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ORIGINAL ARTICLE

Anatomical theater or full digitization? Students' assessment and preferences in the field of anatomy teaching

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ABSTRACT

Background: For many years, teaching of anatomy has been based on traditional forms of teaching, but innovative solutions are currently being implemented on a large scale around the world. The COVID-19 pandemic and distance learning have influenced the development of new technologies in teaching.

Materials and methods: The study was conducted among medical students who studied anatomy in the year preceding the analysis when the restrictions related to the pandemic had been lifted. The questionnaire contained 10 questions with YES/NO answers and a modified 10-point Likert scale. The data was subjected to statistical analysis performed in R studio using the R programming language. 650 respondents were included in the analysis.

Results: Students assessed the modernization of anatomy departments to be unsatisfactory - on a 10-point scale, the most common answer was 2 — the average was 2.69. At the same time, they assessed the accessibility of knowledge as acceptable — median 6, with an average

of 5.58. 75.38% of respondents did not use virtual reality technology, 75.69% did not use a 3D printing. 92.5% did not work with a virtual anatomical table. The vast majority of students claim that new technologies will be useful in their future clinical practice.

Conclusions: New technologies are still rarely used in the teaching of anatomy, despite an increasing availability of such solutions and the conviction of students about the validity of implementing innovations in their future clinical practice. It seems reasonable to enable cooperation between the traditional forms of learning and the modern ones.

Keywords: anatomy learning, VR, MR, 3D printing, new technlologies in anatomy, virtual dissection anatomy table

INTRODUCTION

Knowledge of anatomy is essential to understanding and mastering clinical practice. For hundreds of years, anatomy was taught during autopsies with the use of human specimens. The first educational practices took place as early as the 3rd century BC, in Alexandria [12]. Although human bodies are still the main source of anatomical knowledge, however, access to anatomical specimens is very limited. As a consequence, we can observe the dynamic development of modern methods supporting the teaching of anatomy in recent years. They can not only increase the effectiveness of teaching, but also solve problems such as high costs of running a mortuary [25] and an insufficient number of human corpses obtained by medical universities [28, 38]. These problems often lead to a growing demand for large student groups, which may reduce the teaching effectiveness [22]. The development of modern methods follows the changing preferences of students who are more familiar with the new technology [4]. Traditional textbooks and atlases become increasingly replaced by electronic devices. This process has gained dynamic pace during the COVID-19 pandemic [19, 23]. One of the tools are three-dimensional digital models that are created analogously to images in atlases, but also based on image data of specific patients. Several of imaging modalities have been used to create three-dimensional anatomical models, including computed tomography (CT), magnetic resonance (MR) and ultrasound. Three-dimensional models and imaging can be used not only in teaching, but also for preoperative planning and scientific research [26]. The digital three-dimensional model can be used directly for learning or printed.

3D printing was developed in the 1980s [15]. It was used in medicine at the beginning of the 21st century [21]. Initially, it was used to create medical implants and prostheses,

however currently it is increasingly used for teaching anatomy [1, 21, 27]. There are many 3D printing techniques in terms of methods and materials used (plastics, ceramics, resin, sand, metal or their mixtures) [7].

The development of 3D printing, materials used to create models and the reduction of production costs influence the increasingly common use of this technology in teaching. Models of anatomical structures, e.g. the heart, lungs, liver, are increasingly used during anatomy classes.

Modern anatomy teaching may also be based on the use of tactile anatomical tables. They use CT and MRI scans which, after appropriate processing, can then display the human body, organ systems and organs in their natural size [16]. Thanks to the use of multi-body scans, it is possible to accurately depict anatomical variations and changes resulting from different ages of the body [17]. Moreover, it is possible to visualize three-dimensional bodies affected by diseases, which allows for the gradual implementation of knowledge of pathological anatomy and the clinical significance of anatomical features [3]. Undoubtedly, the advantage of modern anatomical tables is the ability to obtain sagittal, transverse and frontal planes as well as multiple “cutting” of anatomical structures [3]. One of the limitations of 3D printing are the costs associated with printing models and the inability to cut them multiple times to analyse internal structures. These problems can be solved using extended (XR) techniques such as virtual (VR), augmented (AR) and mixed (MR) reality.

A breakthrough in anatomy teaching may occur thanks to the use of VR technology. It enables the creation of an extremely realistic virtual environment [24]. The advantage of this method is the transition from passive to active teaching. Careful viewing of structures from different angles and zoom levels is particularly useful in learning about the construct of complex anatomical structures such as the human heart or joints [30]. It is important that students themselves express great interest in using the VR method for learning. They find it interesting and engaging during class [9, 36]. There are more and more reports in the world literature about the growing interest of students in the use of new technologies in medical sciences. We must remember that there are certain limitations associated with this technology. One example is the possibility of cybersickness [33].

An engaging way of teaching anatomy is to combine traditional and modern methods. This is possible thanks to mixed reality (MR). It allows digital information to be superimposed on real objects, e.g. human corpses [14].

Human cadavers form the basis of anatomy teaching. However, this is not an ideal method, and supplementing it with the use of modern technologies such as 3D printing, VR and MR anatomical tables may contribute to increasing the effectiveness of acquiring knowledge by medical students, as emphasized by the students themselves [14]. Moreover, the use of modern technologies allow the analysis of the gradual changes occurring within the disease progression or with the age.

MATERIALS AND METHODS

The aim of the study was to assess the degree of student interest/students' preferences for using blended learning in teaching anatomy.

The study was designed to consist 10 questions, including YES/NO questions, as well as a modified 10-point Likert scale, where 1 was the lowest declared value and 10 was the highest. The survey conducted among 650 people covered 10 questions. The study was conducted in 2023 thanks to the courtesy of students who voluntarily agreed to participate in an anonymous survey. It was distributed among students in large Polish cities at medical universities that have been educating future doctors for decades. Due to the full anonymization of data, a detailed study of the population in the context of age and gender was abandoned. Descriptive statistics of selected survey questions are presented in Tables 1 and 2.

The inclusion criteria for participation in the study was the status of a medical student at a Polish-speaking medical faculty in a Medical University in Poland, studying anatomy during the year preceding the analysis — this was the group of students studying after the restrictions related to the COVID-19 pandemic had been revoked, and voluntary consent to participate in the anonymous survey. The information entered into the database did not include annotations about a university certain answers came from.

The data were subjected to statistical analysis performed in R studio using the R programming language. Out of 684 surveys received, 650 respondents were included in the final analysis of the results.

RESULTS

When learning anatomy, the vast majority of respondents did not have the opportunity to use virtual reality technology or 3D prints. When asked if they had ever used virtual reality

to learn anatomy, 75.38% answered no, while in the case of using 3D prints, this percentage was similar and amounted to 75.69%. Only 49 people out of 650 respondents (7.5%) took a peek at the virtual anatomy table. Students severely assessed the degree of modernity of anatomy departments — on a 10-point scale, the most common answer was 2 — the average was 2.69. At the same time, they assessed the accessibility of knowledge as acceptable — median 6, with an average of 5.58. It can therefore be concluded that the previous "old" methods are acceptable and are received satisfactorily by students. The vast majority of respondents assessed that new technologies will be useful in their future clinical practice. The most common answer was 10 — max, with an average of 8.78. Students were also asked about their preferences for learning using virtual reality, anatomy table and 3D printing. In each case, the median was the maximum number of points on a 10-point scale. The highest average was obtained by the virtual anatomy table — 8.63; virtual reality — 8.53, and 3D printing — 8.39. When asked about their willingness to participate in classes covering the basics of ultrasound and radiological anatomy as part of anatomy, the vast majority of respondents expressed a strong willingness. The question was asked due to the need to repeat anatomy in the period preceding diagnostic imaging classes in the following years of study. According to the authors, the use of acquired anatomical knowledge that can be applied in practice could give good implications in future clinical practice and would allow for a better understanding of radiology. Charts showing the distribution of answers to questions are presented in Figures 1–10.

DISCUSSION

New technologies that are constantly developed and implemented into new solutions also apply to the areas of education and didactics.

The COVID-19 pandemic contributed to the creation of tools enabling effective distance learning, as well as accelerated the development of previously used technologies on a larger scale. Education, both at the primary and academic levels, at the beginning of the COVID-19 pandemic was not adapted to the epidemic conditions and did not provide students with full opportunities to reliably implement the teaching material [2, 11, 18, 29, 31, 37, 40].

The study conducted a survey of medical students pursuing their education a year after the lockdown, i.e. in the first population studying after the epidemic restrictions have

been lifted, at the same time in which it was possible to implement various innovations that became increasingly popular during the pandemic. Anatomists played a key role in promoting computer-based educational innovations even before the COVID-19 pandemic [10, 35].

To the authors' knowledge, no study has been conducted so far to assess the degree of innovation of entities providing education in the field of anatomy, nor to learn about the preferences of future doctors in the use of new technologies supporting the classical form of learning. The traditional method means learning on human cadaver specimens or learning from anatomical atlases and textbooks.

The assessment of the degree of modernity of Anatomy Departments in Poland was low. The median response was 2 on a 10-point scale, with a mean of 2.69. The analysis of the answers to the first question of the survey allowed the authors to assume the limited availability of new technologies in the field of teaching. No more than 25% of respondents have experienced at least virtual reality or 3D printing technology. Less than 8% of respondents had the opportunity to work with a virtual anatomical table. These results indicate a mediocre degree of innovation in the field of teaching anatomy.

Furthermore, reports from other countries do not indicate a significant availability of innovative anatomy teaching methods. In New Zealand and Australia, between 2008 and 2018, the vast majority of medical universities (82%) invested in new teaching technologies. Only seven universities out of twenty-two (41%) have used virtual reality, three (18%) have used virtual dissection, three (18%) have used Hololens [34]. In the UK and Ireland, 25% of universities used 3D printing technology [32].

Despite the obtained results, 650 students rate the accessibility of the knowledge provided during the course as 6 on a 10-point scale (median). The involvement of assistants and the high availability of human cadaver preparations, as at the Medical University of Silesia in Katowice due to the conscious donation program, allow students to be reliably and conscientiously prepared to implement the education plan, pass exams and, consequently, practice their profession. The results regarding students' willingness to work using virtual reality, 3D printing technology and a virtual anatomical table indicate a high degree of student involvement in the issues discussed, which should constitute the basis for plans for the modernization of anatomy departments and modification of teaching programs, taking into account students' preferences.

According to the authors, new technologies should complement classical teaching methods, but a hybrid of the latest technological achievements with the centuries-old tradition of educating future doctors could have a positive teaching effect. This is consistent with the

opinion of medical students themselves [5, 8]. Teaching using VR and human cadavers is more interesting, authentic, effective and facilitates spatial understanding of anatomical structures than teaching using only an anatomical atlas [6] and better long-term retention of knowledge than teaching using anatomical atlases in previously inexperienced students [13]. Students indicate that VR would be a significant help in learning anatomy also during independent learning at home [20].

The implementation of new technologies for teaching anatomy is also important in the context of the growing problem of lower availability of cadavers at medical universities [34].

The strong will to use new technologies also opens up opportunities for new faculties that do not have adequate resources related to the preparation of a mortuary. Careful preparation of holograms, 3D prints and software can provide a good scientific background before dissection classes. The generation of future doctors are people whose adolescence took place in the era of rapid technological progress, the development of bioengineering, as well as 3D printing, robotics and artificial intelligence. Students commonly use their smartphones to learn anatomy [39]. The vast majority of respondents are convinced of the usefulness of new technologies in their future clinical practice - median of their answers equals 10.

The last question in the survey concerned the students' willingness to extend their classes of anatomy in the field of radiological anatomy with practical exercises in the field of ultrasound examination. The students approached this idea with enthusiasm, considering it to develop needed issues. The teaching of anatomy should be constantly improved and adapted to contemporary educational realities, taking into account the current teaching model. The foundation of learning should be classes on cadaver preparations and cooperation with an anatomical atlas, while supported with new technologies, taking into account the preferences of surveyed students, which may bring real benefits in the form of better and more effective acquisition of knowledge and shortening the time to learn specific parts of the material provided for in the study program. The current study should be a starting point for further considerations in this area and an inspiration to design research works presenting the impact of technology on the effectiveness of learning.

CONCLUSIONS

Despite the development of modern technologies and attempts to implement them into everyday teaching practice. anatomy departments in Poland provide education to students

based on existing. proven methods. New technologies such as virtual anatomy tables, 3D printing and virtual reality are rarely used. despite students' interest in this type of learning support. Students are convinced of the usefulness of new technologies in their future clinical practice. therefore it seems reasonable to enable learning about such solutions already in the first years of studies. It is also worth considering supporting classes in ultrasound so that students can translate theoretical knowledge into practice. According to the authors, new technologies should be increasingly and widely implemented in teaching anatomy, but they should be a supplement to the classic form of teaching - working with human cadavers. They allow not only for precise and reliable learning, but also for shaping ethical attitudes in future clinical practice.

ARTICLE INFORMATION AND DECLARATIONS

Author contributions

Krzysztof Starszak — conception, design, execution and interpretation of the data being published, wrote the paper. **Radosław Karaś** — execution and interpretation of the data being published, wrote the paper. **Andrzej Skalski** — execution and interpretation of the data being published, scientific supervision. **Karolina Czarnecka-Chrebelska** — execution and interpretation of the data being published. **Tomasz Lepich** — conception, design. **Grzegorz Bajor** — conception, scientific supervision.

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Conflict of interest

None declared.

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Question	N	Median	Q1	Q3	Mean	SD
1. How do you assess the degree of modernity of the Department of Anatomy in terms of the availability of new technologies, e.g. virtual anatomical tables, 3D prints, virtual reality?	650	2	1	4	2.69	2.04
2. How do you assess the accessibility of the knowledge provided in the field of anatomy? (1–10)	650	6	4	7	5.58	2.2
4. Would you like to use virtual reality technology to learn anatomy? (1–10)	650	10	8	10	8.53	2.17
6. .Would you like to use prints made using 3D printing technology in learning anatomy? (1–10)	650	10	7	10	8.39	2.34
8. Would you like to use a virtual anatomy table to learn anatomy? (1–10)	650	10	8	10	8.63	2.26
9. How do you assess the usefulness of new technologies in your future clinical practice? (1–10)	650	10	8	10	8.78	1.94
10. Would you like to include radiological anatomy and ultrasound basics as part of your anatomy classes? (1–10)	650	10	8	10	8.96	2

Table 1. Descriptive statistics of selected survey questions.

Table 2. Descriptive statistics of selected survey questions.

Question		n	%	95% CL	
Have you used virtual reality technology while learning anatomy?	No	490	75.38 %	72.07%	79.27 %
	Yes	160	24.62 %	21.30%	28.51 %
Have you used 3D printing technology while learning anatomy?	No	492	75.69 %	72.39%	79.57 %
	Yes	158	24.31 %	21.01%	28.18 %
Have you used a virtual anatomy table while learning anatomy?	No	601	92.46 %	90.43%	94.85 %
	Yes	49	7.54%	5.51%	9.92%

CL — confidence level.

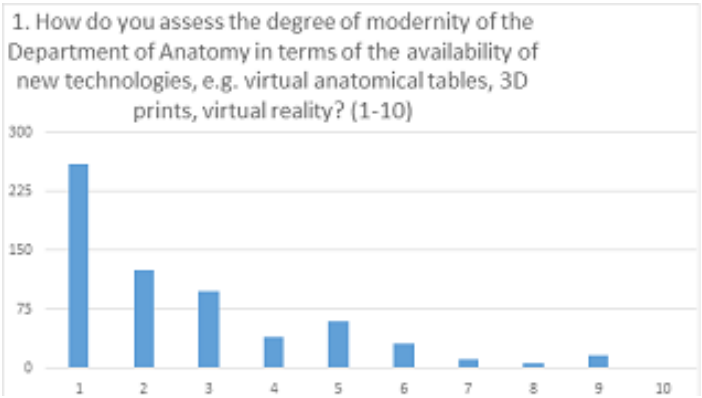

Figure 1. Chart showing the distribution of answers to Question 1.

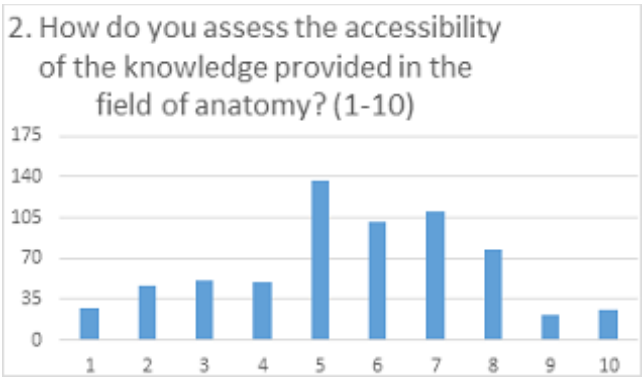

Figure 2. Chart showing the distribution of answers to Question 2.

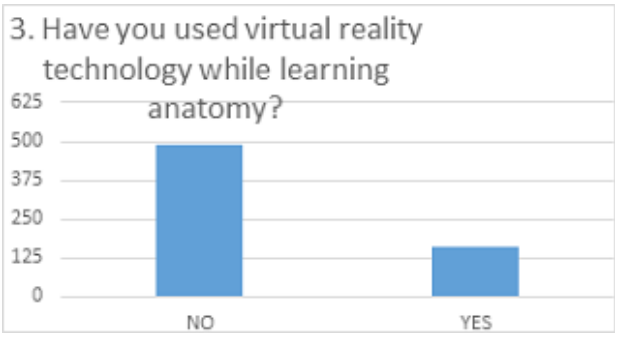

Figure 3. Chart showing the distribution of answers to Question 3.

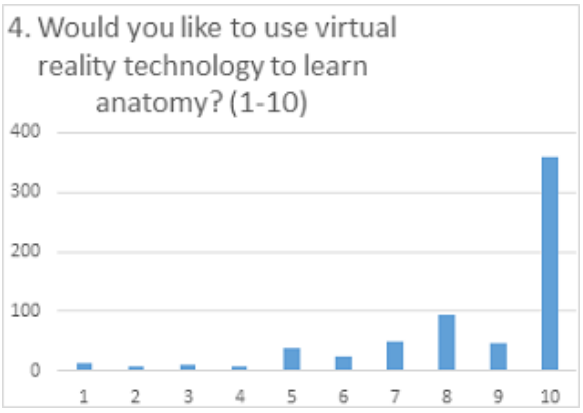

Figure 4. Chart showing the distribution of answers to Question 4.

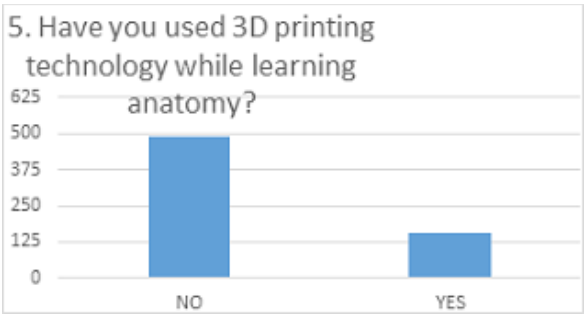

Figure 5. Chart showing the distribution of answers to Question 5.

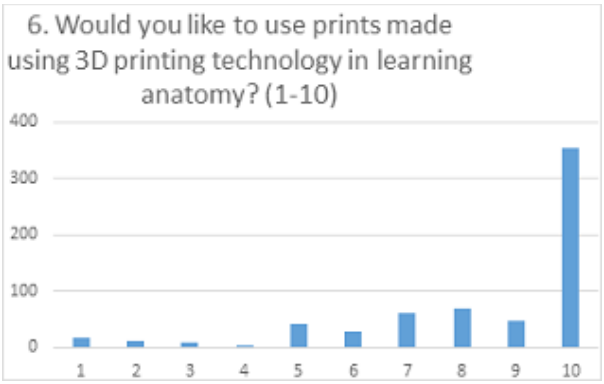

Figure 6. Chart showing the distribution of answers to Question 6.

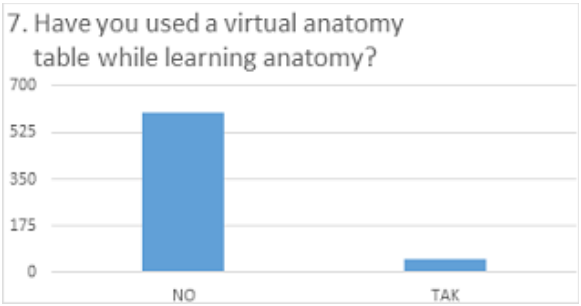

Figure 7. Chart showing the distribution of answers to Question 7.

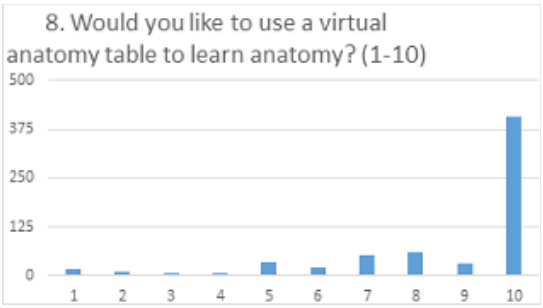

Figure 8. Chart showing the distribution of answers to Question 8.

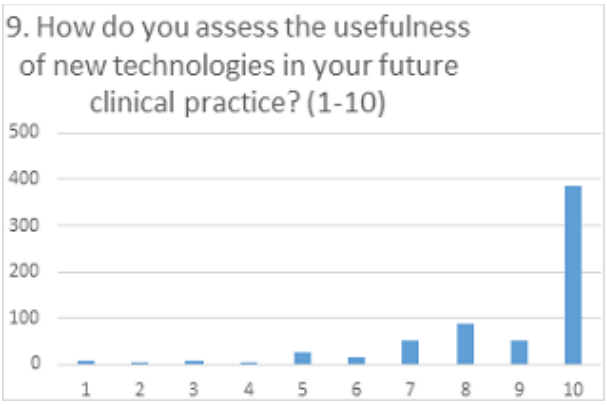

Figure 9. Chart showing the distribution of answers to Question 9.

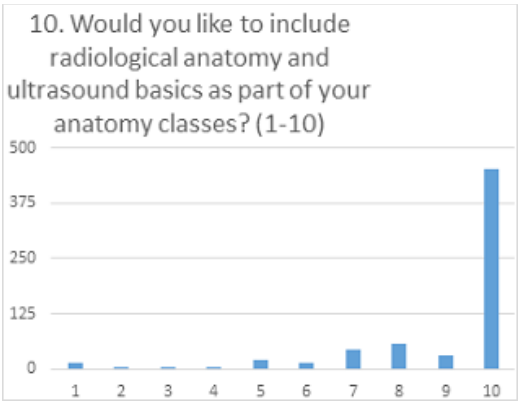

Figure 10. Chart showing the distribution of answers to Question 10.