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Original Research Article

Utilizing images-based self-directed learning to promote anatomy learning during neuroanatomy module

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ABSTRACT

Background: Anatomy education is fundamental to medical training, yet conventional approaches such as cadaveric dissection may be constrained by limited resources, large class sizes, faculty shortages, and ethical considerations. Image-based learning incorporating radiological images and interactive three-dimensional models may serve as a useful adjunct by enhancing conceptual understanding and student engagement. This study evaluated medical students' perceptions of image-based identification sessions across cognitive, affective, and psychomotor domains.
Methods: A cross-sectional study was conducted during the 2022-2023 academic year among 137 second year (MD2) medical students at the College of Medicine and Health Sciences, National University, Sohar, Oman. Ethical approval was obtained, and informed consent was secured in English and Arabic. Students completed pre- and post-tests and a 12-item questionnaire administered through Google Forms. Items assessed the three learning domains using a five-point Likert scale. Data were analysed descriptively.
Results: Students reported positive perceptions across all three domains. In the cognitive domain, 81% agreed or strongly agreed that image-based sessions improved understanding and recall of anatomical concepts. In the affective domain, 83% reported enhanced enjoyment, confidence, and motivation for active participation. In the psychomotor domain, 79% indicated improved clarification of anatomical concepts, information-processing skills, and self-directed learning. Overall, approximately 80% considered the sessions effective and satisfactory.
Conclusions: Image-based identification sessions were positively perceived and supported learning across cognitive, affective, and psychomotor domains. While not a replacement for cadaveric dissection, image-based learning represents an effective adjunct that can support blended, student-centred anatomy curricula, particularly in resource-constrained educational settings.

Keywords: Image-based learning, Anatomy education, Student perception, Cognitive domain, Affective domain, Psychomotor domain, Medical education, Blended learning

INTRODUCTION

Medical education is undergoing continuous transformation, with increasing emphasis on student-centred, interactive, and technology-enhanced approaches to learning. Traditional anatomy education has historically relied on lecturer-centred teaching, textbooks, atlases, and cadaveric dissection. Although these approaches remain fundamental to anatomical education, their effectiveness may be constrained by limited cadaver availability, financial and logistical considerations, ethical issues, large student cohorts, and restricted faculty resources. Furthermore, understanding complex three-dimensional (3D) anatomical relationships from two-dimensional (2D) illustrations and static images can be challenging for students, particularly in resource-constrained educational environments.[1,2]

Advances in educational technology have provided opportunities to complement conventional anatomy teaching through image-based and interactive learning modalities. These include radiological images, digital 3D anatomical models, virtual dissection tables, virtual reality (VR), augmented reality (AR), and other interactive audiovisual resources. Such approaches allow learners to visualise anatomical structures from multiple perspectives, manipulate spatial relationships, and revisit learning materials repeatedly at their own pace. Consequently, technology-enhanced learning may help bridge the gap between theoretical knowledge and practical anatomical understanding while promoting active and self-directed learning.[3-5]

Evidence supporting the educational value of these technologies is increasing. A meta-analysis of randomized controlled trials demonstrated that VR-based anatomy teaching improved examination performance compared with non-VR instructional approaches, with a moderate overall effect size (standardized mean difference=0.53).[3] Similarly, a meta-analysis and regression study evaluating 3D visualization technologies among medical students and residents reported improvements in learner satisfaction and enjoyment, although effects on academic performance varied across studies.[4] These findings suggest that technological interventions may enhance the learning experience, while their effectiveness may depend on instructional design, learner characteristics, and the context in which they are implemented.

Recent studies have further demonstrated the potential of immersive technologies in anatomy education. A 2024 study conducted at a medical school in the Middle East reported generally favourable student perceptions of VR-based anatomy learning, with students indicating improvements in their understanding and memorisation of anatomical structures and, in many cases, expressing a preference for VR over conventional approaches.[5] Similarly, a pilot focus-group study reported that more than 90% of participating medical students believed that VR could improve their anatomy learning experience. Students also reported that the technology was easy to use and expressed willingness to adopt it when available.[6]

Despite these encouraging findings, the integration of technology-enhanced anatomy education requires careful consideration of its limitations. A 2024 systematic review reported that VR, particularly when used as a supplementary educational modality, generally improved academic performance and student satisfaction; however, evidence regarding long-term knowledge retention, clinical skill acquisition, and broader behavioural outcomes remained inconsistent.[7] Furthermore, a recent systematic review comparing virtual dissection tables with conventional cadaveric dissection found that although virtual dissection tables received favourable ratings for student preference and perceived usefulness, digital modalities could not completely replicate the tactile and hands-on experience associated with cadaveric dissection.[8] Thus, current evidence supports the use of digital technologies as complementary rather than replacement strategies within anatomy curricula.

Image-based identification represents a relatively accessible approach within this broader spectrum of technology-enhanced anatomy education. Structured identification sessions using radiological images, anatomical illustrations, and interactive 3D representations can provide repeated opportunities for students to recognise, interpret, and relate anatomical structures to their spatial and clinical contexts. Such activities may be particularly valuable in large or resource-constrained settings where extensive cadaveric teaching may not always be feasible. However, differences in institutional resources, curriculum structure, student characteristics, instructional methods, and assessment strategies make it important to evaluate the effectiveness and acceptability of such approaches within specific educational contexts.

In the present institutional setting, limitations related to resources and the logistics of cadaver-based teaching provide a rationale for incorporating structured image-based identification sessions as an adjunct to conventional anatomy education. Evaluating both students' perceptions and educational outcomes can help determine whether such sessions contribute meaningfully to learning and engagement.

Therefore, this study aimed to evaluate the effectiveness of structured image-based identification sessions in enhancing neuroanatomy learning among undergraduate medical students, assess students' perceptions regarding their satisfaction, usefulness, clarity, engagement, effectiveness, and preference for this self-directed learning approach, and identify its strengths, challenges, and areas for improvement. The findings may inform curriculum planning and support the development of blended, student-centred approaches to anatomy education, particularly in institutions characterised by large student cohorts or the constrained educational resources.

METHODS

Study design and setting

A cross-sectional descriptive study was conducted in 2022 at the College of Medicine and Health Sciences (COMHS), National University, Sohar, Oman. The study aimed to assess the perceptions of second year (MD2) undergraduate medical students regarding structured image-based identification sessions conducted in anatomy teaching. The sessions were designed to integrate visual learning and active engagement in line with the principles of medical education.

Study population

The study population comprised MD2 students enrolled in the neurobiology course (8 weeks) in the academic year 2022-2023 at COMHS, National University, Sohar, Oman. Participation in the study was voluntary. A total of 137 students participated, providing a representative sample of the class cohort.

Inclusion criteria

MD2 undergraduate medical students enrolled in the 8-week neurobiology course at COMHS, National University, Sohar, Oman, during the 2022-2023 academic year, students who participated in the image-based self-directed learning activities, students who completed the required pre-test and post-test assessments, students who completed the online perception questionnaire and students who provided informed consent to participate in the study were included in the study.

Exclusion criteria

Students who did not provide informed consent, students who did not complete the required pre-test or post-test assessment, students who did not complete the online questionnaire and students who participated in the pilot testing of the questionnaire (n=10) were excluded from the main study analysis were excluded from the study.

Ethical considerations

Ethical approval for the study was obtained from the institutional research and ethics committee of COMHS, National University. The registration number for the ethical approval is NU/COMHS/EBC0019/2022. Informed consent was obtained from all participants prior to data collection. Consent forms were provided in both English and Arabic languages to ensure full comprehension and voluntary participation. Participants were assured of the confidentiality of their responses, and data were anonymized before analysis.

Data collection

Pre-test and post-test assessment

A pre-test was administered during week 4 of the neuroanatomy course to establish participants' baseline knowledge. The assessment comprised image-based neuroanatomy identification questions (Figure 1). Following the pre-test, students were provided with a two-week period for independent, self-directed study using the same set of neuroanatomical images.

At the end of the intervention period, a post-test was conducted in Week 6 of the course using a comparable image-based format to evaluate changes in students' neuroanatomy knowledge. Differences between pre-test and post-test performance were used to determine the educational impact of the image-based self-directed learning intervention.

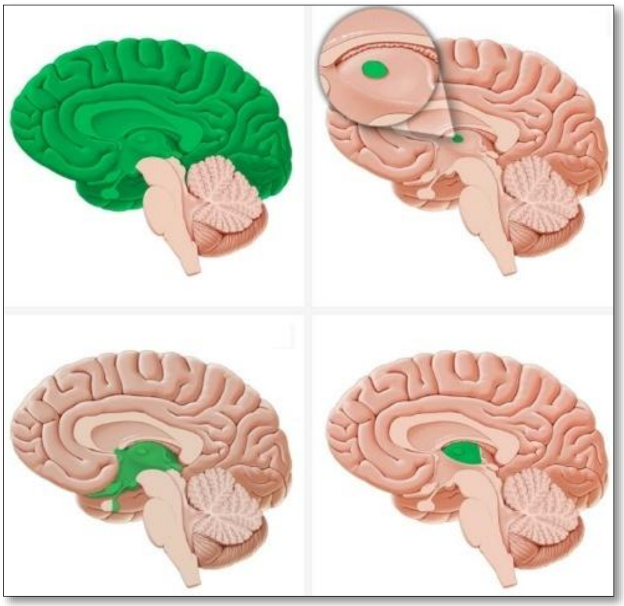

Figure 1: Identification of anatomical structures highlighted in green in the photographs.

Online survey

A structured, self-administered questionnaire was developed specifically for this study and distributed to all eligible participants. The survey consisted of 12 items and was administered online using Google Forms to facilitate accessibility and participant convenience.

The survey items are presented in Table 1. The questionnaire was designed to evaluate students' perceptions across the three domains of learning-cognitive, affective, and psychomotor-as outlined in Bloom's taxonomy.[9]

Table 1: Questionnaire on student perception of the image-based identification learning session.

S. no.	Parameters
1	I enjoyed and felt confident in the Image based identification session.
2	Image based identification session was easier to follow, clear, and understandable.
3	Session holds my attention and Stimulate interest and thinking.
4	Image based identification session was best mode to recall important points.
5	Image based identification session help me to understand the subject better.

Continued.

S. no.	Parameters
6	Image based identification session had motivated me to engage in active discussion.
7	Image based identification session was helpful in clarifying my doubts and misconceptions related to the concepts of the topic.
8	Image based identification session stimulated my information-processing skills.
9	Image based identification session gave me the ability to become a self-directed learner.
10	Image based identification session gave me the ability to become a critical and analytical thinker.
11	Image based identification session helps me to understand Neuroanatomy knowledge.
12	Overall, Image based identification session was effective and satisfactory.

The cognitive domain (Items 2, 4, 5, 8, 10, and 11) assessed students' understanding, knowledge retention, and perceived effectiveness of image-based identification sessions in enhancing neuroanatomy learning outcomes.

The affective domain (Items 1, 3, 6, and 12) evaluated students' attitudes, motivation, engagement, satisfaction, and overall enjoyment of the learning experience.

The psychomotor domain (Items 7 and 9) examined students perceived confidence, skill acquisition, and ability to apply anatomical knowledge during identification tasks and practical examinations.

The questionnaire was disseminated through a secure Google Forms link, which included a brief introduction outlining the study objectives, instructions for completion, and an informed consent statement. Participation was voluntary.

Survey responses were automatically captured within the Google Forms platform and subsequently exported to Microsoft Excel for data coding and preliminary analysis. To ensure confidentiality, all responses were anonymized prior to analysis. Each item was rated using a 5-point Likert scale, ranging from Strongly Agree to Strongly Disagree. The items were intentionally constructed to capture both positive and negative perceptions related to the clarity, usefulness, interactivity, and overall effectiveness of the image-based learning sessions.

Data analysis

Quantitative data were analysed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Student performance scores from the two assessments were compared using the independent t test, with a significance level set at $p<0.05$. Responses to the 5-point Likert scale questionnaire were summarized as frequencies and percentages. For interpretative clarity, responses were categorized as: positive (Strongly Agree and Agree), neutral (Neutral), and negative (Disagree and Strongly Disagree). Analysis focused on identifying trends in student responses across the cognitive, affective, and psychomotor domains, providing insights into both learning outcomes and learner perceptions.

Reliability and validity

To establish content validity, the questionnaire was critically reviewed by five experienced faculty members from the Department of Anatomy and Neurobiology. Each item was assessed for relevance, clarity, and alignment with the cognitive, affective, and psychomotor domains of learning. Based on their feedback, minor modifications were incorporated to enhance clarity and appropriateness.

Pilot testing was subsequently performed with a group of 10 students who were excluded from the main study analysis. The pilot aimed to evaluate the comprehensibility, clarity, and functionality of the online survey instrument. Feedback obtained during this phase was used to refine and finalize the questionnaire, ensuring it was both reliable and user-friendly for the target population.

RESULTS

All 137 second-year undergraduate medical students (MD2) enrolled in the neurobiology course participated in the study and completed both assessments, resulting in a 100% response rate. The pre-test and post-test were each scored out of 10. The mean neuroanatomy score increased from 8.21 ± 1.54 at pre-test to 9.42 ± 1.02 at post-test, with a mean difference of 1.21 points. Paired-samples t test analysis demonstrated a statistically significant increase in post-test scores compared with pre test scores ($t=11.87$, $p<0.001$). The findings demonstrate a statistically significant improvement in neuroanatomical identification performance following the structured image-based self-directed learning intervention.

Student perceptions regarding image-based identification sessions were assessed across cognitive, affective, and psychomotor domains using a structured 12-item questionnaire (Table 2).

Students' perceptions of image-based learning in the cognitive domain

Students demonstrated predominantly favourable perceptions across all six cognitive-domain items, with positive responses ranging from 78.8% to 83.2%. The highest level of agreement was observed for the clarity and ease of following the image-based identification sessions, whereas the lowest positive response concerned the application of acquired knowledge during practical learning. Overall, the cognitive-domain findings indicated consistently favourable perceptions regarding comprehension, recall, information processing, analytical thinking, and practical application of anatomical knowledge. The item-level distribution of positive responses is presented in Table 3.

Students' perceptions of image-based learning in the affective domain

Students reported predominantly favourable responses across all four affective-domain items, with positive responses ranging from 81.7% to 84.6%. The findings indicated favourable experiences in terms of enjoyment and confidence, interest in anatomy, motivation to engage in learning activities, and overall satisfaction with the image-based identification sessions. The highest proportion of positive responses was observed for overall satisfaction, while the lowest was reported for motivation to engage in future sessions. Overall, the affective-domain findings demonstrated consistently positive student responses, indicating favourable engagement and acceptance of the image-based learning approach. Item-level responses are presented in Table 4.

Students' perceptions of image-based learning in the psychomotor domain

The psychomotor domain (Table 5) demonstrated predominantly favourable student responses, with approximately four-fifths of participants reporting positive perceptions. Students generally perceived the image-based identification sessions as useful for clarifying anatomical doubts and misconceptions and for developing self-directed learning abilities. Overall, the findings indicate that image-based learning supported the practical application of anatomical knowledge while encouraging students to take greater responsibility for their learning. Item-level responses are presented in Table 5.

Table 2 presents students' perceptions of the image-based learning approach across the three learning domains. Approximately 80% of students agreed that the intervention improved their understanding and retention of anatomical concepts, enhanced analytical and information-processing skills, and supported practical learning. Students also reported favourable levels of engagement, motivation, and enjoyment during the sessions. Overall, the findings demonstrated positive student perceptions of image-based learning across the cognitive, affective, and psychomotor domains.

Table 2: Students' evaluation of image-based self-directed learning sessions in neuroanatomy, (n=137).

Parameters	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Domain
I enjoyed and felt confident in the Image based identification session	80 (58%)	35 (25.5%)	12 (8.8%)	7 (5.1%)	3 (2.2%)	Affective
Image based identification session was easier to follow, clear, and understandable	82 (59.9%)	38 (27.7%)	10 (7.3%)	5 (3.6%)	2 (1.5%)	Cognitive
Session held my attention and stimulated interest in neuroanatomy	78 (56.9%)	36 (26.3%)	15 (10.9%)	6 (4.4%)	2 (1.5%)	Affective
Image based identification session was best mode to recall key points	75 (54.7%)	37 (27%)	15 (10.9%)	7 (5.1%)	3 (2.2%)	Cognitive
Image based identification session helped me to understand neuroanatomy better	80 (58%)	32 (23.4%)	15 (10.9%)	7 (5.1%)	3 (2.2%)	Cognitive
Image based identification session motivated me to engage in active discussion	78 (56.9%)	34 (24.8%)	15 (10.9%)	6 (4.4%)	4 (2.9%)	Affective
Image based identification session was helpful in clarifying my doubts and misconceptions	75 (54.7%)	34 (24.8%)	16 (11.7%)	8 (5.8%)	4 (2.9%)	Psychomotor
Image based identification session stimulated my information-processing skills	77 (56.2%)	33 (24.1%)	15 (10.9%)	7 (5.1%)	5 (3.6%)	Cognitive
Image based identification session gave me the ability to become a self-directed learner	76 (55.5%)	33 (24.1%)	16 (11.7%)	7 (5.1%)	5 (3.6%)	Psychomotor
Image based identification session gave me the ability to become a critical and analytical thinker	78 (56.9%)	31 (23.4%)	15 (10.9%)	7 (5.1%)	5 (3.6%)	Cognitive
Image based identification session helped me to apply Neuroanatomy knowledge in practical	77 (57.7%)	31 (22.6%)	16 (11.7%)	6 (4.4%)	5 (3.6%)	Cognitive
Overall, Image based identification session was effective and satisfactory	82 (59.9%)	34 (24.8%)	12 (8.8%)	6 (4.4%)	3 (2.2%)	Affective

Table 3: Students' perceptions of image-based learning sessions across cognitive-domain items, (n=137).

Item	Cognitive-domain statement	Positive response, n (%)
2	Image-based sessions were easy to follow, clear, and understandable	120 (83.2)
4	Improved ability to recall key points	112 (81.7)
5	Improved understanding of the subject	112 (81.7)
8	Enhanced information-processing skills	110 (80.3)
10	Improved analytical/critical thinking	109 (79.6)
11	Applied knowledge effectively in practical learning	108 (78.8)
Overall	Positive responses across cognitive-domain items	81.0%

*Note: Positive responses represent students who selected Agree or Strongly Agree on the five-point Likert scale.

Table 4: Students' perceptions of image-based learning sessions across affective-domain items, (n=137).

Item	Affective-domain statement	Positive response, n (%)
1	Enjoyed and felt confident during the session	115 (84.0)
3	Increased interest in the subject	114 (83.0)
6	Motivated to engage in future sessions	112 (81.7)
12	Felt the sessions were satisfactory	116 (84.6)
Overall	Positive responses across affective-domain items	83.0%

*Note: Positive responses represent *Agree* and *Strongly Agree* responses on the five-point Likert scale.

Table 5: Students' perceptions of image-based learning sessions across psychomotor domains, (n=137).

Domains	Item no.	Item description	Positive response, n (%)
Psychomotor	7	Image-based identification session was helpful in clarifying my doubts and misconceptions	109 (79.6%)
Psychomotor	9	Image-based identification session gave me the ability to become a self-directed learner	109 (79.6%)

*Note: Positive response = Agree + Strongly Agree on the five-point Likert scale.

DISCUSSION

In this study, we assessed the effect of a self-directed learning (SDL) session using images during the neuroanatomy course to assess students' performance. The pre-test mean score was 8.21±1.54, increasing to 9.42±1.02 in the post-test. This improvement not only reflects enhanced average performance but also shows reduced score variability, suggesting more consistent comprehension and more uniform performance among students after the intervention. The mean difference of 1.21, and a paired-sample t test result of t=11.87 ($p<0.001$), confirm a statistically significant and educationally meaningful improvement following the SDL activity. These results are in line with recent evidence that SDL can enhance learning outcomes in undergraduate medical education. A large systematic review and meta-analysis comparing SDL with traditional didactic learning reported an overall mean difference favouring SDL (mean difference=2.399) across knowledge application and cognitive performance domains.[10] Thus, our findings reinforce the potential of SDL-even in a brief, image-based format to improve student learning.

Furthermore, the use of visual tools and image-based resources appears to support learning in anatomy, a discipline characterized by complex spatial relationships. Prior work has shown that visualization technologies-3D models, virtual dissection, or image-based learning can improve spatial understanding, retention and student satisfaction in anatomy education.[11] The educational design study using 3D visualization of authentic anatomical cases reported that students valued the opportunity to interpret images, learn on their own, and integrate previous knowledge to poster their understanding of the topic. Another recent investigation found that digital resources for self-study were frequently used by anatomy students and perceived as helpful for understanding, memorization, and examination preparation.[11]

Adopting image-based SDL sessions in neuroanatomy thus aligns with pedagogical trends in medical education that emphasize learner autonomy, flexibility, and visual/interactive learning. Given constraints like limited formal teaching hours, high student-to-resource ratio, and restricted access to cadaveric facilities, image-based SDL offers a feasible, scalable supplement. Moreover, SDL fosters self-regulation, curiosity, and lifelong learning skills qualities essential for medical professionals who must continuously assimilate new knowledge.[10]

In our study, a substantial majority of MD2 medical students reported positive perceptions of the structured image-based identification sessions across cognitive, affective, and psychomotor domains. These findings support the view that image-based (or digitized/interactive) anatomy teaching can be a valuable pedagogical adjunct in medical education.

Cognitive domain-enhanced understanding, retention, and analytical thinking

Students rated highly that the sessions were clear, easy to follow, and helpful in understanding anatomical concepts and recalling important points. This aligns with evidence that 3D/virtual visualization tools improve anatomical knowledge and spatial comprehension. A meta-analysis of randomized controlled trials found that teaching with VR yielded a moderate but significant benefit on anatomy examination scores compared with conventional methods.[12] Similarly, VR/AR applications significantly improve knowledge scores in anatomy courses.[13] Moreover, a mixed-methods study comparing 3D-VR and traditional models showed that VR users maintained higher short-and long-term knowledge retention.[14]

Even cost-effective image-based methods, such as radiological images or digital 2D/3D models, can bridge limitations of traditional atlases or textbook-only teaching, particularly in large classes or resource-limited settings.[15,16] Our results prove that such sessions using visual senses can facilitate comprehension, retention, and analytical thinking, especially in spatially complex areas like neuroanatomy.

Affective domain-motivation, engagement, and satisfaction

High proportions of students reported enjoying the sessions, feeling confident, and being motivated to engage. Positive affective responses are crucial, as motivation and engagement strongly influence learning behaviours and long-term retention.[17] Recent surveys using VR anatomy tools found that most participants reported improved understanding and memorization of anatomy, alongside high enjoyment.[16,18] Similarly, feasibility studies indicate that use of visual senses to learn enhances student satisfaction and engagement.[19]

These affective benefits suggest that image-based sessions can create an effective learning environment, support greater participation and reinforce the cognitive gains.

Psychomotor domain and self-directed learning-confidence, practical skills, and autonomy

Although image-based learning lacks the tactile component of cadaveric dissection, many students felt that sessions helped clarify doubts, improved their ability to learn independently, and increased confidence in neuroanatomical identification. Previous studies indicate that screen-based 3D visualization improves spatial understanding and learner confidence.[13,20,21] Even non-VR, screen-based modalities can foster psychomotor and self-directed learning, particularly in preparing students for practical tasks.[22,23]

Implications for curriculum design

The positive findings across all domains suggest that integrating image-based self-directed identification sessions into anatomy curricula could be highly beneficial, especially where traditional resources (cadaver labs, small-group teaching) are limited. A blended curriculum approach, combining lectures, cadaveric/prosection labs, and self-directed image-based sessions, leverages the strengths of each modality.[24,25] Evidence suggests that VR or 3D visualization improves learner satisfaction and knowledge when used as a supplement to traditional methods.[12,14,26] Furthermore, our participants reported increased self-directed learning capacity, indicating that image-based sessions could enable repeated exposure, individualized pacing, and revision, all of which enhance long-term retention.

Strengths

The study demonstrated high student engagement and positive perceptions across cognitive, affective, and psychomotor domains, confirming the feasibility and acceptability of structured image-based identification self-directed sessions in a resource-limited setting.

Limitations

Despite the positive outcomes, some caveats must be acknowledged. First, our findings are based on self-reported data, which may be influenced by novelty or social desirability bias.[15] There were objective measures of knowledge gain (pre and post-test) but not for long-term memory retention. Second, image-based methods, especially 2D or screen-based modalities, lack tactile feedback, tissue texture, and the depth perception inherent to cadaveric dissection.[24,25] Third, our study was conducted at a single institution with one cohort, limiting generalizability.[15]

Future directions

Future research should adopt a more comprehensive approach by combining students' subjective perceptions with objective measures of learning, such as practical examinations and knowledge retention tests.[12,13] Controlled or comparative study designs are recommended to directly evaluate the effectiveness of image-based methods against traditional teaching approaches.[14] Additionally, long-term retention and clinical applicability, including the ability to interpret radiological and anatomical images, should be assessed.[16,21] Investigations into blended curricula that integrate lectures, dissection/prosection, and image-based sessions may further optimize learning outcomes.[24,26] Finally, studies should consider equity and accessibility, ensuring that all students can effectively use digital learning tools regardless of prior experience or resource availability.[17,20]

CONCLUSION

Structured image-based identification sessions are widely perceived as beneficial by medical students across cognitive, affective, and psychomotor domains, enhancing understanding, motivation, and self-directed learning. While they cannot fully replace dissection, these sessions provide a feasible, effective adjunct to traditional anatomy teaching, particularly in resource-limited settings, and should be integrated into a blended anatomy curriculum for optimal outcomes.

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