference by Demographic Characteristics

Table 2 referred to the respondents' order of preference by demographic characteristics. Of all the 159 male respondents, the highest percentage (almost) equally preferred the face-to-face and blended modes whereas, the highest percentage of the females surveyed (almost) equally preferred the remote and F2F modes. Moreover, ranking by levels showed that most of the 400 level students preferred the face-to-face mode whereas the highest percentage of the 300 level students ranked the blended mode as their 1st choice. Most (92%) of the respondents fell within the age range of 18 - 30 (See Table 1), and Table 2 showed only slight difference in their preferences for F2F and blended modes; whereas more than 50% of the adults (>30yrs) preferred the face-to face approach.

The *p*-values of the Chi-square test conducted for each demographic characteristic was displayed at the last column of Table 2. From the values we inferred that, at the 5% level of significance, the preferences of the students only differed by age since $p < .05$.

Table 2

Distribution of order of preference by demographic characteristics

<i>Demographic characteristics</i>	<i>Remote (in %)</i>	<i>F2F (in %)</i>	<i>Blended (in %)</i>	<i>Chi-sq test p-value</i>
Gender				
Male	28.3	36.5	35.2	0.43
Female	36.1	35.5	28.4	
Level				
300L	31.0	33.2	35.8	0.31
400L	33.9	40.2	26.0	
Age				
Below 18	50.0	50.0	0.0	< .01
18-30	32.1	34.5	33.4	
Above 30	30.0	55.0	15.0	

5. Discussion

The empirical findings reveal a discernible shift in learning preferences, with the blended mode emerging as the most preferred. The respondent's preference for blended mode may reflect the need for students to have structured in-person sessions to grasp complex concepts, while also benefiting from the flexibility of online resources for independent study. This result supports the notion that students see blended learning as a way to enhance both flexibility and effectiveness in mastering challenging content.

Several studies post-COVID-19 had documented a shift in students' learning preferences, similar to our findings, where blended learning has become more prominent. Research by Jin (2023) indicated that students became more receptive to flexible learning environments after experiencing remote education during the pandemic, but also expressed a strong desire for the social and academic engagement offered by in-person learning. A study by AbiRaad and Odhabi (2021) on blended learning also reported that students favoured hybrid models due to the flexibility and convenience of online learning, combined with the engagement and structure of face-to-face interactions. This preference for blended learning, particularly for technical subjects, suggested that students value the balance between autonomy and support. Gadia et al. (2021) also emphasized student preferences for online learning and high vaccination rates. Our findings extended this by showing that among Nigerian undergraduates, the blended learning mode was preferred over other modes of learning, which suggests a nuanced view of student preferences.

The shift in preference from face-to-face to blended learning among Nigerian public university students mirrored global trends where students increasingly sought the flexibility of online learning without completely abandoning the benefits of traditional classroom instruction. This shift indicated an evolving educational landscape where hybrid models were likely to be the

preferred path forward in higher education.

The recognition in this study of the continued importance of face-to-face interaction in mathematics education was supported by numerous studies emphasizing the need for personal engagement, especially in technical disciplines. Jin (2023) highlighted that face-to-face learning remained crucial for subjects requiring immediate feedback and collaborative problem-solving, which were harder to replicate in online environments. This underscored the idea that while blended learning was favoured, students still valued traditional in-person learning for more intricate, interactive elements of mathematics. Our findings reinforced the argument that personal interaction with instructors was irreplaceable in certain contexts, especially for immediate clarification of doubts or difficult concepts.

We also found that remote learning was the least preferred mode. The decreased preference for remote learning in mathematics could be attributed to the challenges of understanding abstract mathematical concepts without direct access to instructors and peers (Kalogeropoulos et al., 2021). This aligned with studies that pointed to the limitations of remote learning in fostering critical thinking and in-depth understanding in technical fields like mathematics (Almarashdi & Jarrah, 2021; Sullivan et al., 2020).

Our findings about the preferences of Nigerian students must also be viewed in the context of research highlighting the digital divide in developing countries. Studies, such as that by Igboeli and Bisallah (2021) showed that technological infrastructure issues – like poor internet connectivity and limited access to devices – were significant barriers to the widespread success of remote learning in Nigeria. This could partially explain the lower preference for remote learning in our study, as students may struggle with the practical challenges of fully online education. Finally, the study also found that out of three demographic factors tested, age was the only significant determinant of the students' choices. This inference was in agreement with Adeoye and Adeoye (2017) who earlier noted that certain factors such as age could affect the level of digital literacy of undergraduates.

6. Conclusion

The unpleasant event of COVID-19 forced all public universities in Nigeria to abandon the face-to-face mode being practiced for a long time for the newly-introduced remote and blended modes. The study examined the effect that this decision may have had on the learning preferences of the public universities' undergraduates in Nigeria. A case study approach was adopted. The target population was a sample of undergraduates of a renowned first generation university in the South-West who had been exposed to the three modes of learning. The Borda count method was used to analyze data. Our result showed clearly that new learning approaches introduced during COVID had indeed changed the learning preferences of undergraduates of public universities in Nigeria. Students' learning preferences had shifted towards blended mode following their education experience during COVID.

Our study aligned well with global research that showed a growing preference for blended learning models, particularly for technical subjects like mathematics, while also highlighting the limitations of fully remote education. It emphasized the enduring need for face-to-face interaction in complex learning scenarios, consistent with findings from recent studies. Furthermore, our work contributed to understanding the technological challenges and regional specificities that influence learning preferences in Nigerian higher education, echoing similar studies from developing regions.

While the study made important contributions to the evolution of higher education in terms of the modes of delivery, it did not measure the actual effectiveness of remote, blended, and face-to-face modes in terms of student performance or learning outcomes in mathematics. Thus, it was unclear whether the preferred modes led to better academic results. However, the study provided a snapshot of learning preferences which was essential in efficient delivery of educational instructions in higher institutions.

7. Recommendations

While the pandemic had posed significant challenges, it had also presented opportunities for innovation in educational practices (Paguio et al., 2021). Based on the results and conclusions of the study we made the following recommendations:

➤ The preference for blended learning highlighted the need for education policymakers to formally integrate hybrid learning models into university curricula. Policies should encourage a combination of online and face-to-face learning for technical subjects like mathematics, allowing students to benefit from both the flexibility of online learning and the interpersonal engagement of traditional classroom settings.

➤ Given the growing preference for blended learning, there is an urgent need to improve digital infrastructure in public universities. Policymakers should prioritize investments in high-speed internet access, modern educational technologies, and digital literacy programs to ensure that both students and faculty have the tools necessary to engage effectively in blended learning environments.

➤ While policymakers continue to intensify efforts to improve on technological infrastructure, some immediate resolutions could be taken immediately to enhance online learning. For instance, the ICT centres that were mostly restricted to serve administrative purposes in public tertiary institutions in Nigeria could be effectively utilized.

➤ To facilitate the successful implementation of blended learning, policies should include comprehensive training programs for university educators. Faculty members need to be equipped with the skills to deliver online content effectively while maintaining the benefits of face-to-face instruction, particularly for complex subjects like mathematics.

➤ The results emphasize the need for policymakers to adapt curricula for technical subjects, such as mathematics, to better suit blended learning environments. This may involve rethinking how certain concepts are taught, incorporating interactive online tools, and finding the right balance between independent online study and structured in-person sessions.

➤ Universities should be encouraged to adopt flexible learning policies that allow students to choose learning modes based on their preferences and learning styles. The government could promote policies that facilitate student-centered learning pathways, particularly in mathematics and other technical subjects where blended learning is shown to be effective.

➤ Education policies should include mechanisms for regularly assessing the effectiveness of blended and remote learning approaches. This would involve continuous monitoring of student performance, learning preferences, and the overall impact of hybrid learning models on educational outcomes. Feedback from these evaluations should be used to refine policies and practices.

➤ While blended learning was favoured, our findings underscored the importance of face-to-face interaction in mastering complex subjects like mathematics. Policies should ensure that in-person components of blended learning are carefully structured to maximize interaction, problem-solving, and immediate feedback in ways that online platforms cannot replicate.

➤ The current study had provided feedback on emergency remote teaching from students' perspective. In future research, it may be interesting to examine this same subject from the teachers' perspective for a comprehensive understanding of the evolution of education in Nigeria. In addition, further study could measure the actual effectiveness of remote, blended, and face-to-face modes in terms of student performance or learning outcomes in mathematics to ascertain whether the newly-introduced modes led to better academic results.

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Data availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of interest: The authors declare that no conflicts of interest occur.

Ethics statement: The authors also declare that approval was sought from the student participants and they were also assured of the confidentiality of the information provided before carrying out the research.

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