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Bridging the Expectation-Reality Gap in Anatomy Education Among Undergraduate Anatomy Students at Al-Hikmah University

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ABSTRACT

Anatomy is a core component of health sciences education, yet it remains challenging, particularly in resource-constrained settings. This study examined the relationship between students' perceptions, expectations, and learning challenges among undergraduate anatomy students at Al-Hikmah University, Ilorin, Nigeria. A cross-sectional design was employed, involving 140 students across 200–400 levels. Data were collected using a structured questionnaire and analyzed with descriptive statistics, correlation, and multiple linear regression. Students demonstrated high perception scores (mean = 32.66 ± 6.23), reflecting strong recognition of anatomy's relevance to clinical practice and professional development. Despite this, moderate learning challenges were reported (mean = 24.48 ± 5.57), driven mainly by content overload, memorization burden, overcrowded practical sessions, and limited access to learning resources. A significant positive correlation was found between perception and challenge scores ($r = 0.500$, $p < 0.001$), indicating that higher appreciation of anatomy is associated with increased perceived difficulty. Regression analysis identified perception as the only significant predictor of learning challenges ($\beta = 0.488$, $p < 0.001$), while academic level and extent of exposure showed no significant effects. Qualitative findings revealed a "positive but demanding" learning experience and emphasized the need for improved practical exposure, better teaching strategies, and enhanced resources. Overall, the study highlights a clear expectation–reality gap; addressing this gap requires a shift toward learner-centered, experience-driven approaches that optimize cognitive load and improve instructional effectiveness.

Keywords: anatomy education, medical education, student perception, learning challenges, undergraduate students

INTRODUCTION

Anatomy remains a cornerstone of health sciences education, underpinning the understanding of human structure, functional integration, and clinical decision-making. Its centrality within medical and allied health curricula is widely recognized, as competence in anatomy is essential for safe and effective clinical practice [1,2]. However, despite its importance, anatomy education continues to present substantial challenges to learners across diverse educational settings. These challenges are multifactorial, arising from the intrinsic complexity of the subject, the extensive volume of content, and the requirement for spatial visualization and integrative reasoning beyond rote memorization [2,3]. Consequently, anatomy is frequently perceived by students as both intellectually valuable and academically demanding, creating a persistent tension between its recognized relevance and the difficulty of mastering it [4, 5].

In resource-constrained educational environments, these inherent challenges are further amplified by systemic limitations. Large class sizes, limited access to cadavers and anatomical models, inadequate supervision during practical sessions, and restricted teaching time significantly reduce opportunities for experiential learning and individualized instruction [6-8]. Additionally, infrastructural constraints, including poor access to digital learning tools and unreliable internet connectivity, hinder the effective implementation of modern, multimodal teaching approaches that have been shown to enhance anatomical understanding [9-11]. As a result, anatomy education in such contexts

often remains heavily content-driven, with a strong emphasis on memorization at the expense of conceptual integration and applied learning [11,12].

Empirical studies across health sciences populations consistently demonstrate that students recognize the importance of anatomy to their academic and professional development but encounter significant barriers, including information overload, limited practical exposure, and difficulty integrating theoretical knowledge with clinical application [4,13]. Moreover, students in resource-limited settings often express a preference for multimodal and technology-enhanced learning tools, such as 3D visualization platforms and instructional videos, while simultaneously highlighting institutional challenges such as cadaver scarcity and inadequate teaching infrastructure. These findings collectively point to a disconnect between how anatomy is taught and how it is most effectively learned.

Although previous studies have documented students' perceptions of anatomy and identified various challenges associated with learning the subject, much of this work has largely focused on describing isolated aspects of the learning experience rather than examining how these factors interact in a comprehensive manner [6-8]. This limits a deeper understanding of how perceptions, expectations, and learning challenges collectively influence students' academic experiences and outcomes. Anatomy, as a standalone discipline, involves complex structural and spatial learning that requires more than memorization, making its learning experience distinct from other health sciences and important for understanding how students learn and engage with the subject.

Despite this, there remains a relative paucity of recent studies that specifically explore how undergraduate anatomy students' perceptions, expectations, and learning challenges interact within a dedicated anatomy training context. Understanding these dynamics is essential, as anatomy students are future educators, researchers, and specialists whose training experiences directly influence the sustainability and advancement of anatomical sciences education [1, 12].

Addressing this gap requires a focused exploration of the anatomy learning experience that moves beyond general descriptions toward identifying the underlying factors that shape student engagement and difficulty. Therefore, this study examined the relationship between students' perceptions, expectations, and learning challenges among undergraduate anatomy students, with a particular emphasis on identifying the determinants of learning difficulty and the factors contributing to the gap between educational expectations and lived academic experience in a resource-constrained setting.

MATERIALS AND METHODS

Study design and setting

This study employed a cross-sectional design and was conducted at the Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Sciences, Al-Hikmah University, Ilorin, Nigeria.

Study population and sampling

The study population comprised undergraduate students of the B.Sc. Anatomy (200–400 level) enrolled in the Department of Anatomy who were actively undertaking anatomy coursework. Eligible participants were registered B.Sc. Anatomy students, who provided informed consent. Students not enrolled in the B.Sc. Anatomy program and those with incomplete questionnaire responses were excluded from the study.

The sample size was calculated using Cochran's formula for sample size estimation at a 95% confidence level, 5% margin of error, and an assumed population proportion of 50%. Following the application of finite population correction for an estimated population of 200 students, the minimum required sample size was determined to be 100. A total of 145 responses were collected. After excluding five incomplete responses, 140 questionnaires were retained for final analysis. A non-probability convenience sampling technique was employed for recruiting the participants. The questionnaire was distributed using a hybrid approach involving both online and paper-based formats to enhance response rates and accessibility.

The online version was distributed via official class communication channels, while paper-based questionnaires were administered during scheduled lectures to ensure inclusion of students with limited internet access. To maintain consistency, both versions contained identical questions and were self-administered under similar instructions. Duplicate submissions were prevented by restricting one response per participant, and all questionnaires were screened for completeness prior to analysis, with incomplete responses excluded to reduce the risk of missing data bias.

Instrument development and data collection

Data were collected using a structured, self-administered questionnaire developed following a review of relevant literature on anatomy education and student learning experiences. The questionnaire comprised four sections:

Section A: Sociodemographic characteristics

Section B: Students' perceptions and expectations regarding anatomy education (measured using a 5-point Likert scale)

Section C: Perceived learning challenges in anatomy (5-point Likert scale)

Section D: Open-ended questions exploring expectations, experiences, challenges, and suggested improvements

Content validity of the instrument was established through expert review by IAL and ATA. A pilot study involving 50 students outside the main study population was conducted to assess the clarity, relevance, and structural adequacy of the questionnaire using Cronbach's alpha coefficient. The perception scale demonstrated excellent internal consistency ($\alpha = 0.892$), while the learning challenges scale showed acceptable reliability ($\alpha = 0.786$). Both values exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency of the instrument. Data collection was conducted over a one-month period using a hybrid distribution strategy (online and paper-based). Participation was voluntary and anonymous, and informed consent was obtained from all participants before questionnaire completion.

Ethical consideration

Ethical approval for the study was obtained from the Ethical Review Committee of the Faculty of Basic Medical Sciences, College of Health Sciences, Al-Hikmah University (Approval number: HUI-FHS-ERC-25-0047). All procedures were conducted in accordance with institutional ethical standards. Participants were assured of confidentiality and anonymity, and they were informed of their right to withdraw from the study at any stage without penalty.

Data management and statistical analysis

Data were coded and analyzed using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequencies, percentages, means, and standard deviations. Composite mean scores were computed for the perception/expectation scale (Section B) and the learning challenges scale (Section C) by aggregating individual Likert-scale items. Inferential statistical analyses were conducted to examine group differences and associations. Chi-square tests were used for categorical variables, while one-way analysis of variance (ANOVA) was applied to compare mean scores across academic levels and programmes of study.

Multiple linear regression analysis was performed to identify independent predictors of perceived learning challenges. The composite challenge score was treated as the dependent variable, while perception scores and relevant demographic variables were included as independent predictors. Adjusted beta coefficients (β) with 95% confidence intervals were reported. Statistical significance was set at $p < 0.05$. Qualitative responses from the open-ended questions were analyzed using thematic content analysis following the framework of Braun and Clarke (2006). Responses were reviewed repeatedly to achieve data familiarization, coded inductively, and grouped into categories and themes. The final themes identified were overall learning experience, expectations of anatomy education, perceived learning challenges, suggested improvements, and barriers to virtual learning. Analysis was conducted using Microsoft Excel, and the qualitative findings were integrated with the quantitative results to enhance interpretation.

RESULTS

Who are the Learners? A snapshot of the study population

The study comprised 140 undergraduate anatomy students, with a male predominance (73.6%), and the majority aged between 21 and 24 years (Table 1). Most respondents were in the 400 level (58.6%), followed by the 200 level (22.9%) and the 300 level (18.6%), indicating a relatively senior-heavy cohort. Regarding exposure to anatomy practicals, 61.4% of respondents reported moderate exposure (2–3 semesters), 28.6% reported extensive exposure (>3 semesters), and 10.0% reported minimal exposure (1 semester).

High value, moderate satisfaction: students' perceptions of anatomy education

Descriptive analysis (Table 2) revealed generally high perception scores across all items, indicating a strong positive orientation toward anatomy education. The highest-rated item was "Anatomy provides essential foundational knowledge" (mean = 4.36 ± 0.983), followed by its influence on student confidence (mean = 4.23 ± 0.984) and support for clinical reasoning (mean = 4.09 ± 0.988). Notably, overall satisfaction with anatomy learning was also relatively high (mean = 4.06 ± 0.935), suggesting that, within this cohort, students not only recognize the value of anatomy but also report a satisfactory learning experience. However, comparatively ($p = 0.011$) lower ratings for lecturer support (mean = 3.84 ± 1.140) indicate a relative gap in perceived instructional engagement. Overall, the consistently high mean values (>3.5) reflect a uniformly positive perception profile among anatomy students (Table 2).

Table 1: Demographic characteristics of respondents (N = 140)

Characteristic	*Category*	*Frequency (n)*	*Percentage (%)*
Gender Distribution	Female	37	26.4
	Male	103	73.6
Age Range	<18 years	14	10.1
	18–20 years	64	10.0
	21–24 years	52	45.7
	25–29 years	8	37.1
	≥30 years	2	5.7
Level of Study	200 Level	32	22.9
	300 Level	26	18.6
	400 Level	82	58.6
Extent of Exposure to Anatomy Classes/Practicals	Minimal (1 semester)	14	10.0
	Moderate (2–3 semesters)	86	61.4
	Extensive (>3 semesters)	40	28.6

Table 2: Descriptive statistics of students' perceptions of anatomy education

	N	**Mean**	**Std. Deviation**
Anatomy provides essential foundational knowledge	140	4.36	.983
Learning anatomy is intellectually meaningful rather than purely memorization-based.	140	3.98	1.178
Anatomy positively influences my confidence as a medical/allied health sciences student.	140	4.23	.984
I can clearly see the relevance of anatomy to my current or future professional role.	140	4.01	.974
Anatomy learning supports the development of my clinical or applied reasoning skills.	140	4.09	.988
Studying anatomy has contributed to my professional identity as a future health professional.	140	4.08	1.039
Anatomy lecturers are approachable and supportive in enhancing student learning.	140	3.84	1.140
My experience learning anatomy has been satisfactory	140	4.06	.935

Despite positive perceptions, students reported moderate levels of learning challenges across all domains (Table 3). The highest-rated challenge item related to practical session constraints (mean = 3.69 ± 1.230), followed closely by memorization burden (mean = 3.64 ± 1.067) and content complexity (mean = 3.61 ± 1.130). Resource-related constraints, including limited access to cadavers and models (mean = 3.59 ± 1.223), also contributed significantly to perceived difficulty. In contrast, integration of anatomy with clinical contexts was the least challenging domain (mean = 3.11 ± 1.279).

Bridging the gap: composite scores of perceptions and learning challenges

The composite perception score (mean = 32.66 ± 6.23) indicates a high overall perception level, corresponding to an average Likert rating above 4 per item. In contrast, the composite challenge score (mean = 24.48 ± 5.57) corresponds to an average Likert rating of approximately 3.5, reflecting moderate difficulty. Students maintain strong positive perceptions of anatomy while simultaneously experiencing notable learning

challenges. The coexistence of these patterns highlights a dual educational experience characterized by both engagement and difficulty.

Comparison of perception and challenge scores across academic levels and exposure categories

One-way ANOVA revealed no statistically significant differences in perception scores across academic levels ($F = 0.267$, $p = 0.766$) or extent of exposure ($F = 1.298$, $p = 0.276$). Similarly, challenge scores did not differ significantly by level ($F = 0.893$, $p = 0.113$) or exposure ($F = 1.599$, $p = 0.206$).

When positive perception meets difficulty: correlation analysis

Pearson's correlation analysis demonstrated a moderate positive relationship between perception and challenge scores ($r = 0.500$, $p < 0.001$). This statistically significant association indicates that students with higher perceptions of anatomy also tend to report higher levels of learning challenges.

What truly drives learning challenges? Evidence from regression analysis

Multiple linear regression analysis revealed (Table 4) that the overall model was statistically significant, explaining 25.7% of the variance in challenge scores ($R^2 = 0.257$, Adjusted $R^2 = 0.241$). Among the predictors, perception score emerged as the only statistically significant predictor of learning challenges ($\beta = 0.488$, $t = 6.550$, $p < 0.001$), indicating that higher perception levels are associated with increased reported difficulty.

In contrast, academic level ($\beta = -0.018$, $p = 0.823$) and extent of exposure ($\beta = 0.093$, $p = 0.254$) were not significant predictors, as their p-values exceeded the 0.05 threshold. This suggests that neither progression in training nor increased exposure independently influences perceived challenges when controlling for perception.

The findings indicate that perception is the dominant explanatory variable, reinforcing the correlation results and highlighting a paradoxical dynamic in which greater academic appreciation is associated with increased cognitive and experiential burden.

Beyond numbers: students' voices on anatomy learning

Qualitative findings corroborated the quantitative results (Table 5), revealing a consistent pattern of high engagement alongside notable difficulty. The most frequently reported experience was "positive but demanding" (mean = 0.60), followed by "academically overwhelming" (mean = 0.53), reflecting a dual perception of value and strain. Key expectations centered on increased practical exposure (mean = 0.68) and improved teaching methods (mean = 0.62), indicating a strong demand for more applied and interactive learning approaches.

Table 3: Descriptive statistics of perceived learning challenges in anatomy

	N	Mean	Std. Deviation
The volume and complexity of anatomy content are overwhelming.	140	3.61	1.130
Anatomy learning often places excessive emphasis on memorization.	140	3.64	1.067
Limited access to cadavers, models, and high-quality visual resources affects my learning.	140	3.59	1.223
Anatomy practical sessions are often overcrowded or insufficient in duration.	140	3.69	1.230
It is difficult to integrate anatomy knowledge with clinical and applied contexts.	140	3.11	1.279
Feedback and academic support in anatomy courses are often inadequate.	140	3.33	1.226
Resource limitations reduce the quality of anatomy education in my institution.	140	3.51	1.249

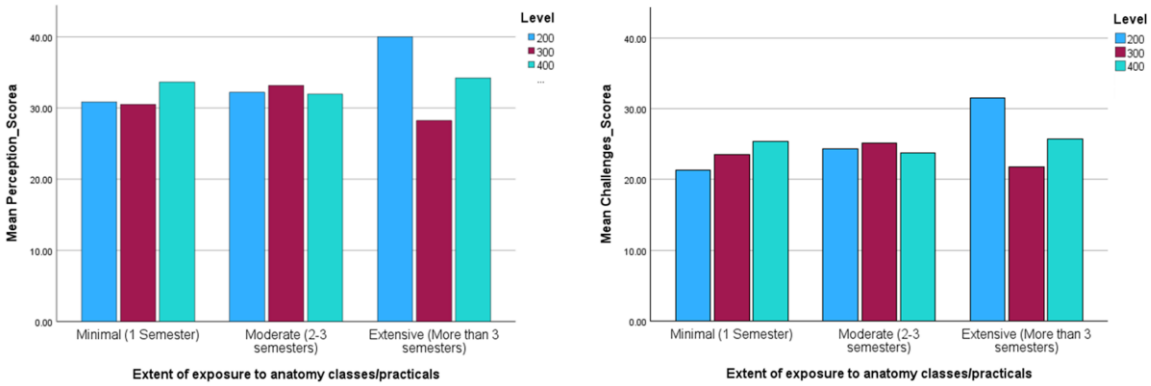

Figure 1: Mean perception and learning challenge scores by extent of exposure and academic level. Error bars represent standard deviations. Statistical comparisons were performed using one-way ANOVA.

Table 4: Multiple Linear Regression Analysis Predicting Challenge Score

Variable	*Beta (β)*	*t-value*	*p-value*
Constant	—	3.307	0.001
Level	-0.018	-0.224	0.823
Extent of Exposure to Anatomy Classes/Practicals	0.093	1.146	0.254
Perception Score	0.488	6.550	<0.001

Model Summary: R = 0.507 | R^2 = 0.257 | Adjusted R^2 = 0.241 | Std. Error = 4.853

Table 5: Thematic distribution of qualitative responses: overall experience, expectations, challenges, suggested improvements, and barrier to virtual learning (N= 140)

Overall Experience	Frequency (n)	Mean	Std. Deviation
Positive but demanding	84	0.60	0.49
Academically overwhelming	73	0.53	0.50
Interesting but stressful	70	0.50	0.50
Moderate satisfaction	64	0.46	0.50
Poor practical engagement	54	0.39	0.49
Lecturer-related concerns	45	0.32	0.47
Expectations			
More practical exposure	95	0.68	0.47
Better teaching methods	87	0.62	0.49
Clinical integration	81	0.58	0.49
Improved resources	78	0.56	0.50
Academic support	71	0.51	0.50
Digital learning tools	60	0.43	0.49
Challenges			
Content overload	97	0.70	0.46
Memorization burden	90	0.64	0.48
Limited practical exposure	84	0.60	0.49
Resource constraints	78	0.56	0.50
Clinical integration difficulty	62	0.44	0.50
Time constraints	58	0.42	0.49
Suggested Improvements			
More practical sessions	101	0.72	0.45
Improved teaching methods	88	0.63	0.48
Better resources	82	0.59	0.49
Use of technology	73	0.53	0.50
Curriculum restructuring	65	0.47	0.50
Reduce workload	59	0.43	0.49
Barriers to Virtual Learning			
Poor internet access	93	0.66	0.47
High cost of data	87	0.62	0.49
Lack of devices	71	0.51	0.50
Limited digital literacy	64	0.46	0.50
Low awareness	57	0.41	0.49
Preference for traditional methods	50	0.36	0.48

Content overload (mean = 0.70) and memorization burden (mean = 0.64) emerged as the dominant challenges, aligning closely with quantitative findings. Suggested improvements were led by increased practical sessions (mean = 0.72), reinforcing the central role of experiential learning. Additionally, infrastructural barriers such as poor internet access (mean = 0.66) and high data costs (mean = 0.62) were identified as major limitations to digital learning adoption. Collectively, these insights provide contextual depth, confirming that the expectation–reality gap is driven by structural and pedagogical constraints rather than lack of student motivation.

DISCUSSION

The findings of this study indicate that positive perceptions of anatomy can coexist with substantial learning challenges. While students generally recognized the value and relevance of anatomy education, they reported difficulties related to content volume, memorization demands, practical exposure, and learning resources. This suggests that appreciating the importance of anatomy does not necessarily reduce the challenges associated with learning the subject [2, 14, 15]. Students reported generally positive perceptions of anatomy, recognizing its importance as a foundational discipline that contributes to confidence development and future professional practice[16]. At the same time, they reported moderate learning challenges related to content volume, memorization demands, practical exposure, and learning resources[17]. The coexistence of positive perceptions and learning difficulties suggests that appreciating the value of anatomy does not necessarily reduce the challenges associated with learning the subject. These findings are consistent with previous studies indicating that anatomy is often regarded as both highly relevant and academically demanding[18, 19].

However, in the absence of adequate instructional scaffolding, this productive difficulty risks evolving into unstructured cognitive overload, as evidenced by the prominence of content volume, memorization burden, and limited practical engagement as key constraints [2]. The similarity of perception and challenges across academic levels further reinforces the interpretation that these challenges are systemic rather than developmental, irrespective of progression or increased contact time with anatomy[14, 16, 1]. This finding is particularly consequential, as it challenges the assumption that greater exposure alone translates into improved learning outcomes, instead suggesting that repeated engagement within an unchanged pedagogical structure merely prolongs the experience of difficulty without resolving it [2].

At the core of this issue lies the inherently high cognitive load of anatomy, which, when compounded by suboptimal teaching structures and limited experiential learning opportunities, leads to inefficient knowledge processing and reliance on surface memorization strategies. The insufficient integration of hands-on, spatially grounded learning experiences is especially critical in a discipline that is fundamentally three-dimensional and experiential, creating a disconnect between how anatomy is taught and how it is best understood[17, 20, 21]. Moreover, subtle but consistent signals regarding instructional support point to the role of the teaching interface itself as a determinant of learning quality, where the absence of guided facilitation, structured feedback, and interactive engagement limits students' ability to navigate complexity effectively[22,23].While students express interest in technological enhancements, infrastructural constraints such as limited internet access and high data costs highlight the need for context-sensitive solutions, as reliance on high resource digital interventions may inadvertently exacerbate inequities [24,25,13]. Collectively, these findings point toward the necessity of a systemic shift from a predominantly content-heavy, exposure-based model to a more structured, learner-centered approach that actively manages cognitive load, prioritizes guided experiential learning, and aligns pedagogical strategies with the realities of the learning environment[26-28]. In practical terms, this entails redesigning anatomy instruction to emphasize task-oriented practical sessions, integrating theory with application through structured scaffolding, enhancing instructor–student interaction through active learning strategies, and adopting low-cost, accessible innovations that support spatial understanding [29,30]. Ultimately, the implication is not that anatomy education should be simplified, but that it should be made more cognitively navigable and pedagogically coherent, ensuring that the evident student engagement is matched by an equally supportive and effective learning framework.

CONCLUSION

This study demonstrated that undergraduate anatomy students generally perceive anatomy as an important and valuable component of their training. Despite these positive perceptions, students reported moderate learning challenges, particularly related to content overload, memorization demands, practical exposure, and access to learning resources. The findings suggest that positive perceptions alone may not be sufficient to mitigate the academic demands of anatomy education. Strengthening practical learning experiences, improving access to educational resources, and adopting more interactive and learner-centered teaching approaches may help optimize student learning and engagement in anatomy. The findings of this study should also be interpreted in light of several limitations. The cross-sectional design provides only a snapshot of students' experiences and does not permit causal inferences. As the study was conducted in a single institution, the generalizability of the findings may be limited. Furthermore, the use of self-reported measures may have introduced response bias. Nevertheless, the inclusion of both quantitative and qualitative data provided complementary insights into students' perceptions and learning challenges in anatomy education.

REFERENCES

1. Bergman EM, De Bruin AB, Herrler A, Verheijen IW, Scherpbier AJ, Van Der Vleuten CP. Students' perceptions of anatomy across the undergraduate problem-based learning medical curriculum: a phenomenographical study. BMC Med Educ. 2013;13:152. doi:10.1186/1472-6920-13-152.
2. Cheung CC, Bridges SM, Tipoe G. Why is anatomy difficult to learn? The implications for undergraduate medical curricula. Anat Sci Educ. 2021;14(6):752-763. doi:10.1002/ase.2071.
3. Hall S, Stephens J, Parton W, Myers M, Harrison C, Elmansouri A, *et al.* Identifying medical students' perceptions of the difficulty of learning different topics of the undergraduate anatomy curriculum. Med Sci Educ. 2018;28(3):469–472. doi:10.1007/s40670-018-0572-z.
4. Mwabaleke JA, Usman IM, Tito AE, Obeten KE, Isyaku MU, Etukudo EM, *et al*. Perceptions and challenges faced by undergraduate medical students in studying anatomy: a case study at Kampala International University–Western Campus, Uganda. Adv Med Educ Pract. 2023;14:1129–1135. doi:10.2147/AMEP.S427136
5. Ray A, Mandal L. A study on the evolving facet of anatomy education based on the learners' perspective of medical students in Kolkata, India. Asian J Med Sci. 2022;13(7):28–33. doi:10.3126/ajms.v13i7.45678.
6. Ojukwu CP, Anyanwu EG, Onyebuchi CB, Uchenwoke CI, Okemuo AJ, Okafor CJ, *et al*. Anatomy education in physiotherapy training: perceptions of Nigerian-based undergraduate physiotherapy students. Phys Ther Rev. 2022;27(1):60–67. doi:10.1080/10833196.2021.2000276
7. Alese MO, Bamisi OD, Ibitoye BO, Oladokun AO, Oluwadiya KS. A comparative study of attitude and perception of students to the online learning of anatomy in low-resource settings during COVID-19. Med Sci Educ. 2025;35(3):1249–1258. doi:10.1007/s40670-025-02295-x
8. Mbagwu SI, Edem EE, Adegbilero-Iwari OE, Akunna GG, Makanjuola VO, Ogbo FO, *et al*. Medical school students' perspectives on virtual anatomy education in a developing country. Anat Sci Educ. 2024;17(6):1345–1357. doi:10.1002/ase.2486
9. Mora Carpio AL, Romero-Reveron R, Vasquez M, Bonilla Castillo JA, Gaitán Concepción L, Pano Carrera R, *et al*. Leveraging technology to improve access to medical education in anatomy and physiology in resource-limited settings: a mixed methods study. Anat Sci Educ. 2024;17(6):1283–1298. doi:10.1002/ase.2474.
10. Pettersson A, Karlgren K, Hjelmqvist H, Meister B, Silén C. An exploration of students' use of digital resources for self-study in anatomy: a survey study. BMC Med Educ. 2024;24:45. doi:10.1186/s12909-023-04987-7
11. Saverino D. Teaching anatomy at the time of COVID-19. Clin Anat. 2020;34(8):1128–1131. doi:10.1002/ca.23616
12. Naidoo N, Akhras A, Banerjee Y. Confronting the challenges of anatomy education in a competency-based medical curriculum during normal and unprecedented times (COVID-19 pandemic): pedagogical framework development and implementation. JMIR Med Educ. 2020;6(2):e21701. doi:10.2196/21701.
13. Owolabi J, Bekele A. Implementation of innovative educational technologies in teaching of anatomy and basic medical sciences during the COVID-19 pandemic in a developing country: the COVID-19 silver lining? Adv Med Educ Pract. 2021;12:619–625. doi:10.2147/AMEP.S295239
14. Zhang M, Yu Y, Sun B, Xiao C, Yang J, Yu Z, *et al*. Investigating clinically relevant learning in the anatomy curriculum: perspectives and effectiveness for undergraduate medical students. J Med Educ Curric Dev. 2025;12:23821205251328952. doi:10.1177/23821205251328952.
15. Sbayeh A, Qaedi Choo MA, Quane KA, Finucane P, McGrath D, O'Flynn S, *et al*. Relevance of anatomy to medical education and clinical practice: perspectives of medical students, clinicians, and educators. Perspect Med Educ. 2016;5(6):338–346. doi:10.1007/s40037-016-0310-4
16. Matveeva N, Bogdanovska JZ, Zafirova B, Chadikovska E, Dodevski A,

Trpkovska B, *et al*. Anatomy education and clinical practice: students' views. Folia Morphol (Warsz). 2025;84(3):690–701. doi:10.5603/fm.102829
17. Niu S, Zhang J, Lin J, Wang B, Yan J. Enhancing anatomy education with virtual reality: integrating three-dimensional models for improved learning efficiency and student satisfaction. Front Med (Lausanne). 2025;12:1555053. doi:10.3389/fmed.2025.1555053.
18. Karakas AB. From pandemic to earthquakes: crisis-driven challenges in distance anatomy education. BMC Med Educ. 2025;25:1409. doi:10.1186/s12909-025-07991-1
19. Qiao YQ, Shen J, Liang X, Ding S, Chen FY, Shao L, *et al*. Using cognitive theory to facilitate medical education. BMC Med Educ. 2014;14:79. doi:10.1186/1472-6920-14-79.
20. Silén C, Karlgren K, Hjelmqvist H, Meister B, Zeberg H, Pettersson A. Three-dimensional visualisation of authentic cases in anatomy learning: an educational design study. BMC Med Educ. 2022;22:477. doi:10.1186/s12909-022-03539-9
21. Lunn-Collier R, Layman-Lemphane JI, Baatjes KJ, Correia J. Clinicians' opinions on the clinical relevance of anatomy education at Stellenbosch University. Anat Sci Educ. 2022;15(4):745–753. doi:10.1002/ase.2175.
22. Yammine K, Violato C. A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy. Anat Sci Educ. 2015;8(6):525–538. doi:10.1002/ASE.1510
23. Lee JWY, Low LXT, Ong DW, Bello F, Soh RCC. An activity theory approach to analysing student learning of human anatomy using a 3D-printed model and a digital resource. BMC Med Educ. 2025;25:553. doi:10.1186/s12909-025-07172-0
24. Chang Chan AYC, van Leeuwen M, Custers E, Bleys R, Ten Cate O. Anatomy education in low-resourced countries: challenges and effective, affordable educational strategies. Med Teach. 2025;47(5):883–893. doi:10.1080/0142159x.2024.2383373
25. Balogun WG. Using electronic tools and resources to meet the challenges of anatomy education in Sub-Saharan Africa. Anat Sci Educ. 2019;12(1):97–104. doi:10.1002/ase.1831
26. Wang J, Li W, Dun A, Zhong N, Ye Z. 3D visualization technology for learning human anatomy among medical students and residents: a meta-analysis. BMC Med Educ. 2024;24:461. doi:10.1186/s12909-024-05403-4
27. Zhao J, Gong X, Ding J, Xiong K, Zhuang K, Huang R, *et al*. Integration of case-based learning and three-dimensional printing for tetralogy of Fallot instruction in clinical medical undergraduates: a randomized controlled trial. BMC Med Educ. 2024;24:571. doi:10.1186/s12909-024-05583-z
28. Telecan T, Capraș RD, Filip GA, Bonea M, Crivii CB. Dissection in the 21st century: virtual tables versus traditional methods and their influence on medical students' perception: a systematic review. BMC Med Educ. 2025;25:1332. doi:10.1186/s12909-025-07946-6
29. Hryn VG, Ryabushko MM, Petryshyn OV, Fedorchenko IL, Lytovka VV, Kondratyeva EO, *et al*. Methodological approaches for interdisciplinary integration of anatomy and rehabilitation using modern immersive technologies. Curr Probl Mod Med. 2025;25(2):197–201. doi:10.31718/2077-1096.25.2.197
30. Al-Ani SA, Chandla D, Delieu J, Yu ST, Fratini A, Gkountiou R, *et al*. Use of a 3D foot and ankle puzzle enhances student understanding of skeletal anatomy in early medical training. Surg Radiol Anat. 2024;46(9):1429–1438. doi:10.1007/s00276-024-03439-1