Original paper

Rethinking anatomy education for Generation Z: insights from Polish nursing students on learning needs and preferences

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Medical Studies
DOI: https://doi.org/10.5114/ms.2026.161557

Key words: anatomy, education, nursing, student perceptions.

Abstract

Introduction: How to adapt teaching methods and strategies to the needs of Generation Z is an immense challenge for medical educators. Hence, we are interested in exploring the topic of learning anatomy from the students' perspective. In our study, we have asked nursing students about their needs and expectations regarding anatomy classes.
Aim of the research: This study aimed to explore how anatomy teaching methods can be adapted to the needs of Generation Z and to inform the discussion on undergraduate nursing anatomy education.
Material and methods: A cross-sectional study involving Polish first-year nursing students was carried out at two biggest medical universities in Poland. Data were collected using an original questionnaire designed based on the review of the literature and a focus group discussion among authors. Students' opinions at the beginning and after completing the anatomy course were compared.
Results and conclusions: Despite using digital tools, students valued traditional teaching methods. After the anatomy course, support grew for structured learning with pre-class preparation and frequent in-class assessments. Preferences shifted toward integrating anatomy with related subjects and extending course duration, while emphasising consolidation with a group of basic subjects like physiology, morphology, and histology. There is much debate over suitable methods of delivering anatomical knowledge. Changing anatomy education for Generations Z and Alpha is one of the conditions for successfully training, and retaining nursing students. Engaged teachers, face-to-face learning, and hands-on, practical classes cannot simply be replaced by technology.

Introduction

In Poland, first-cycle (Bachelor's level) nursing/midwifery studies last six semesters. Anatomy is taught as a separate course within the preclinical sciences module. This module also includes physiology, pathology, genetics, biochemistry and biophysics, microbiology and parasitology, pharmacology, and radiology, comprising a minimum of 500 teaching hours and 20 ECTS credits. Education standards for healthcare providers (nurses and midwives) in Poland stipulate that registered nurses and midwives should know and understand the structure of the human body in a topographic approach (upper and lower limbs, chest, abdomen, pelvis, back, neck, head) and a functional approach (muscular system, circulatory system, respiratory system, digestive system, urinary system, reproductive systems, nervous system, sense organs, common integument) and can use anatomical nomenclature in practice and use knowledge of the topography of the organs of the human body [1]. However, the exact way and didactic methods of how such learning outcomes should be met remain open to interpretation. Anatomy is one of the basic sciences of medicine and the knowledge of the human body is essential in the training process of any healthcare professional. However, students struggle with anatomy because of the complicated terminology and difficulty handling large amounts of information. To promote effective and attractive learning, teachers need to understand the needs of learners and to motivate them by enabling them to perceive any gaps that exist between their present level of ability and the desired level. It is important to explore innovative, stimulating, engaging, multimodal means to encourage proactive and deep learning but also regularly validate approaches to learning and the students' learning preferences. Over the last few years, with the pick from 2020 due to the SARS-CoV-2 pandemic, the availability of digital learning tools has systematically increased and has displaced or even replaced traditional anatomy education techniques (lectures and cadaveric dissections). Many studies evaluated new, sophisticated ways to teach anatomy including digi-

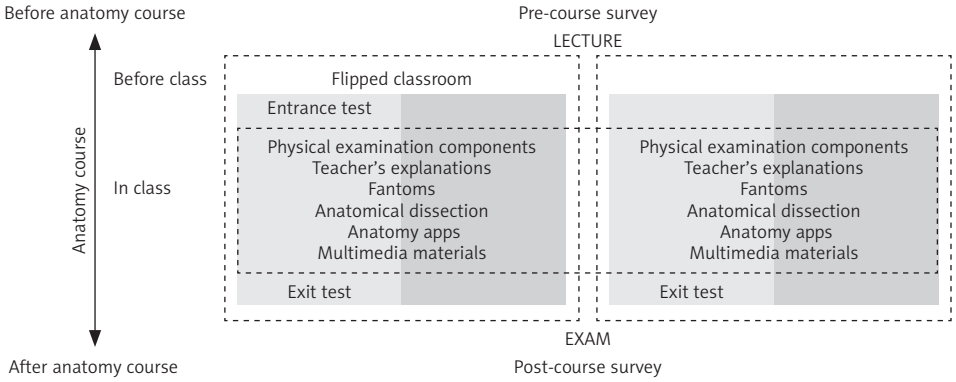

Figure 1. Study design

tal learning methods like computer-assisted learning, game-based learning, virtual reality, and anatomy apps for new generation for whom the digital world is a natural environment [2, 3]. How these digital tools, aid the hands-on learners and applying theory to practice and how often students have the opportunity to compare classical and digital methods? Are digital methods truly the most nursing students-oriented concept? But is this direction of changes not dictated by modifications in the education market, such as the shortage of anatomy teachers, the lack of necessary resources: cadaveric materials, fully equipped anatomy lab and the need to reduce education costs?

The aim of this study was to examine how anatomy teaching methods and strategies may be adapted to address the needs of Generation Z and to contribute to the scholarly debate on the current state of undergraduate nursing anatomy education. How do nursing students perceive learning anatomy before the course, and how do they perceive learning anatomy after the anatomy course is over? What motivates nursing students to learn anatomy?

Changes in anatomy education, including the curriculum, teaching models, and education innovations, are designed and implemented by teachers as the main agents in the education change. The effects of teachers' beliefs and education reforms are examining as students outcomes.

Aim of the research

The aim of the study was to explore students' opinions and expectations versus the reality of anatomy courses for Generation Z nursing students. What is important to Generation Z nursing students during anatomy classes? What motivates nursing students to learn anatomy? Do new technologies facilitate anatomy learning, and do nursing students change pre- and post-course opinion and perception of learning anatomy?

Material and methods

Study design and setting: This prospective, comparative, two-stage (pre–post) study was conducted during the 2022/2023 and 2023/2024 academic years at two leading medical universities in Poland: the Medical University of Warsaw and Pomeranian Medical University in Szczecin. Participants were first-year undergraduate students enrolled in nursing and midwifery bachelor programmes who were attending a basic anatomy course. According to the Polish national education standards, there are no differences in the learning outcomes related to anatomical content between nursing and midwifery degree programmes. At both universities, anatomy programmes were similar and consisted of 30 hours of lectures and 30 hours of practical classes. The course was delivered in a hybrid format, combining asynchronous online lectures covering theoretical content with synchronous, in-person practical sessions. Anatomy classes incorporated a wide range of teaching and learning methods, including traditional resources (textbooks and atlases), flipped classroom strategies, entrance and exit tests, physical examinations, plastic models, plastinated and prosected cadavers, peer examination, peer tutoring, self-directed study using models or fantoms, problem-based learning, group presentations, and digital tools such as anatomy apps, virtual platforms, VR environments, and anatomical tables. A graphical overview of the study procedure, including time points for data collection, is presented in Figure 1.

Sampling and recruitment

A convenience sample of first-year students enrolled in the nursing and midwifery bachelor's programmes was recruited. Participation was voluntary and anonymous. A total of 893 students (756 nursing and 137 midwifery) completed the pre-course questionnaire, and 746 students (638 nursing and 108 midwifery) completed the post-course questionnaire. Due to the anonymised nature of the responses, data from the two time points were treated as independent samples.

Data collection

Data were collected at two time points: (i) baseline (pre-course), during the first week of the semester before the start of anatomy classes, and (ii) follow-up

(post-course), immediately after course completion and the final assessment. At both stages, participants completed an identical online questionnaire.

Tool

The self-administered questionnaire consisted of 18 statements rated on a five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree". The instrument also included one open-ended question inviting additional comments and a set of sociodemographic questions. The Likert scale was designed to capture various constructs related to students' experiences and attitudes, including motivation to learn, perceived difficulty of the subject, educational value of the course, teaching methods used, and preferred learning approaches. The questionnaire was developed specifically for this study and reviewed by subject matter experts before administration. Its complete content is available in the Supplementary Material.

Ethical consideration

The study protocol was reviewed and approved by the Ethics Committee of the Pomeranian Medical University (Approval No. RPW/10749/2022P). The study followed the ethical principles outlined in the Declaration of Helsinki, participation was voluntary, and informed consent was implied through questionnaire completion. The data collection process preserved participant anonymity and confidentiality.

Statistical analysis

Statistical analyses were performed to compare students' attitudes and perceptions before and after the anatomy course. Descriptive statistics, including means and standard deviations, were calculated for Likert-type items. Chi-squared (χ^2) tests were used to assess differences in categorical variables such as gender, university affiliation, and previous exposure to anatomy education. To evaluate differences between pre- and post-course responses, the Brunner-Munzel test was applied, a non-parametric method suitable for ordinal data and unequal variances in independent samples. Although data were collected at two time points, individual responses were not matched, justifying the use of independent-sample comparisons. The test assessed changes in constructs such as motivation to learn, perceived difficulty, perceived educational value, teaching methods, and learning preferences. Relative effect sizes and 95% confidence intervals were calculated to interpret the magnitude of changes. All analyses were conducted using Jamovi software (version 2.6), with statistical significance set at $p < 0.05$.

Results

Data were compiled from 893 completed pre-course questionnaires and 746 post-course questionnaires. All students were in nursing and midwifery bachelor's degree programme, for most of them, it was their first anatomy course (Table 1). Only 10 students reported having taken an anatomy course in another field of study.

Several hypotheses were considered in the design of the survey. The first hypothesis posited that, in the opinion of students, a basic anatomy course is sufficient for learning human anatomy. Four thematic areas related to hypothesis H1 were analysed: (1) motivation to learn, (2) perceived difficulty, (3) perceived necessity of anatomy in further education, and (4) perceived need for elective classes. The analysis of relative effects indicates the direction of changes in participants' opinions following the anatomy course (Table 2). The results show that the intervention led to a decline in motivation to learn (relative effect 0.66; 95% CI: 0.64–0.68), an increased perception of the subject's difficulty (relative effect 0.44; 95% CI: 0.41–0.46), and a reduced perception of anatomy as essential (relative effect 0.57; 95% CI: 0.54–0.59). However, it did not have a significant impact on the perceived need for additional classes. The findings suggest that, upon completing the anatomy course, students exhibited a decreased interest in learning the subject and a diminished perception of its importance, while simultaneously regarding it as more challenging. These observations may indicate a need to revise current teaching methods and strategies.

New technologies and digital learning tools are used during anatomy classes. We assumed that for Generation Z, they would be sufficient and attractive to master basic issues of human anatomy. The obtained results presented in Table 3 indicate greater support among respondents for the use of multimedia programs as well as cadaver-based sessions – considered the most traditional method of learning anatomy – in the anatomy course for nursing and midwifery students (for both interventions, the relative effect was identical: 0.47; 95% CI: 0.45–0.50). Interestingly, after completing the anatomy course, participants were less likely to agree that anatomy teaching should include elements of physical examination – the mean rating decreased from 4.36 before the intervention to 4.15 afterward. Also surprising was the respondents' lower recognition of the effectiveness of quizzes and games in learning anatomy (relative effect of 0.55; 95% CI: 0.53–0.58). Thus, it is not possible to clearly indicate whether students prefer traditional or modern methods of teaching anatomy. Certainly, diverse and mixed methods should be chosen to adapt them to the different learning styles of students.

The third hypothesis posited that students are more inclined to prefer a learning environment characterized by a supportive and welcoming atmosphere, in which prior preparation for classes and frequent assessments – such as entry and exit tests – are not required. A friendly classroom environment im-

Table 1. Sociodemographic information of participants

Parameter	Pre-course (*n* = 893)		Post-course (*n* = 746)		χ^2	*P*-value*
	N	%	*N*	%		
University						
Warsaw	590	66.07	532	71.31	5.18	0.023
Szczecin	303	33.93	214	28.69		
First anatomy course						
No	75	8.40	87	11.66	4.86	0.027
Yes	818	91.60	659	88.34		
Age [year]						
17	7	0.78	1	0.13	-	-
18	180	20.16	72	9.65		
19	455	50.95	340	45.58		
20	121	13.55	196	26.27		
21	36	4.03	46	6.17		
22	29	3.25	30	4.02		
23	18	2.02	20	2.68		
24	14	1.57	15	2.01		
> 25	33	3.7	26	3.49		
Gender						
Female	837	93.73	698	93.57	0.29	0.867
Male	47	5.26	42	5.63		
Non-binary person	9	1.01	6	0.80		

χ^2 test.

Table 2. Changes in students' perceptions of anatomy education: pre- vs. post-course comparison

Variable	Measurement	M	SD	Statistic	d*f*	*P*-value*	Relative effect	95% CI	
								Lower	Upper
I want to learn the basics of human anatomy.	Post-test/ course	4.14	0.762	13.30	1529	< 0.001	0.66	0.64	0.68
	Pre-course	4.57	0.557						
Anatomy is a difficult subject.	Post-test/ course	4.31	0.765	–5.07	1575	< 0.001	0.44	0.41	0.46
	Pre-course	4.16	0.741						
Anatomy is a necessary subject to understand all issues at further stages of study.	Post-test/ course	4.14	0.83	5.18	1499	< 0.001	0.57	0.54	0.59
	Pre-course	4.37	0.655						
The basic cycle of education in my field of study should be supplemented by optional/ additional anatomy classes, available to interested students also from second-cycle studies.	Post-test/ course	3.86	0.885	–1.63	1507	0.104	0.48	0.45	0.51
	Pre-course	3.82	0.779						

Brunner-Munzel test.

Table 3. Comparison of students' opinions on selected anatomy teaching methods before and after the course

Variable	Measurement	M	SD	Statistic	d*f*	*P*-value*	Relative effect	95% CI	
								Lower	Upper
Teaching anatomy should include elements of physical examination (inspection/palpation, percussion, auscultation).	Post-test/ course	4.15	0.88	4.55	1467	< 0.001	0.56	0.53	0.59
	Pre-course	4.36	0.71						
Anatomy classes in your degree programme should include cadaver-based sessions in the dissection room.	Post-test/ course	4.48	0.83	–2.24	1613	0.025	0.47	0.45	0.50
	Pre-course	4.38	0.91						
Anatomy classes in my degree programme should be conducted primarily using multimedia programs and applications.	Post-test/ course	3.25	1.01	–2.26	1569	0.024	0.47	0.44	0.50
	Pre-course	3.14	0.97						
A printed anatomical atlas is a sufficient tool for learning anatomy.	Post-test/ course	2.43	1.03	3.43	1463	< 0.001	0.55	0.52	0.57
	Pre-course	2.53	0.88						
Multimedia quizzes and games facilitate the learning of anatomy.	Post-test/ course	4.24	0.91	3.96	1454	< 0.001	0.55	0.53	0.58
	Pre-course	4.45	0.69						

**Brunner-Munzel test.*

Table 4. Effect of the anatomy course on students' views regarding flipped classroom and group work

Variable	Measurement	M	SD	Statistic	d*f*	*P*-value*	Relative effect	95% CI	
								Lower	Upper
Frequent tests during classes motivate me to study.	Post-test/ course	2.93	1.27	–6.42	1451	< 0.001	0.41	0.39	0.44
	Pre-course	2.54	1.12						
Teachers should require students to have preparation/be prepared for classes.	Post-test/ course	3.53	0.90	–5.94	1584	< 0.001	0.42	0.40	0.45
	Pre-course	3.25	0.93						
Discussion and group work make learning easier.	Post-test/ course	4.17	0.95	–4.73	1585	< 0.001	0.44	0.41	0.46
	Pre-course	3.97	0.98						

**Brunner-Munzel test.*

proves student participation in their opinion, but after the course, the majority of students indicated that there should be a requirement for obligatory student pre-class preparation (relative effect 0.42; 95% CI: 0.40–0.45) and students pointed out that frequent in-class testing: entry and exit quizzes motivated them to study (relative effect 0.41; 95% CI: 0.39–0.44) (Table 4). In summary, the analysis of relative effects and the direction of change indicates that, following the completion of the anatomy course, there was a statistically significant increase in students' agreement regarding the necessity of class preparation, the motivating role of frequent assessments, and the positive value attributed to group work and peer discussion.

Several items in the questionnaire addressed students' preferences regarding the organisation of the anatomy course (Table 5). With the experience gained through studying anatomy, participants expressed stronger support for integrating anatomy into a broader block of related subjects like physiology, histology, and morphology (relative effect 0.43; 95% CI: 0.40–0.45) and indicated a clear preference for extending the course beyond a single semester (relative effect 0.39; 95% CI: 0.36–0.41). Notably, their views on the preferred mode of content delivery – topographic versus systemic – remained unchanged. However, post-course responses revealed a decreased level of agreement regarding the inclusion of ana-

Table 5. Students' preferences regarding the organization of the anatomy course

Variable	Measurement	M	SD	Statistic	d*f*	*P*-value*	Relative effect	95% CI	
								Lower	Upper
Anatomy should be integrated into a broader block of subjects, including physiology, morphology, and histology.	Post-test/ course	3.52	1.00	–5.43	1390	< 0.001	0.43	0.40	0.45
	Pre-course	3.31	0.82						
It is easier to learn anatomy by body regions(topographically) rather than by systems.	Post-test/ course	3.32	1.21	–1.80	1429	0.073	0.48	0.45	0.50
	Pre-course	3.22	1.06						
The anatomy course should be conducted over two semesters rather than in a single semester.	Post-test/ course	4.04	1.09	–8.49	1481	< 0.001	0.39	0.36	0.41
	Pre-course	3.65	1.01						
The basic anatomy course should take into account structural variations related, for example, to age, ethnic group, or disease.	Post-test/ course	3.82	0.90	3.48	1519	< 0.001	0.55	0.52	0.57
	Pre-course	3.98	0.77						
Classes should include English or Latin nomenclature for the most important structures.	Post-test/ course	2.38	1.07	3.58	1065	< 0.001	0.56	0.53	0.59
	Pre-course	2.58	1.10						

**Brunner-Munzel test.*

tomical variations associated with age, ethnic group and pathological conditions (relative effect 0.55; 95% CI: 0.52–0.57), as well as the use of English/Latin terminology in anatomy instruction (relative effect 0.56; 95% CI: 0.53–0.59). In summary, the analysis of relative effects and the direction of changes indicates that the intervention had a significant impact on participants' perception of the need to conduct anatomy as part of a broader block of subjects and to extend the course over two semesters. At the same time, following the intervention, participants were less inclined to support the inclusion of anatomical variations and changes and English or Latin nomenclature in anatomy education.

In students' comments collected after the completion of the course, a recurring suggestion was the insufficient number of contact hours. Students indicated a preference for shorter, more focused sessions with a smaller amount of material covered at a time, but delivered over a longer period. They also expressed a need for classes that would help consolidate their knowledge and integrate larger sections of the content covered.

Discussion

Historically, anatomy teaching has been strongly oriented towards encyclopedic and memorisation-based knowledge, relying on traditional methods such as lectures, seminars, textbooks, anatomical atlases, models, dry or wet anatomical specimens, and dissection room classes. With the spread of the Internet in the early 21st century, new resources emerged: e-learning platforms, digital anatomical atlases, instructional videos, virtual reality (VR) and augmented reality (AR) models, mobile applications, and digital dissection tables. In the last decade, the development of multimedia in medical education has accelerated, particularly in response to the needs of digital natives (Generation Z) and the COVID-19 pandemic, which forced a rapid transition to remote learning. Currently, multimedia methods (digital teaching) are commonly used, initially as a supplement and increasingly as an alternative to traditional anatomy education methods [2]. Today, education without these tools is unimaginable. A hybrid approach integrating modern technologies with contact practice can increase teaching effectiveness and student satisfaction, but it has to be conducted prudently. In the studied group of students, a significant decrease was observed in the perceived effectiveness of using textbook atlases, physical examination components, and multimedia quizzes/games in classes. Although most students generally enjoy using digital tools, in the study by Pagels *et al.*, many pointed to unfamiliarity with application interfaces and difficulties in operation as barriers to effective learning. Familiar, easy-to-use tools – even analogue ones – may be more effective than modern digital solutions if the latter are not properly introduced and familiarised by the user. Further research into complementary methods such as quizzes, discussion forums, or educational games is recommended [3].

Effective integration of virtual tools requires not only access to technology, but also appropriate student preparation, technical support, consideration of psychological and social factors, and the use of gamification elements [4]. Another issue is that many developing non-English-speaking countries lack multimedia tools in students' native languages. In our study group, the inclusion of English or Latin nomenclature of key structures was not well accepted and may be a contributing factor.

Surprisingly, results showed a decrease in acceptance among nursing students for using physical examination elements (palpation, percussion, auscultation) in learning anatomy. While most people use a multimodal approach to learning, studies show that nursing students are more likely to be kinesthetic learners, with up to 85% valuing hands-on experience as their preferred learning style [5, 6]. Kinesthetic or tactile learners need to physically touch or try something to best understand a concept. This style is often referred to as multisensory learning – students learn by hearing or seeing and then solidify knowledge through practice and physical contact [7, 8]. In health education, physical examination is essential for many procedures and interventions. In this context, the effectiveness of using digital applications, anatomical tables, virtual/augmented reality, machine learning, and AI-based learning becomes debatable. Practical anatomy teaching should resemble real clinical practice and better prepare nursing students to deal with the complexity of the human body and patient care [9]. However, tactile examination and palpation anatomy is a challenging method that requires knowledge of the surface and topographical representation of structures. Therefore, it may not have been widely accepted by students during the basic anatomy course, where the material is presented by individual systems.

Students rated the dissection room experience highly. Working with real bodies not only enhances anatomical knowledge but also develops students' non-technical skills such as empathy, communication, ethical reflection, humanistic values, and professional identity. Replacing these experiences with technology does not replicate the authenticity of the donor relationship, nor does it teach respect for the deceased or informed decision-making in the context of bioethics [10]. However, such classes significantly increase the cost of anatomy education and face limitations due to the need for special lab facilities, highly trained staff, and limited cadaver availability – factors that lead only a few nursing programmes to include dissection in their curricula [11].

Using a variety of didactic methods is recommended, as research shows that combining different approaches, including technology-based and hands-on experience, improves engagement, motivation, and knowledge retention [12].

Before the course, all students expressed a desire to learn anatomy, but by the end, they were not convinced they had achieved that goal. Students underestimated the difficulty of the subject before the course. The large volume and complexity of material lead to a drop in motivation, as students realise they cannot fully master even basic topics. They begin to see their limitations, which may cause them to downplay the importance of anatomy in further education. The observed post-course decline in students' motivation to learn anatomy is likely multifactorial and should be interpreted cautiously. One contributing factor may be assessment-related stress, as the post-course survey was administered immediately after final examinations, a period commonly associated with fatigue and cognitive overload. While frequent assessments were ultimately perceived as motivating, their cumulative burden may temporarily reduce intrinsic motivation.

Additionally, variability in teaching quality and instructional approaches across teachers may have influenced students' experiences, despite consistent national standards and contact hours. A further explanation lies in the misalignment between students' initial expectations and the actual demands of anatomy learning. Many students underestimated the subject's complexity, and confronting its extensive terminology and cognitive load may have led to frustration and a reassessment of motivation.

Finally, the decline in motivation may reflect broader curricular overload, as anatomy is taught alongside several demanding preclinical subjects, particularly challenging for first-year students transitioning from secondary education. Together, these factors suggest that reduced motivation does not necessarily indicate disengagement from anatomy itself, but rather the cumulative impact of assessment pressure, workload, and expectation–reality mismatch.

In our opinion, several indicators suggest that the anatomy course requires reorganisation. Students themselves suggested extending its duration, integrating anatomy into a year-long cycle of basic courses, and abandoning detailed discussions of structural differences related to age, ethnicity, or pathology. The lack of interest in anatomical variants may also result from the dominance in literature and teaching materials of images/descriptions of adult, middle-aged, light-skinned, average-body-type males [13]. This highlights the need for systemic action by publishers, universities, and content creators to promote inclusivity and representativeness in anatomical resources.

Educators emphasise the importance of pedagogical background in anatomy teaching, including material volume, teaching time, and the need for repetition [14].

In Poland, nursing students are typically young (average age in our study: 19), entering university directly from high/secondary school. Anatomy is often their first exposure to academic study, and they face

completely new learning realities. Therefore, it is important that anatomy educators have strong pedagogical and teaching skills. Unfortunately, global shortages in anatomy teaching staff mean it is not always possible to meet the crucial needs of medical students in terms of support, motivation, and matching teaching methods to the specifics of a given programme [15]. In light of the shortage of anatomy educators, could AI, machine learning algorithms, simulation-based learning, and virtual platforms help fill this gap?

The flipped classroom model, when implemented early and consistently, supports the development of independent learning strategies, understanding difficult content, and better educational outcomes – as confirmed by both research and student preferences [16]. Interestingly, students expressed a desire for frequent entry and exit tests, which they found motivating.

Students see a need for deep changes in anatomy teaching and their feedback can be valuable in designing more equitable and representative curricula [17]. They expect practical, active anatomy learning – something that cannot be replaced by apps or distance learning methods. Committed teachers, assessment of preparation and student performance enhance motivation among our student population.

Although this study was conducted within the Polish educational context, its findings may be transferable to other countries and healthcare education systems. Many of the challenges identified – such as high cognitive load, assessment pressure, declining motivation, and the need to balance digital tools with hands-on learning – are common across nursing and medical education internationally.

What should the anatomy education of the future look like? Will it be based on AI, simulation, and individualisation of the learning process? It is a fact that over the past few years, the anatomical knowledge level of medical students has declined, and the number of medical errors and lawsuits due to anatomical ignorance has increased [18]. This should not be attributed to new educational technologies, but rather to the reduced number of teaching hours, the abandonment of cadaveric dissections, the lack of integrated anatomy curricula tailored to clinical needs, and the shortage of qualified anatomy faculty. The solution should include curriculum standardisation and the introduction of exams that emphasise the practical clinical application of anatomical knowledge.

There are some limitations of this study. First, the use of convenience sampling may have introduced selection bias, as participation was voluntary and students with stronger opinions or higher engagement may have been more likely to respond. Second, because pre- and post-course data were analysed as independent samples, individual-level changes could not be tracked, and observed differences should be interpreted as group-level trends rather than within-person effects. Finally, the reliance on self-reported measures may be subject to response biases, including social desirability and recall bias, which could influence students' ratings of motivation and learning experiences.

Conclusions

Rather than viewing digital methods and face-to-face teaching as mutually exclusive alternatives, in nursing students' opinion, the most effective approach in anatomy education appears to be a hybrid model, in which digital technologies complement – but do not fully replace – traditional in-person instruction.

Digital and multimedia tools, apps, virtual platforms, quizzes and games provide opportunities for repeated content exposure and interactive exploration of anatomical structures at the student's own pace, hence can be an element of the flipped classroom and students' pre-class preparation for face-to-face learning.

Hands-on learning, contact with real anatomical material, and practical classes (e.g., dissection, palpatory sessions, group activities) continue to play a crucial role in developing practical skills, spatial reasoning, and professional attitudes and are appreciated by Polish nursing students. Further, in-person learning fosters student–instructor relationships, facilitates immediate feedback, and supports motivation and a sense of educational community. These experiences are not to be underestimated in health care providers' anatomy education.

Acknowledgments

The authors are grateful to the students who participated in this study.

Funding

No external funding.

Ethical approval

The study received the positive ethical approval from the Ethics Committee of the Pomeranian Medical University (RPW/10749/2022P).

Conflict of interest

The authors declare no conflict of interest.

References

1. Regulation of the Minister of Science and Higher Education of October 10, 2024. (https://dziennikustaw.gov.pl/DU/2024/1514).
2. Shin M, Prasad A, Sabo G, Macnow ASR, Sheth NP, Cross MB, Premkumar A. Anatomy education in US Medical Schools: before, during, and beyond COVID-19. BMC Med Educ. 2022; 22: 103.
3. Pagels L, Eschke RC, Luedtke K. Effectiveness of digital and analog learning methods for learning anatomical structures in physiotherapy education. BMC Med Educ. 2024; 24: 500.

4. Singer L, Evans L, Zahra D, Agbeja I, Moyes S. Fostering engagement in virtual anatomy learning for healthcare students. BMC Med Educ. 2024; 24: 414.
5. James S, D'Amore A, Thomas T. Learning preferences of first-year nursing and midwifery students: utilising VARK. Nurse Educ Today. 2011; 31: 417-423.
6. Burne-Johnston AN, McAllister M. Back to the future with hands-on science: students' perceptions of learning anatomy and physiology. J Nurs Educ. 2008; 47: 417-421.
7. Hernandez JE, Vasan N, Huff S, Melovitz-Vasan C. Learning styles/preferences among medical students: kinesthetic learner's multimodal approach to learning anatomy. Med Sci Educ. 2020; 30: 1633-1638.
8. Padmalatha K, Kumar JP, Shamanewadi AN. Do learning styles influence learning outcomes in anatomy in first--year medical students. J Family Med Prim Care. 2022; 11: 2971-2976.
9. Manchester KR, Roberts D. From classroom to clinic: Bridging the gap in nursing anatomy and physiology education. Nurse Educ Pract. 2024; 75: 103870.
10. Cornwall J, Hildebrandt S, Champney TH, Goodman K. Ethical concerns surrounding artificial intelligence in anatomy education: Should AI human body simulations replace donors in the dissection room? Anat Sci Educ. 2024; 17: 937-943.
11. Neri I, Cercenelli L, Marcuccio M, Lodi S, Koufi F-D, Fazio A, Marvi MV, Marcelli E, Billi AM, Ruggeri A, Tarsitano A, Manzoli L, Badiali G, Ratti S. Dissecting human anatomy learning process through anatomical education with augmented reality: AEducAR 2.0, an updated interdisciplinary study. Anat Sci Educ. 2024; 17: 693-711.
12. Dove E, Hennessy K, Kirou-Mauro A, Aitkens L, Duncan A, Agur A, Ho ES. Gross and applied anatomy pedagogical approaches in occupational therapy education: a scoping review. Can J Occup Ther. 2024; 91(2): 136-148.
13. Beresheim A, Zepeda D, Pharel M, Soy T, Wilson AB, Ferrigno C. Anatomy's missing faces: an assessment of representation gaps in atlas and textbook imagery. Anat Sci Educ. 2024; 17: 1055-1070.
14. Gangata H, Vigurs K. Pedagogical principles used by anatomy teachers to facilitate the teaching and learning of anatomy to physiotherapy undergraduates in the United Kingdom. Clin Anat. 2023; 36: 795-808.
15. Hall TR, Mosley CF, Balta JY. Graduate anatomy education: How are we training the future generations of anatomy educators? Anat Sci Educ. 2024; 17: 422-432.
16. Xiao J. Improving student learning and performance through a continuous flipped anatomy teaching model. Anat Sci Educ. 2024; 17: 219-226.
17. Longhurst GJ, Bazira PJ, Finn GM. Student's perspectives of inclusive practices in anatomy education. Anat Sci Educ. 2024; 17: 571-590.
18. Kumar R, Singh R. Model pedagogy of human anatomy in medical education. Surg Radiol Anat. 2020; 42: 355-365.

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Received: 6.11.2025
Accepted: 16.02.2026
Online publication: 4.05.2026