

From Virtual to Classroom: A Within-Student Comparison of Engagement, Interaction, Perceived Learning and Satisfaction across Online and Face-to-Face Computer Instruction

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Research Article

Keywords: online learning, face-to-face instruction, student engagement, interaction, perceived learning, satisfaction, blended learning, higher education, Nigeria

Posted Date: October 21st, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11001274/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background

Higher education has retained online learning alongside renewed face-to-face instruction, yet many comparisons rely on different student groups and provide limited evidence from resource-constrained settings. This study examined within-student differences in engagement, interaction, perceived learning and satisfaction after the same accessible student cohorts experienced online computer instruction in one semester and face-to-face computer instruction in the subsequent semester.

Methods

A retrospective within-subject comparative survey was conducted among undergraduate students drawn from accessible cohorts in the researchers' institution. Of 483 eligible students, 399 responded (82.6%), and 394 met the prespecified analytic eligibility criteria of informed consent and exposure to both instructional modes. Data were collected with the Online and Face-to-Face Computer Instruction Experience Questionnaire (OFCIEQ), comprising matched six-item domains for engagement, interaction, perceived learning and satisfaction. Psychometric evaluation included expert content validation, split-sample exploratory and confirmatory factor analyses, and longitudinal measurement-invariance testing across instructional modes. Substantive analyses used paired-samples *t* tests, Holm-adjusted multiplicity control, Cohen's *d*_z, non-parametric sensitivity analyses and a 2 × 2 mode-by-gender mixed comparison.

Results

The four-domain measurement structure showed a clean theory-specified exploratory pattern, with primary loadings from .607 to .920 and no cross-loading ≥ .30. Confirmatory factor analyses showed acceptable-to-good fit, particularly in the full sample (online: CFI = .948, TLI = .942, RMSEA = .080, SRMR = .035; face-to-face: CFI = .962, TLI = .957, RMSEA = .070, SRMR = .024). Longitudinal metric and scalar invariance were supported by minimal changes in fit indices ($\Delta\text{CFI} \leq .003$). Face-to-face instruction received higher ratings than online instruction for engagement (*M* = 4.24 vs 4.09; *d*_z = 0.21), interaction (4.26 vs 3.73; *d*_z = 0.52), perceived learning (4.23 vs 4.01; *d*_z = 0.27), and satisfaction (4.16 vs 3.86; *d*_z = 0.31), all Holm-adjusted *p* < .001. The overall mode effect was moderate (*d*_z = 0.41), while the mode-by-gender interaction was negligible and non-significant (*p* = .987). Internet connectivity, data cost and electricity/device problems were common online barriers, yet 69.0% valued online flexibility and 70.1% preferred a blended option.

Conclusions

The findings do not support a simple online-versus-classroom dichotomy. Face-to-face teaching was particularly advantageous for interaction, with smaller gains in engagement, perceived learning and satisfaction, while online instruction retained a valued flexibility advantage. A deliberately blended model that protects interactive face-to-face teaching while preserving purposeful online components may fit the learning and infrastructural realities of similar settings.

1. Introduction

The post-pandemic higher-education landscape is no longer defined by a binary choice between online and face-to-face teaching. Institutions increasingly need to decide which learning activities should remain digital, which require physical presence, and how the two can be combined without sacrificing engagement, interaction or learning quality. Student engagement is multidimensional and consequential for learning, retention, satisfaction and academic success; importantly, recent measurement work supports assessing engagement across face-to-face, blended and online course modalities (Heilporn et al., 2024). Likewise, a generic engagement scale developed for both online and face-to-face higher education identifies teacher–student interaction, cognitive strategy use, self-regulated learning and experienced emotion as important components of the student experience (Li et al., 2023).

The Community of Inquiry (CoI) framework provides a useful theoretical lens for understanding why instructional modality may shape experience. CoI conceptualises meaningful learning through the interdependence of teaching presence, social presence and cognitive presence (Garrison et al., 2000; Shea & Bidjerano, 2009). Face-to-face environments can make social cues, immediate clarification and spontaneous dialogue easier, whereas online environments can expand flexibility and access. Consequently, modality differences should not be assumed to operate uniformly across all educational outcomes.

Satisfaction is also a multidimensional quality indicator rather than a superficial preference. A systematic review of 98 studies found that learner characteristics, engagement and course delivery are recurring determinants of online learner satisfaction, while survey-based designs dominate the evidence base (Martin & Bolliger, 2022). Earlier meta-analytic evidence similarly cautions against assuming that one delivery mode is universally superior: learning and satisfaction effects vary with the form of online delivery and the nature of the comparison (Gegenfurtner & Ebner, 2019).

These questions are particularly important in Nigeria, where online learning has demonstrated both educational value and persistent infrastructural constraints. Nigerian university studies have documented poor or unstable internet connectivity, data costs, electricity problems, limited lecturer–student interaction and device constraints (Ebohon et al., 2021; Ogolodom et al., 2022). Comparable evidence from Ghana shows that computer access, stable electricity and high-speed connectivity remain important dimensions of the digital divide in Sub-Saharan African higher education (Baidoo-Anu & Gyamerah, 2023). Among Nigerian engineering students, blended learning was preferred by a majority even when perceptions of fully online learning were less favourable (Abdulkareem et al., 2022). A recent

post-pandemic study of medical students in Southern Nigeria similarly found stronger perceived interaction and effectiveness for classroom teaching while students still recognised the flexibility of online learning (Onyenagubo et al., 2026).

Recent syntheses reinforce the need to move beyond a simple modality contest. A 2024 systematic review found that well-designed blended learning can support multiple dimensions of student engagement and learning outcomes, while also showing substantial heterogeneity in design and measurement (De Bruijn-Smolters & Prinsen, 2024). A 2026 systematic review similarly identified instructional support, assessment and feedback, course delivery, individual learner factors and interaction as recurring correlates of engagement in blended higher education, while noting continued reliance on one-time self-report measures (Heilporn et al., 2026). Within the Community of Inquiry literature, meta-analytic evidence indicates that teaching, social and cognitive presence are positively related to learning outcomes in online and blended environments (Martin et al., 2022). These findings support examining modality differences at the level of specific experiential dimensions rather than assuming a uniform online or face-to-face effect. Consistent with this position, Wang et al. (2023) concluded that blended instructional strategies grounded in the Community of Inquiry framework can support purposeful integration of teaching, social and cognitive presence across learning environments.

A methodological limitation of much comparative work is that online and face-to-face experiences are often assessed in different groups, institutions or courses, making observed differences vulnerable to between-student heterogeneity. Studies that hold instructor or course characteristics more constant can provide a more informative comparison; for example, Soffer and Nachmias (2018) compared online and face-to-face versions of courses with matched instructional characteristics and examined both objective and subjective outcomes. The present study exploits a naturally occurring within-student transition: accessible cohorts experienced computer instruction online in one semester and face-to-face in the next, allowing each student to serve as their own comparison on matched experiential measures.

Accordingly, this study compared within-student ratings of four outcomes—engagement, interaction, perceived learning and satisfaction—and tested whether the overall difference varied by gender. It also examined contextual barriers and future modality preferences to distinguish perceptions of online pedagogy from constraints of access and infrastructure. The study therefore addresses not only whether students rated the two modes differently, but which dimension was most modality-sensitive and how those differences should inform post-pandemic blended course design.

2. Research Questions and Hypotheses

RQ1. How do students' engagement ratings differ between online and face-to-face computer instruction?

RQ2. How do students' interaction ratings differ between online and face-to-face computer instruction?

RQ3. How do students' perceived-learning ratings differ between online and face-to-face computer instruction?

RQ4. How do students' satisfaction ratings differ between online and face-to-face computer instruction?

RQ5. Does the within-student difference between online and face-to-face instructional experiences vary by gender?

H01–H04: There are no significant within-student differences between online and face-to-face instruction in engagement, interaction, perceived learning and satisfaction, respectively.

H05: There is no significant interaction between instructional mode and gender in overall learning-experience scores.

3. Methods

3.1 Design and setting

A retrospective within-subject comparative survey design was used. Participants were drawn from accessible undergraduate cohorts within the researchers' institution who had experienced computer instruction online during the preceding semester and face-to-face instruction during the subsequent semester. Because both modality ratings were collected at one survey occasion after the face-to-face semester had begun, the design is retrospective and observational rather than experimental. Instructional mode was not randomly assigned, and semester-, course- and maturation-related influences could not be separated fully from modality effects.

3.2 Participants and analytic sample

The Google Form was made available to 483 eligible students drawn from the accessible cohorts. A total of 399 responses were received, representing an overall response rate of 82.6%. Of the 399 respondents, three did not provide informed consent, while two consented respondents indicated that they had not participated in the preceding online computer instruction. These five responses were therefore excluded from the primary analysis. The final analytic sample comprised 394 students, representing 81.6% of the total eligible population, all of whom provided informed consent and confirmed exposure to both the online and face-to-face instructional modes.

Characteristic	Category	n	%
Gender	Male	100	25.4
	Female	294	74.6
Age	16 – 18 years	42	10.7
	19–21 years	235	59.6
	22–24 years	88	22.3
	25 years and above	29	7.4

Participants represented 17 academic programmes. The largest groups were Prosthetics & Orthotics (n = 81), Nursing Sciences (n = 61), Biomedical Engineering (n = 54), Healthcare Management (n = 44), Microbiology (n = 38), Social Work (n = 36), Dental Technology (n = 34), and Speech Therapy (n = 26); the remaining programmes each contributed four or fewer participants.

3.3 Instrument

Data were collected using the Online and Face-to-Face Computer Instruction Experience Questionnaire (OFCIEQ), which was developed specifically for this study. An English-language version is provided in Additional file 1. Four matched six-item domains assessed engagement, interaction and communication, perceived learning and understanding, and satisfaction. Every domain item was answered twice—once for online instruction and once for face-to-face instruction—on a five-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Six additional context-specific items assessed internet connectivity, data cost, electricity/device problems, travel burden, immediate clarification and online flexibility. One categorical item assessed preferred future instructional mode, and an optional open-ended item requested the reason for that preference.

The paired item structure was informed conceptually by multidimensional engagement research applicable across instructional modalities and by literature linking interaction, course delivery and satisfaction to the quality of online learning (Heilporn et al., 2024; Li et al., 2023; Martin & Bolliger, 2022). The OFCIEQ was developed for the present study rather than adopted as a previously published instrument.

3.4 Validity of the Instrument

The Online and Face-to-Face Computer Instruction Experience Questionnaire (OFCIEQ) was subjected to expert content validation prior to data collection. Three experts—two in Computer Science and one in Measurement and Evaluation—assessed item relevance, wording clarity, coverage of the intended constructs and alignment with the research questions. Their observations informed revision of the wording and organisation of the questionnaire before administration. Because a quantitative content-validity index was not calculated, this procedure is reported as expert content validation rather than as evidence of criterion or construct validity.

3.5 Construct validity and measurement invariance

Construct validity was examined using a split-sample strategy to reduce same-sample overfitting. The analytic sample was randomly divided (seed = 2026) into a discovery subsample (n = 197) and a validation subsample (n = 197). In the discovery subsample, the online ratings showed excellent factorability (Kaiser-Meyer-Olkin = .957; Bartlett's test of sphericity, $\chi^2(276) = 6208.31$, $p < .001$). Parallel analysis indicated a strong general factor and suggested a lower-dimensional solution; however, because the OFCIEQ was designed a priori around four theoretically distinct domains, a four-factor principal-axis solution with oblimin rotation was examined. The resulting pattern was clean: primary

absolute loadings ranged from .607 to .920, and no item had a secondary loading of .30 or greater. The four rotated factors corresponded to engagement, interaction, perceived learning and satisfaction.

The four-factor structure was then evaluated by confirmatory factor analysis (CFA). In the independent validation subsample, fit was acceptable for online ratings (CFI = .939, TLI = .932, RMSEA = .087, SRMR = .043) and good for face-to-face ratings (CFI = .956, TLI = .951, RMSEA = .076, SRMR = .030). When estimated in the full analytic sample to obtain more stable coefficients, fit improved to CFI = .948, TLI = .942, RMSEA = .080 and SRMR = .035 for online ratings, and CFI = .962, TLI = .957, RMSEA = .070 and SRMR = .024 for face-to-face ratings. A one-factor alternative fit poorly in both modes (online: CFI = .737, RMSEA = .178; face-to-face: CFI = .668, RMSEA = .205), supporting the relative adequacy of the four-domain representation despite substantial inter-domain correlations.

Longitudinal measurement invariance across the online and face-to-face ratings was evaluated using repeated-measures CFA with corresponding constructs modelled at each mode. The configural model showed acceptable absolute fit (CFI = .910, TLI = .904, RMSEA = .075, SRMR = .039). Constraining corresponding factor loadings to equality produced negligible deterioration (metric model: CFI = .909, TLI = .904, RMSEA = .075, SRMR = .041; Δ CFI = $-.001$, Δ RMSEA < .001). Adding equality constraints on item intercepts likewise produced only a small change (scalar model: CFI = .907, TLI = .904, RMSEA = .075; Δ CFI = $-.002$, Δ RMSEA < .001). Using conventional change-in-fit criteria, these results support metric and scalar invariance across modes, indicating that paired mean comparisons are unlikely to be artifacts of substantial changes in item functioning.

3.6 Reliability

Domain	Online Cronbach α	Face-to-face Cronbach α
Engagement	0.952	0.964
Interaction	0.944	0.944
Perceived learning	0.963	0.971
Satisfaction	0.970	0.970

Internal consistency was excellent for all four domains in both modes (α = .944–.971). The combination of expert content validation, a clean four-factor exploratory pattern, acceptable-to-good CFA fit, poor fit of a one-factor alternative, and support for metric and scalar invariance provides substantially stronger evidence for score interpretation than alpha alone. The very high alpha coefficients nevertheless suggest that some items may be redundant, and future independent validation should examine test-retest reliability, ordinal CFA with polychoric correlations, convergent/discriminant validity and replication in other institutions.

3.7 Data analysis

Domain scores were calculated as the mean of the six constituent items for each mode. Psychometric analyses were conducted before substantive comparisons. Factorability was assessed with the Kaiser-Meyer-Olkin statistic and Bartlett's test; exploratory factor analysis used principal-axis extraction with oblimin rotation in the discovery subsample, while CFA was conducted in the validation subsample and replicated in the full sample. Model fit was evaluated using the comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR). Longitudinal measurement invariance across instructional modes was assessed sequentially at configural, metric and scalar levels; changes in CFI and RMSEA were used alongside absolute fit to judge invariance. Primary mode comparisons then used paired-samples t tests with two-sided $\alpha = .05$, 95% confidence intervals and Cohen's d_z . Because four co-primary domain tests were conducted, Holm-adjusted p values were evaluated. Wilcoxon signed-rank tests served as sensitivity analyses. An overall learning-experience score was calculated as the mean of the 24 core items per mode, and a 2×2 mixed comparison tested mode, gender and the mode $\times$ gender interaction. Context items were summarised using means and the proportion selecting Agree/Strongly Agree.

3.8 Ethical considerations

Ethical approval

was granted by the Faculty of Healthcare Management and Leadership Research Ethics Committee, Federal University of Allied Health Sciences, Enugu, Nigeria (approval reference: FHML/RD/VOL.1/022; 20 August 2026). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional requirements for research involving human participants. Informed consent was obtained electronically from all participants included in the study through the consent statement presented at the beginning of the Google Form. Participants were informed that participation was voluntary and that participation or non-participation would not affect their grades, assessment, academic standing or relationship with the lecturer or the University. All participants were aged 16 years or older; no participant was younger than 16 years. Accordingly, parental or legal guardian consent for participants younger than 16 years was not applicable. Responses were treated confidentially and reported in aggregate form. Submissions from respondents who did not provide consent were excluded from the analysis.

4. Results

4.1 Psychometric evaluation

The discovery-sample EFA yielded a clear four-domain pattern corresponding to the intended OFCIEQ structure, with all primary loadings above .60 and no salient cross-loadings. Although parallel analysis reflected a dominant common factor and suggested fewer dimensions, the prespecified four-factor solution displayed substantially better conceptual differentiation and was carried forward to CFA. The CFA results supported the relative adequacy of the four-domain representation, especially compared with the poorly fitting one-factor alternative. Measurement-invariance testing further indicated that the

factor loadings and intercepts were sufficiently stable across online and face-to-face ratings to support interpretation of within-student mean differences.

As shown in Table 2, the exploratory factor analysis produced a clean four-domain pattern, with strong primary loadings and no salient secondary loadings.

Table 2
Exploratory factor analysis summary (discovery subsample, n = 197)

Domain	Primary loading range	Maximum secondary loading
Engagement	.607–.920	< .30
Interaction	.707–.881	< .30
Perceived learning	.688–.899	< .30
Satisfaction	.734–.892	< .30

Table 3 summarises the confirmatory factor analysis and longitudinal measurement-invariance models used to evaluate the stability of the four-domain structure across online and face-to-face ratings.

Table 3
Confirmatory factor analysis and longitudinal measurement-invariance fit

Model	χ^2	df	CFI	TLI	RMSEA	SRMR
CFA: Online, full sample	869.45	246	.948	.942	.080	.035
CFA: Face-to-face, full sample	723.69	246	.962	.957	.070	.024
Longitudinal configural	3397.90	1052	.910	.904	.075	.039
Longitudinal metric	3449.50	1072	.909	.904	.075	.041
Longitudinal scalar	3524.01	1092	.907	.904	.075	—

Note. Metric versus configural: $\Delta CFI = -.001$, $\Delta RMSEA < .001$. Scalar versus metric: $\Delta CFI = -.002$, $\Delta RMSEA < .001$. The scalar fit was evaluated with equality constraints on corresponding item intercepts and freely estimated face-to-face latent means.

4.2 Within-student comparisons

Outcome	Online M (SD)	F2F M (SD)	Δ	95% CI for Δ	t(393)	p	Holm p	Dz
Engagement	4.09 (0.90)	4.24 (0.83)	0.15	0.08 to 0.22	4.13	< .001	< .001	0.21
Interaction	3.73 (1.04)	4.26 (0.80)	0.53	0.43 to 0.63	10.35	< .001	< .001	0.52
Perceived learning	4.01 (0.86)	4.23 (0.82)	0.21	0.14 to 0.29	5.44	< .001	< .001	0.27
Satisfaction	3.86 (0.96)	4.16 (0.86)	0.30	0.20 to 0.40	6.06	< .001	< .001	0.31

All four outcomes were rated significantly higher under face-to-face instruction, and every result remained significant after Holm correction. The largest change was in interaction ($\Delta = 0.53$; $dz = 0.52$), a medium within-student effect. Satisfaction ($dz = 0.31$) and perceived learning ($dz = 0.27$) showed small effects, while engagement showed a smaller but statistically reliable shift ($dz = 0.21$). Wilcoxon sensitivity analyses produced the same substantive conclusion for engagement ($p < .001$), interaction ($p < .001$), perceived learning ($p < .001$) and satisfaction ($p < .001$).

Across all 24 core items, the mean score increased from 3.92 (SD = 0.84) online to 4.22 (SD = 0.73) face-to-face, a mean within-student increase of 0.30; $t(393) = 8.04$, $p < .001$, $dz = 0.41$. Thus, the overall difference was moderate, but its magnitude varied meaningfully by domain.

Figure 1 illustrates the magnitude and 95% confidence intervals of the within-student mean differences for engagement, interaction, perceived learning and satisfaction, with interaction showing the largest shift.

4.3 Gender and change across modes

Gender	n	Online overall M	F2F overall M	Mean change
Male	100	3.83	4.13	0.300
Female	294	3.96	4.25	0.298

The main effect of instructional mode on the overall score was significant, $F(1,393) = 64.72$, $p < .001$, partial $\eta^2 = .141$. The overall gender main effect was not significant, $F(1,392) = 2.54$, $p = .112$, partial $\eta^2 = .006$. Most importantly, the mode $\times$ gender interaction was essentially zero, $F(1,392) < 0.001$, $p = .987$, partial $\eta^2 < .001$. Male students improved by 0.300 points and female students by 0.298 points. Domain-specific exploratory interaction tests were likewise non-significant (all $p \geq .570$).

4.4 Contextual constraints and affordances

Context item	Mean	Agree/Strongly agree (%)
Internet connectivity affected online participation	3.67	64.7
Cost of internet data affected online participation	3.72	66.0
Electricity/device problems affected online experience	3.59	61.9
Travel to lecture venue affected face-to-face participation	3.05	43.4
Face-to-face provided better immediate clarification	4.18	82.0
Online instruction provided greater location flexibility	3.86	69.0

The context indicators help interpret the modality differences. Approximately two thirds of participants endorsed internet connectivity and data cost as barriers, and 61.9% endorsed electricity/device problems. At the same time, 69.0% agreed that online instruction offered greater flexibility. The strongest contextual endorsement was the advantage of face-to-face instruction for immediate clarification (82.0%).

4.5 Preferred future instructional mode

Preferred mode	n	%
Entirely face-to-face	103	26.1
Mainly face-to-face with some online activities	152	38.6
Equal combination of online and face-to-face	83	21.1
Mainly online with occasional physical meetings	41	10.4
Entirely online	15	3.8

Although face-to-face ratings were higher on all four core domains, only 26.1% preferred an entirely face-to-face future course. Combining the three blended options shows that 276 of 394 participants (70.1%) preferred some mixture of online and face-to-face instruction, whereas only 3.8% preferred entirely online instruction. This pattern indicates that students distinguished the weaknesses of fully online delivery from the value of retaining selected digital components.

5. Discussion

This study found a consistent within-student advantage for face-to-face computer instruction across engagement, interaction, perceived learning and satisfaction. Before interpreting these differences, the psychometric analyses provided evidence that the OFCIEQ's four-domain structure was reasonably defensible across instructional modes: the theory-specified EFA showed a clean simple structure, CFA fit was acceptable-to-good and markedly superior to a one-factor model, and metric/scalar invariance criteria were satisfied. Accordingly, the observed paired differences are less likely to reflect major

changes in how the items functioned across modes. The magnitude of the substantive effects, however, remains more informative than statistical significance alone. Interaction showed the largest shift ($d_z = 0.52$), whereas engagement, perceived learning and satisfaction showed smaller effects.

This interpretation aligns with the Community of Inquiry framework, in which social, teaching and cognitive presence are interdependent rather than interchangeable (Garrison et al., 2000; Shea & Bidjerano, 2009). The strong interaction result is also consistent with engagement research that treats teacher–student interaction and social engagement as integral components of the learning experience across modalities (Li et al., 2023; Heilporn et al., 2024). The present data extend that literature by showing the pattern within the same students rather than relying solely on between-group comparisons.

The theoretical contribution is therefore one of differentiated modality sensitivity. The results suggest that the dimensions of student experience are not equally responsive to a change in delivery mode: interpersonal interaction showed the clearest difference, consistent with the social- and teaching-presence components of the Community of Inquiry framework. This interpretation is compatible with meta-analytic Col evidence linking the three presences to learning outcomes and with recent blended-learning reviews that emphasise interaction and purposeful instructional design (Martin et al., 2022; De Bruijn-Smolters & Prinsen, 2024). The implication is that modality should be treated as a design resource whose value depends on the learning function being supported, rather than as a unitary treatment expected to affect all outcomes equally.

The Nigerian context provides an important explanation for why online ratings may be lower without implying that online pedagogy itself is intrinsically inferior. In this study, 64.7% reported connectivity problems, 66.0% data-cost constraints and 61.9% electricity/device problems. These findings closely resemble prior Nigerian evidence documenting unstable internet access, financial constraints, limited interaction and power or device limitations during online learning (Ebohon et al., 2021; Ogolodom et al., 2022). They also accord with recent Nigerian medical-education evidence in which technical problems were a prominent disadvantage of online learning and classroom teaching was strongly favoured for interaction (Onyenagubo et al., 2026). Thus, observed modality effects partly reflect the ecology in which a modality is delivered.

At the same time, the findings argue against abandoning online learning. More than two thirds of students acknowledged its flexibility, and 70.1% preferred a blended future arrangement. This resembles Abdulkareem et al. (2022), where most Nigerian engineering students preferred mixed learning despite reservations about fully online instruction. It is also compatible with broader evidence showing that online and face-to-face formats need not produce a simple hierarchy of outcomes and that design characteristics matter (Gegenfurtner & Ebner, 2019; Soffer & Nachmias, 2018). A defensible institutional response is therefore not 'return to classroom only', but 'use modality strategically'.

The absence of a mode-by-gender interaction is also informative. Male and female students showed virtually identical mean change scores despite different group sizes. This suggests that the observed transition was not meaningfully gender-specific in this sample. Because the study was not designed to

test broader gendered mechanisms of digital access, the result should be interpreted narrowly as evidence that the within-student modality difference in the measured outcomes did not differ by gender.

5.1 Implications for teaching and institutional policy

First, interactive and explanation-intensive components of computer instruction should be protected for face-to-face delivery when feasible, because interaction was the domain with the clearest advantage. Second, online components should be retained where they add flexibility, access to materials, revision opportunities or continuity. Third, institutions seeking blended delivery should treat connectivity, data affordability, electricity and device access as pedagogical variables rather than merely technical inconveniences. Finally, course design should focus on purposeful integration: online activities should complement rather than simply duplicate classroom lectures.

5.2 Strengths and limitations

The principal strength is the matched within-student structure: every analysed participant rated both modalities on parallel items, reducing confounding by stable individual differences that affect between-group comparisons. The analysis also reports confidence intervals, effect sizes, multiplicity-adjusted p values and non-parametric sensitivity tests rather than relying on statistical significance alone. The 82.6% response rate and representation of multiple allied-health and related programmes further strengthen the descriptive evidence within the institution. Importantly, the study separates statistical significance from practical magnitude, showing that interaction—not every outcome uniformly—was the dimension most sensitive to instructional mode.

Several limitations constrain interpretation. First, the study is observational and retrospective; the online experience occurred in the preceding semester, creating recall bias and temporal confounding. Second, course content, assessment demands, semester context and students' accumulated experience may have changed alongside modality, so the results cannot establish a causal effect of instructional mode. Third, participants were accessible cohorts from one institution rather than a probability sample, limiting population generalisability. Fourth, outcomes are self-reported perceptions rather than objective achievement measures. Fifth, although the OFCIEQ received expert content validation and the present data supported a clean four-factor exploratory pattern, acceptable-to-good CFA fit and metric/scalar invariance, the instrument remains study-specific. Parallel analysis also suggested a strong general dimension, and the high inter-domain correlations and alpha coefficients indicate that construct overlap and item redundancy warrant further investigation. Future studies should use independent multi-institutional samples, ordinal CFA based on polychoric correlations, convergent/discriminant validity testing and prospective repeated measurement. Sixth, the unequal gender distribution reduces precision for male-specific estimates. Finally, although the overall response rate was high (82.6%), non-response bias cannot be entirely excluded because the experiences of eligible students who did not participate are unknown.

6. Conclusion

Among 394 undergraduates who had experienced both instructional modes, face-to-face computer instruction was rated more positively than online instruction for engagement, interaction, perceived learning and satisfaction, with the strongest difference in interaction. Yet students simultaneously valued the flexibility of online learning and overwhelmingly preferred a blended future arrangement. These findings support a modality-by-function approach: use face-to-face teaching where immediate interaction, clarification and social presence are central, while retaining well-designed online components for flexibility and resource access. In resource-constrained higher-education settings, improving digital infrastructure and instructional design may be as important as choosing the delivery mode itself.

Declarations

Ethics approval and consent to participate: Ethical approval was granted by the Faculty of Healthcare Management and Leadership Research Ethics Committee, Federal University of Allied Health Sciences, Enugu, Nigeria (approval reference: FHML/RD/VOL.1/022; 20 August 2026). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional requirements for research involving human participants. Informed consent was obtained electronically from all participants included in the study through the consent statement presented at the beginning of the Google Form. Participants were informed that participation was voluntary and that participation or non-participation would not affect their grades, assessment, academic standing or relationship with the lecturer or the University. All participants were aged 16 years or older; no participant was younger than 16 years. Accordingly, parental or legal guardian consent for participants younger than 16 years was not applicable. Responses were treated confidentially and reported in aggregate form. Submissions from respondents who did not provide consent were excluded from the analysis.

Consent for publication: Not applicable; no identifying participant information is reported.

Availability of data and materials: The de-identified dataset supporting the findings can be made available by the corresponding author on reasonable request, subject to institutional and ethical requirements. The English-language questionnaire developed for this study is provided in Additional file 1.

Competing interests: The authors declare that they have no competing interests.

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Author contributions: A.N.O.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing. L.C.A.: Supervision, Methodology, Writing – Review & Editing. O.O.: Supervision, Validation, Writing – Review & Editing.

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Figures

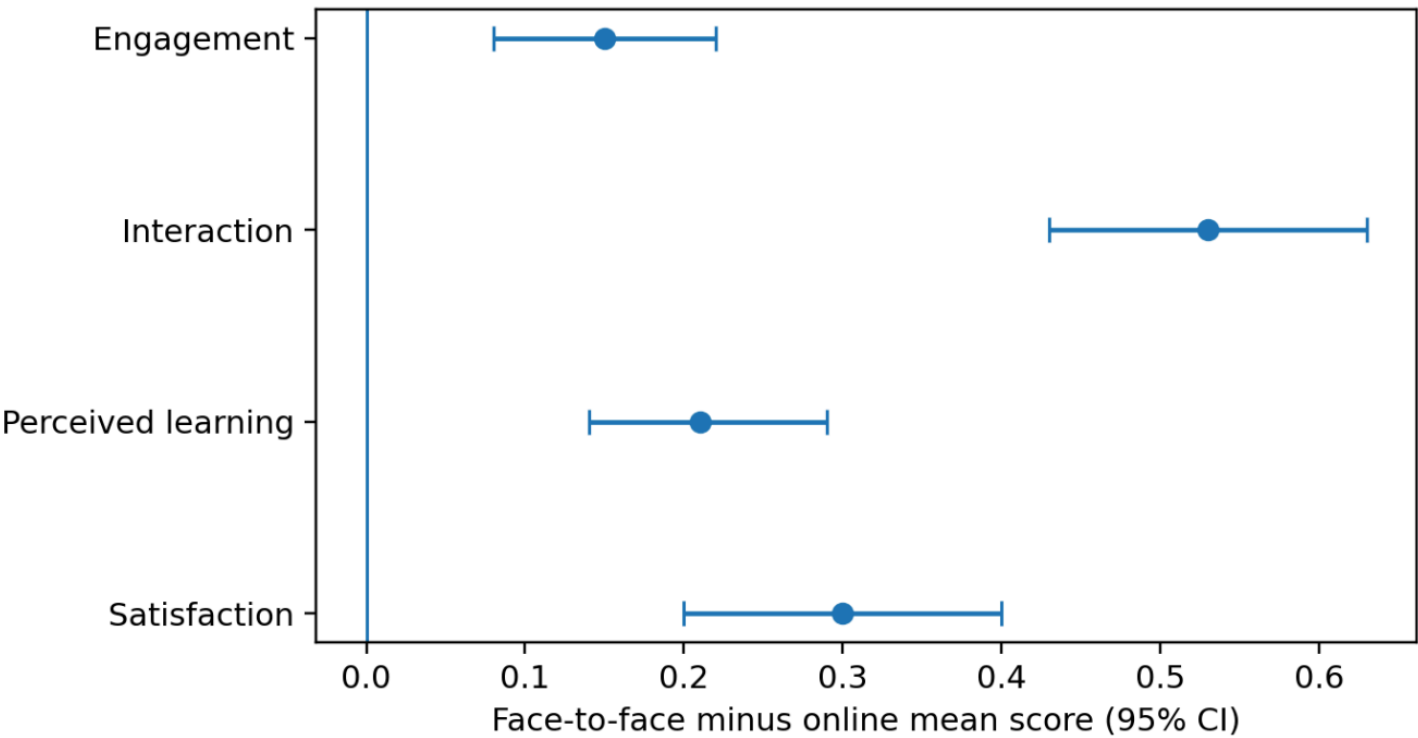


Figure 1

illustrates the magnitude and 95% confidence intervals of the within-student mean differences for engagement, interaction, perceived learning and satisfaction, with interaction showing the largest shift.

Figure 1. Within-student mean differences (face-to-face minus online) with 95% confidence intervals.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AdditionalFile1OFCIEQEnglishQuestionnaire.docx](#)