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THE ROLE OF AI FOR TEACHING ANATOMY IN MEDICINE

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Abstract. The purpose of this report is to systematize the role of artificial intelligence for the teaching of anatomy in medicine. Experience of teachers in using new technologies (Google Classroom, 3D atlases, WordPress, Facebook, Virtual Reality, etc.) in teaching human anatomy to students of various health specialties for the last 4 years is described. Currently available tools such as ChatGPT 4, Google Gemini, Microsoft Bing Copilot, are not designed for this purpose and fail to generate anatomically correct training images. This situation attends professional attention as well as needs some philosophical remarks on the problem. Popular directions for the development of AI technologies are video generators and editors, image and art generators, painting and drawing tools, writing tools and text generators, music and audio generators, face generators, avatar generators. The benefits and drawbacks of the introduction of artificial intelligence in the teaching of anatomy are discussed and the conclusion that there is a benefit and necessity of its practical inclusion in the pedagogical tools is substantiated.

Keywords: AI; Medicine; Learning; Anatomy; Philosophy of medicine

The field of medical education has gone through significant and extremely rapid transformations in recent years, with technology playing an increasing role in teaching[1] and learning, diagnosis, radiology, pathology, endoscopy, cardiology etc. The teaching of anatomy is a key aspect of medical education, and the potential for artificial intelligence (AI) to revolutionize the way students learn and understand anatomical concepts has sparked interest. Despite the growing number of research on technology in medical education, there is a paucity of research that specifically focuses on new technologies in the teaching of anatomy. The purpose of this study is to describe the experiences of university teachers in using new technologies. The aim for this study is, to indicate benefits and limitations of using AI in anatomy education and to provide insight into the practical integration of AI as a pedagogical tool. The research question guiding this study is: What is the role of AI in anatomy teaching and what are the benefits and limitations of using AI in this context? It is hypothesized that the use of AI in anatomy teaching has

the potential to improve outcomes of student learning and to improve the overall quality of medical education. In connection with this strings to some problems in philosophy of medicine will be marked.

1. Overview

Since the publication of the first web page in year 1991, in the short period of 23 years, more than 2 billion pages of different content are now accessible, and they are already old technology. The new modern way to master the cyber space is through applications, first for computers, then for mobile devices and a whole houses (Smart home technology). Anatomy teaching has also seen a similar trend, from galleries and information archives, through interactive web pages (KenHub), computer atlases (Visual Body) and to smartphone apps (3D Anatomy). Even a completely automated robot, which could perform the tasks of procuring, preparing, embalming, dissecting, plastination and mounting anatomical specimens in a single organized facility was proposed. Artificial intelligence is the logical next step that has not yet been taken. In the list of the most professional and popular applications for studying anatomy are such programs as: Complete Anatomy 2024[2], Biodigital Human, Human Anatomy Atlas 2024, Gray's Anatomy, Visual Anatomy, Anatomy Learning – 3D Anatomy, TeachMe Anatomy[3].

Importance is given to:

– Selected visual style: 2D or 3D, clear and attractive images, options to zoom, rotate and like. 2. Description: a comprehensive and detailed description of the structures. 3. Intuitive and accessible: easy reading and seamless navigation, tutorial. 4. Multiple languages support, adjustable settings, as similar as possible across devices, available offline, small size and RAM requirement. 5. Pricing: Free version or subscription 6. Additional features: audio, video and interactive quizzes.

Educational platforms with clinical anatomical information such as KenHub[4] are particularly useful and popular.

Anatomy teaching is a conservative discipline with an established standard and terminology reflected in numerous textbooks, publications, websites and applications, both paid and free versions. The accumulated information is huge, unattainable for processing by one person, and difficult even for the largest and most professional teams[5]. Artificial intelligence is a possible solution for processing this information, but existing models have not yet proven to be suitable for such a task. On the contrary, they continue to demonstrate a deficit in this direction and the need for additional work.

Starting form 1956 y. (McCarthy 1956), the concept of AI is now commonly known with definitions freely available from many sources. The various ways in which AI is integrated into anatomy education, highlighting its potential benefits, challenges, and implications for both educators and learners.

2. Materials and methods

The experience of the teachers in the Department of Anatomy of the Faculty of Medicine, Trakia University, Stara Zagora, Bulgaria is described. During most of the academic year, 2 professors, 2 associate professors and 9 assistants work in the department, with more than 300 students (for 2024: social activities 20, nurses 36, medicine 97, medical assistants 20, kinesitherapy 18, midwifery 13, English-language training in medicine 108).

Randomized blind trail for generating anatomy images was performed with the key words (prompts): anatomically true image of the human hand. "Bad anatomy" and "six fingers" were added as negative prompts (Anti-Description) and the Art Style was set to professional photo. These settings were used with different models by different cooperators who were not informed about the topic of the study, or given any other instructions. Each person generated at least 33 images that were evaluated for compliance with the normal human anatomy and variations.

– ChatGPT 4, with DALL·E 2 for generating images. DALL·E 2 is an improved version of the original DALL·E model, offering higher-quality image outputs and better understanding of complex prompts. It is designed to create more detailed and accurate images based on textual descriptions[6]. Game designer and children's author, manager of "Gametale" EOOD Nikola Raykov. Professional in the daily practical use of the Internet and AI.

– Model epiCRealism[7]. Bogomil Hristov, medical student, first year.

– Stable Diffusion text-to-image model[8]. Nikola Pirovski, ass. professor, Department of Anatomy.

The resulting images were then discussed in the form of a free-flowing open-ended interview with departmental faculty and students.

3. Results

Given the complex nature of the human body, the subject is vast and can be challenging for students. In these formative years of medical education, students often experience learning difficulties, which can lead to a decline in academic achievement. To address this issue, ongoing efforts are being made to develop new curricula and teaching methods that promote logical learning and long-term retention of anatomical knowledge. This fundamental knowledge is essential to all aspects of medical practice.

Distance learning draw our interest back in 2006 (Ivanov et. al. 2006), when we did successful trials for it, but we were unable to impose it as a regular practice in the schedule.

With the decision of the Council of Ministers of the Republic of Bulgaria dated 17.08.2018, the National scientific program "Electronic healthcare in Bulgaria" (e-health[9]) was approved, in which we participated in the development of a Dictaphone for use in healthcare.

From 31.05. to 02.06.2019, the 24th National Congress of the Bulgarian Anatomical Society (BAD) was held at the Stara Zagora Mineral Baths, with international participation, where we had the opportunity to use for the first time, for a trial period, a virtual dissection table[10]. These were ordered, but due to limited financial resources, in 2020 we were instead supplied with 6 large-format TVs (163 cm) and an interactive screen with the Visual Body program, as well as a Leica video system to broadcast video from the microscopes in real time.

During the same year we had the chance to test the "Avatar therapy" in collaboration with Prof. Mark Huckvale, form the Speech, Hearing and Phonetic Sciences at the University College London.

As of 2020, we had to improve our skills and increase the use of new technologies in teaching. In connection with the widespread introduction of distance learning, following the rector's order No.91/15.01.21 for the use of all forms of the electronic learning environment, we were mainly based on Google classroom. This service was accessible daily for communication, lectures, tests and provision of training materials. It was easy to use, and free of fees, but without any anatomical resources, that we had to create and provide personally. 3D atlases, each assistant used independently, of his choice and at his own expense. A student evaluation of the online learning was conducted with an anonymous survey and published in 2021 (Pirovski et al. 2021).

After the decision of the faculty council No.10/16.09.21, we managed to create a website based on WordPress[11], with an anatomical archive, photos, text and video for educational purposes and a Facebook group (Student Anatomical Organization). The group is mainly for news and current communication, but with little activity from the students who, despite creating it, have since taken a passive role. On YouTube, we created a video dissection channel. These efforts were primarily directed toward the students to provide educational, scientific, and administrative information. The site also featured an online bookstore powered by Gumroad. In a short time we reached 341 members for the group and over 25 thousand page views. These successful results were reported as a poster presentation at the National Conference with International Participation "Morphological Days" June 10 – 12, Sofia, Bulgaria.

In November 2022, we ordered and received 3D printed anatomical models. Including 20 augmented reality Oscar type skulls and 4 hand skeleton models. Skulls are difficult to prepare and study as bone structures, and are available in smaller quantities. These models have proven useful. The hand models turned out to be anatomically incorrect, having an extra non-existent wrist bone, and were unusable. 3D printed models are cheap and accessible, standardized and uniform. This allows for their mass usage, but also predisposes to the loss of the ability to improvise and facilitates a mechanically memorize information. The preparation of human tissue is always individual, and working with it provides a variety that

predisposes to the study of ideas and principles, not objects. Into the process of education it is important to introduce distinction between standard (uniform) and individual (specific) differences. One of the key role in this process can play introduction of problems from the field of philosophy of medicine in medical educational programs. (Vasseva-Dikova 2023).

On November 23, 2023, we organized a lecture and workshop on the topic "Stereoscopic anatomy of the brain. Cortical architecture and subcortical brain pathways" with the guest lecturer Dr. Toma Spiriev, part-time assistant in anatomy at the Department of "Anatomy, Histology, Pathoanatomy and Forensic Medicine" of the Faculty of Medicine, Sofia University. First-, second-, third- and fourth-year students and faculty members tried virtual reality on a demo computer-generated dissection and examined the preparations, taking advantage of the potential of state-of-the-art 3D multimedia technologies (Spiriev et al. 2023). Each step of the dissection was scanned using photogrammetric technology, which allows processing of 3D data from two-dimensional photographs through a simple algorithm based mainly on a dedicated mobile phone application and open source 3D modeling software. For selected microscopic 3D anatomy, we used an operating microscope to generate 3D models.

Despite the efforts made, the lack of prior preparation and development strategy led to partial success and many difficulties in introducing these technologies as part of the education process.

From 2023, there is also a Cyber security club at the University.

With a vote of the faculty council on 01.02.2024, the website with the anatomical archive was removed. This shows inertia in pedagogical skills and resistance to innovations. On the other hand, it provided an incentive for modernization and a motivation to transition to even newer technologies. The time has come to change our mindset from being reactive to being proactive with regard to new technology. In early 2024, we tested currently available tools such as ChatGPT 4, Google Gemini and Microsoft Bing Copilot to generate anatomically correct images. These programs are not intended for this purpose and fail to generate anatomically correct images for education. With 100 images of a human hand generated using three different models, only one anatomically correct image was obtained. Models based on random image compilation fail to generate an anatomically correct image.

On the one hand, the technologies used accelerated some activities and made them visually more attractive, but at the expense of this, part of the personal transmission of knowledge, understanding the context of the questions, and the development of personal practical skills and competencies was lost. A complex abstract text from which one learns through personal effort and engages more intellectual and emotional resources in the learning process leads to a different education than after consuming a ready-made standard images. The one-time fascination with multimedia quickly wore off for most students. Screen dependence of the use of electronic devices for

the teaching of anatomy was not observed, because they were used professionally, for work, and not for pleasure. However, other disadvantages such as overstrain of the musculoskeletal system and vision remained. Perhaps, after the introduction of voice and image capabilities, this could decrease. As it has been presented here the ability to understand contexts with connection to development of practical skills is of big importance into the process of education. Implementation of the methods from social sciences (philosophy, philosophy of science, philosophy of medicine) could be helpful in this direction (Vasseva-Dikova 2023).

The linear, predetermined in the interface, responding to situations is very different from the neuromorphological processes of parallel information processing. Even models based on neural networks are still far from natural processes in the brain. As software improves, compatibility improves, which on the one hand facilitates information processing, but on the other hand reduces neuroplasticity and switchability in thinking, simultaneously leading to a false sense of superiority, confidence and high performance. During the first class, students were captivated by the clean shape and surface of the new 3D models compared to the pale color and rough, sticky surface of real bone preparations. They only noticed the error in the 3D printed model after several hours of research or when it was specifically shown to them. Obvious inaccuracies such as the location and number of fingers are easy to detect, but others could prove more difficult and lead to wrong simulations, interpretations and practices. This is also one of the reasons for the recommendation of the American Association for Anatomy for expert supervision of the AI generated content[12]. In this case, the issue of taking responsibility for the content of the provided materials is paramount.

Our experience has shown the speed and accessibility of communications to be the main advantage. Second, the easy processing and storage of a large amount of information, as well as the diversification of the learning process are also improvements. The remote connection has proven useful as a backup option, and automation has facilitated laborious processes such as learners' enrollment, assessment and administration tasks. Simulated friendship of the interface sometimes turned out to be off-putting, due to the fact that it was not sincere, but programmed. Although there is great potential to reduce errors and quickly offer solutions to previously known problems, our experience has shown an increase in errors and a decrease in efficiency due to the inexperience of both faculty and students in using some of the new technologies described. As automation improves, staff engagement will also decrease, however for the time being it has increased due to the need to develop and organize activities in a new way. The maximum intensity of this process is yet to come. Self-training provided an opportunity for in-depth preparation, but also brought to the fore problems with motivation and concentration of the students, who, left without a teacher, encountered difficulties in the self-organization of learning.

Logical future development of our efforts was the developing of Machine Learning Architecture to Create an AI-Powered Chatbot for Anatomy Education. There has already been an example of this kind (Li et al. 2021). We choose a company based in Stara Zagora to start with this project for Bulgarian speaking chat bot, specialized in anatomy training. It is based on AI Model: GPT-3.5-Turbo, Vector database: Weaviate. We faced some fundamental problems, like the lack of ability to divide to multitudes. Demo version was presented on the conference: Philosophy of medicine: approaches and perspectives, 26.03.2024 in Sofia, Bulgarian academy of sciences. It has free access and is operational, but we still have a lot to improve until it is ready for use.

4. Discussion

AI is being used in finance, automotive engineering, economics, medicine and education (Chan & Zary 2019).

We support the ideas of the authors to engage AI only to extend human capacities (Lazarus et al. 2024), and that the use of large language models (LLMs) like ChatGPT and Google Bard, in medical education requires caution (Ilgaz & Çelik 2023). The AI generated information did not meet the criteria for scientific explanation. There is substantial continuity between explanations found in science and some forms of explanation found in ordinary, non-scientific contexts[13]. However the AI explanations were not true, inaccurate, unexplanatory and a strange mixture of existing evidence. Those problems are already have been discussed in philosophy of science (Vasseva-Dikova 2007) and philosophy of medicine and it is important to implement some elements of knowledge from this fields to education programme in medicine. One of the central problems in philosophy of science connects to the specific structure and function of scientific knowledge. The other problems analysed the importance of the fundamental knowledge for development of the applied knowledge. (Vasseva-Dikova 2022)

There are specific advantages to incorporating AI in education, such as in-depth learning, storage of large electronic data, teaching from remote locations, and reduced need for human instruction, quick feedback, innovative assessment methods, and user-friendly alternatives. Recent new AI techniques such as Artificial Neural Networks (ANN), Convoluted Neural Networks (CNN) and Bayesian U-Net, are used for teaching anatomy (Abdellatif et. al. 2022).

Objective assessment sometimes could also be a problem that AI could be used to improve. We share the expectations of some authors (Basu et al. 2020), for positive change from the integration of AI.

Our observation is that the use of digitized learning and in-person education have to intercept in a new form of hybrid education, is supported by many authors (Guimarães et al. 2017), (Rizzolo et al. 2010). This will necessitate that future medical educators have sufficient technological background and be adaptive

thinkers, in order to leverage such implementation (Torda 2020). Professional training on the use of AI in healthcare are already available at high cost.

Some authors suggest that AI could be helpful especially in reference to complex regions in the human body, such as neural pathways in the brain, complex developmental processes in the embryo or in complicated miniature regions such as the middle and inner ear (Abdellatif et al. 2022). However, for now all artificial intelligences have problems with the number of fingers, limbs, etc. when generating an image. They are only reproducing the logic we set in advance. This could help us with processing a large quantity of the information, but the quality of the analysis would still depend on our programming and information source that often come mistakes, which would be multiplied.

Chatbot has the potential to increase engagement by encouraging students to ask further questions (Totlis et al. 2023). We could argue with the notion that "AI are able not only to store, process, analyze, compute and deliver data, but also to improvise their own machine learning skills over time, 'thinking' and searching for the best options, thus functioning much like the human brain" (Ramesh et al. 2004). Our results so far demonstrate that the options that AI offers are not only inappropriate, but also incorrect in a revolting "Frankenstein" manner. Other authors also shared that feeling, that the laws of physics are being broken somehow, producing the "stuff of nightmares"[14]. Even if at some point it meets the first two Hempel views on scientific explanation (1. Understanding is pragmatic/relativistic, and 2. nonpragmatic and objective), it would always lack the third one, that the goal is understanding (Xingming 2021).

There are financial arguments for limiting the development of anatomically correct images, which have to do with competing high-paying software products and paper publications. Religious arguments for the limitation of development in this direction are related to the trend of transhumanism and the idea of the post-human, thus opposing the idea of a standard for what is human.

AI can change the way of Anatomy teaching and learning, hopefully for deep and logical learning with 3D virtual reality experience and design for varied curricula and diverse cultural, racial and ethnic settings. Servers, training, development of tools, adequate computers, internet connectivity to access such tools are needed for the successful performance.

A new type of model[15], based on building a physical model of the world, promises to show better results. Sora is an AI model that can create realistic and imaginative scenes from text instructions. Generating a minute of high fidelity video and scaling video generation models is a promising path towards building general-purpose simulators of the physical world. Employing systems thinking as the basis for an algorithm in AI is a promising possibility. In anatomy, this means opening up the question not only of how the human body is built, but also of what a human is and what the demarcation between human and machine is. The "Spiral theory of the human body" offers a new perspective on this matter (Pirovski & Genov 2021). Discussions should focus on what system to

be used for a fundament in the new models and how to personalize them for certain tasks. All of this problems and questions are new for medicine but they are already problematised in philosophy of science and philosophy of medicine. It will be helpful for medical researches to be acquainted with analyses in this disciplines.

5. Conclusions

There is a good awareness of existing technologies with tutors and student, with little application in practice in terms of quantity and quality. A certain inertia in the pedagogy practice is slows the process of implementation of new technologies in the university education even though despite the great advantage to perform automated processes and reduce staff were demonstrated. AI technology for teaching anatomy still has high cost for equipment and training[17], and the available free and paid AI models need to be upgraded or new ones made. An AI-based anatomy learning product is not available and physicians and data scientists need to continue collaboration to build meaningful AI systems for this purpose. Individual solutions for a complex context is needed.

AI is already improving anatomical research and medical education, yet very dependent on the expert touch. It will evolve, forcing research and professors to change education practices. In this direction the problems discussed in the philosophy of medicine can help in investigation of the situation presented here. Once ready for use, more ethical dilemmas would appear for discussion. The future of AI in healthcare is bright and promising, and still much remains to be done.

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NOTES

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