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Analysis of Methods and Tools for Visualising Anatomy in the Professional Training of Future Design Teachers

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Abstract: Design teachers are trained in anatomy through the use of conventional atlases and textbooks specifically tailored for artists. The training did not use modern visualisation tools, widely used in medical universities, to popularise knowledge. The focus of the study was the techniques and approaches used for visual representation. The purpose of the study was to systematise methods and means of visualising anatomy in the training of design teachers, to determine the features of presenting knowledge in this area for designers. The research methodology involved the use of an integrated approach, which took into account all the features of the application of anatomical knowledge in design, affecting the format of their presentation. General scientific methods were used to systematise the material on the research topic, to formulate the problem, form a hypothesis as well as to formulate conclusions. It was found that at the moment there is a sufficient number of education platforms on the Internet with free access, which contain information in various visual formats. There were also educational applications and interactive atlases. But they focus on the medical component, so it was necessary to adapt them to the tasks of training designers. In general, all the considered tools can be used in different forms of training: theory and practice, didactic lectures, modeling, simulation. For design training, important issues were the ergonomics

of space and objects in it, which were largely based on human anatomy. Therefore, ergonomic models can be used as visualisation tools for preparation. Thus, the range of visualisation tools and methods is quite wide, their use proves to be effective, but there was an urgent need to adapt existing programs, models, platforms to meet design requirements. It is promising to develop an interactive anatomical atlas for the designer, which can be used in the educational process in the classroom and independently as a reference manual for students, teachers, and designers.

Keywords: visual model, human body structure, anatomy for designers, modeling, simulation.

Introduction

The incorporation of a 3D visualisation tool in anatomy education is not a recent approach in instructional techniques. It is consistently enhanced, offering fresh prospects for diverse areas of expertise. Traditionally, the exploration of the human body has relied on two-dimensional imaging tools, which pose challenges when it comes to forming mental representations of the three-dimensional structure of anatomy. This structure primarily consists of dimensions such as length, width, and depth. The three-dimensional model was a sculptural model that solved the problem of visibility. Currently, modern technologies enable the creation of three-dimensional computer models, but also to use virtual reality (VR) and augmented reality (AR) technologies to "revive" them. The capabilities of various technologies simplify the process of understanding the structure of the human body and its mechanics, which is necessary in design education. A design teacher must be able to use all modern methods and means, based on the peculiarities of using knowledge of anatomy in design.

Research Problem

Digital technologies have a strong impact on all sectors of the economy and social sphere, higher education and science are no exception. Therefore, it is necessary to ensure the formation of new models of organising trainings in the field of higher education: changing the educational environment and organisational forms of the educational process, introducing new tools and information technologies. The Covid-19 pandemic has demonstrated the importance of education's response to the overall digital transformation; the war has further intensified this process, demonstrating its relevance and the prospects of using digital technologies in various areas of education.

Anatomy is one of the most important disciplines in the training program for designers and design teachers. An analysis of teaching aids and approaches to presenting material based on literary sources showed the following: atlases and anatomy textbooks for artists are used to train design teachers (Ebenstein J.,2020); Simblet S., 2020); visual information is presented in graphic tables (2D format) and sculptural models (3D format) (Husieva L.H., 2019; Natalukha I.M., 2021). Methodological publications with recommendations for the study of anatomy relate to medical specialties and museum interactive exhibitions aimed at popularizing knowledge. This work is aimed at systematising tools and methods for visualising anatomy in the training of design teachers, since there is no development in this direction.

Research Focus

Considerable time is dedicated to sketching during the process of designing. A person is the main, most complex and meaningful object of study and depiction in academic drawing and sculpture, therefore, first of all, it is necessary, to be able to depict a person, convey his plastic

characteristics, and express his spiritual world. The process of mastering academic drawing and sculpture, in which the predominant importance is given to the image of a person, requires not only the creative activity of the student, but also knowledge, and, above all, plastic anatomy, which helps to study the structure of the human body. This explains the special interest in the methods of applying anatomy in the system of art and pedagogical education and, directly, in design education. The expansion of visualisation methods and tools needed in the study of anatomy requires future teachers to be able to use them in the required context.

Research Aim and Research Questions

The purpose of this study was to systematise tools and methods for visualising anatomy for the professional training of design teachers. The following tasks were assigned:

- To determine the need to introduce visualisation tools and methods into the educational process;
- To analyze the features and nature of visualisations presented in the literature and on the Internet for the study of anatomy;
- To determine the features of studying anatomy for design purposes;
- To identify the possibilities of visual models in the context of training design teachers.

Literature Review

The field of domestic science is primarily focused on advancements in technology integration in education, the process of digitising learning materials, and exploring the potential of utilising online resources.

Anatomy training for design teachers is largely based on the traditional approach of using stationary layouts in drawing classes. Accordingly, the literature presents a methodology for teaching anatomical drawing and the basics of plastic anatomy for designers. (Modlo et al., 2017; Parshukova et al., 2023; Chemerys et al., 2021; Chemerys & Briantsev, 2021).

Zhytienova (2019) examines issues of preparing teachers to visual materials creation . Today, the use of visualisation in the process of studying disciplines is undeniably educational trend, however, such activity requires appropriate training from the teacher. The article covers practical issues of training the future teacher for the use of didactic visual aids c professional activity. The author proposed four groups of practical tasks, which can be use in the process of preparing future teachers for the application and creation of didactic visual aids.

The work of Silén et al. (2021), is devoted to the use of 3D images in teaching anatomy. The authors identifies the key factors that need to be considered when designing educational activities using 3D images in anatomy teaching. These include the inclusion of complex, authentic images and case studies that encourage students to engage in independent exploration.

The article Suárez-Escudero et al. (2020) is devoted to the ways of teaching and learning anatomy. The main goal of the authors is to review the educational aspects and reflect on the pedagogical models, resources and didactics used in teaching/learning of human anatomy (history, present and trends), maintaining the value of anatomical knowledge in the training of health professionals. Modern tools and new trends in computational anatomy can complement, enhance, and enhance (but not replace) basic pedagogical models.

The examination of the challenges associated with adopting novel teaching methods for the subject of anatomy, including its multidisciplinary nature, is being explored. The work presents the development of new educational platforms based on the principles of a system-integrated structure.

Technology platforms involve the use of moderation: the adaptation - standardisation - integration - conformity (ASIC) framework across four key terms (Ha et al., 2023).

Three-dimensional printed anatomical models (3DPAMs) can serve as visualisation tools for studying anatomy. The article provides a description and analysis of the methods used to create 3DPAM for teaching human anatomy, and evaluates the effectiveness of their use in the educational process (Brumpt et al., 2023).

The papers by (Chytas et al., 2020; Triepels et al., 2020; Ye et al., 2020) provide reviews of various 3D digital visualisations used to study anatomy. An assessment is made of the quality of students' understanding of anatomy in comparison with traditional teaching methods. Users' attitudes towards 3D visualisations are also analysed. The articles compare emerging 3D anatomical imaging techniques (e.g., virtual reality, augmented reality, and computer-aided 3D imaging) with traditional techniques that have been used for a long time (e.g., cadavers and textbooks) based on users' understanding of anatomy. Data are provided on the effectiveness of using three-dimensional visualisation methods in comparison with two-dimensional methods. It is emphasised that students were motivated and interested in using new imaging techniques to study anatomical structures.

There are a large number of resources on the Internet that can be used in the study of anatomy. They provide a wide range of tools, volumetric visualisation, all information is systematised and easy to study: ACGME (https://www.acgme.org/), Augmented Reality Magic Mirror using the Kinect (http://campar.in.tum.de/Chair/ProjectKinectMagicMirror), and 3D4Medical (https://3d4medical.com/).

Thus, it can be concluded that the raised problem is poorly covered in the literature. Almost all developments are aimed at different levels of medical education; there are no special platforms for the field of design; traditional textbooks and anatomy atlases with illustrations are available.

Research Methodology

The research methodology involved the use of an integrated approach, which took into account all the features of the application of anatomical knowledge in design, affecting the format of their presentation. General scientific methods were used to systematise the material on the research topic, formulate the problem, form a hypothesis and formulate conclusions.

The research was aimed at studying the process of mastering anatomy by future design teachers, identifying the most effective auxiliary methodological tools in teaching. The study was based on an analysis of scientific and methodological literature, Internet sources and platforms for learning. The reason for selecting this source base was influenced by the particularities of contemporary teaching methods, the increasing implementation of digital technology, and the emphasis on interactive learning. An integrated approach allowed taking into account all the features of using anatomical knowledge in design, influencing the format of their presentation. General scientific methods were used to systematise the material on the research topic, pose the problem, form a hypothesis and formulate conclusions.

Results

Plastic anatomy is an indispensable attribute of training in art universities. Design teachers also master this discipline, since it is the basis for design, which then allows them to better understand the basics of ergonomics of space and objects surrounding a person. In order to learn about the human body's structure, it is essential to have a visual depiction when studying anatomy. Traditional means and methods consist of the use of visual aids: posters, sculptural models. Mastery occurs in

the process of their depiction. Modern digital technologies have significantly expanded the possibilities of visually studying anatomy. All innovations primarily concern medical education. However, they can be successfully used in design education after the necessary adaptation to design tasks.

In the case of design teacher training, the discipline of plastic anatomy is mandatory. Plastic anatomy or anatomy for artists is a branch of the science of the structure of the human body that is of interest to the visual arts. Literally translated, the word “plastic” comes from the Greek “plastike” and means sculpting. The word "anatomy" is also of Greek origin. It comes from the word “anatemno”, which means I cut.

Thus, in its original semantic meaning, plastic anatomy means the totality of the knowledge that an artist can obtain using information obtained from studying the internal structure of the human body, which determines its external forms.

The study of the structure of the human body has traditionally been carried out step by step in the process of learning to draw: skeleton, muscle corset, nude. Special attention was paid to the construction and drawing of individual elements - eye, nose, ear, hand. Movements were mastered with the help of cultural images and anatomical tables.

Advances in information technology and internet accessibility are reshaping design education, providing new learning environments and new ways of learning. Thanks to the introduction of web technologies, coupled with the increasing availability of educational software and information databases via the Internet, computer-assisted learning (CAL) is being introduced into anatomy as a means to complement or replace traditional anatomy teaching.

Computer-assisted learning represents an important alternative pedagogical tool. The different modes of instruction used in computer-based learning are as follows:

1. Training and practice: educational material is first provided to the student, subsequent assessment of the student’s knowledge on questions with multiple answers, using quizzes, diagrams and drawings that represent a certain anatomical structure in order to identify and designate structural elements.

2. Didactic lecture: digitised video lecture, slide or other educational material available on a computer. The advantage of this approach is that relevant reference material can also be made available through links at specific points in the lecture.

3. Modeling. One of the most effective approaches, but extremely difficult to implement on a computer, is the constructive learning approach.

A relatively simple example is the study of anatomy by reconstructing the human body, either by combining separated body parts or by correctly placing cross-sections in the body.

4. Simulation: Teachers can use 3D modeling to demonstrate human anatomy, including spatial relationships. The student can follow the path of a nerve tract, follow the flow of a blood vessel, study the structure of a body part or organ layer by layer, hide external signs to reveal the main structures, or see muscles, producing movements in the joint.

Numerous websites and software are available with anatomy teaching tools that can be used by students for both self-study and classroom learning. The Visible Human Project provides color scans of a man's body using 1,871 cross-sections at 1mm intervals. Brainstorm, developed at Stanford University, is an interactive atlas of neuroanatomy with images of dissection steps and techniques, cross-sections, diagrams, and extensive supporting text. Anatomy Laboratory's

multimedia interactive software improves both memorization and visualization and has been said to be an effective teaching aid. Other popular programs, such as ADAM Interactive Anatomy or Dynamic Human, are good at conveying spatial images through layering of complex patterns that can reveal deeper structures step by step (Zhytienova, 2019).

Here is a classification of simulation models according to the method of implementation:

1) algorithmic models: an algorithm, a computer program that allows simulating the change of states in the system and, thus, will represent the behavior of the simulated system;

2) graphic models: application programs for vector and raster graphics. Methods of representing objects in raster graphics - in the form of geometric primitives.

In raster graphics, objects are made up of pixels (2D graphics) or voxels (3D graphics);

3) structural and functional models: block diagrams, network and hierarchical graphs.

The physical characteristics of the human body are the basis for the implementation of ergonomic requirements for industrial design developments. To establish whether the characteristics of the product being developed meet the requirements of ergonomics, assess its anthropometric properties, convenience and comfort of use, testers are involved. They assess both the strengths and weaknesses of the product, complete a specific standardised report, and then give it to designers and engineers for evaluation and rectification of any flaws. This practice of evaluating physical models and prototypes has a number of features. Particularly, real testers have unique physical parameters, differ in functional abilities and specific perceptions, and have subjective ideas about ease of use and other properties of the product. In order to reduce the need to attract testers and increase the objectivity of the assessment of finished products, as well as in situations where pilot testing is required with the involvement of a large number of testers or testers with atypical physical parameters, working ergonomic human models or computer manikins are used.

Physical or computer dummies that simulate the human body and its actions are used at the design stage, when testing prototypes, and when testing critical operations (crash tests). At the testing stage, ergonomic models enable the quick and easy identification of a possible lack of space, assess the possibility of a person entering a confined space and the accessibility of the subject environment for him. To expand the range of functionality of the model, various functions can be integrated into its computer system, for example, indication of the reach area, visualisation of the field of view, biomechanical calculation of the required forces, and others.

In design engineering, a physical or computer ergonomic model of a person is traditionally used to design a workspace. The state standard establishes clear requirements for the static accuracy of ergonomic models (ergonomics), lists the main anthropometric parameters of ergonomic groups and their functional properties: standard postures, variability of measurements in basic postures, joint mobility, reach areas. Existing methods for developing ergonomics are based on the principle: the more static and dynamic characteristics are embodied in an ergonomic model of a person, the more accurately it takes into account the physiological characteristics of a person in developing the shape of the designed objects of the subject environment. Accounting for anthropometric parameters is realised through a schematic representation of a person (Augmented Reality Magic).

There are two-dimensional (2D) and three-dimensional (3D) graphical computer models of a person. A physical two-dimensional, articulated, contour model of the human body is constructed taking into account anthropometric measurements and is based on the techniques of engineering graphics and prototyping. 2D mannequins are characterised by fixed anthropometry, in which the

selected fixed values represent differences in a person's gender, age and body shape. Two-dimensional models are implemented in different projections (top, side, front, back) and poses (sitting, standing, lying down), and are used to demonstrate movements, create diagrams and evaluate the design of an object environment in two-dimensional design.

When developing artistic and design documentation, three-dimensional geometric ergonomic models are used, the geometric complexity of which varies from simple rib and frame models to a realistic image of the human body. Usually the human body is represented as a collection of solid bodies connected by means of holding bonds. For example, the three-dimensional mathematical ergonomic model of R1 incorporates a hinge system that allows it to take working positions "standing" and "sitting". R1 can be used as a tool for modeling sensorimotor areas for the placement of controls and information display systems. There are different versions of biomechanical models, but a universal comprehensive model of human biomechanics has not yet been developed.

3D ergonomic models facilitate more efficient workspace design through the following functionality:

– segmentation and detailing of body shape, for example in cases where functional anatomical details involve finger joints or spinal components;

– transfer of biomechanical features of the body, including the structure of joints and the mechanics of moving joints to ensure natural movements;

– fixed anthropometry, parametric anthropometry, which allows you to store data in files and select anthropometric options depending on specific design tasks;

– animation of movements using computer graphics to simulate dynamic ergonomic parameters;

– use of complex software of a computer manikin system, customizable to the specific requirements of the user.

One of the key areas of digital transformation in the field of science and higher education is the development of digital services, among which it is necessary to note such as the introduction and use of artificial intelligence technology, virtual and augmented reality technologies, microlearning and mobile learning as formats for presenting information. Artificial intelligence technology, as a rule, is used to personalise training, allowing for the optimal choice of training program and specialist development trajectory, taking into account his preferences and capabilities (Chemerys H., Briantseva H. et al., 2021).

Virtual and augmented reality technologies are considered the most promising areas for the development of digital solutions in the field of education, as they allow providing unlimited access to new knowledge, practicing skills, and making the learning process simpler and safer.

Virtual reality (VR, Virtual reality) is an artificially created interactive world using various technical means and technologies (alternative reality). The effects are as close to reality as possible, allowing to feel and experience believable sensations. Virtual reality is actively used in many areas of clinical and preventive medicine in a wide variety of applications. Using VR, you can quickly create a personal 3D model of a person based on a basic human model, which can be used in anatomy training for designers. Future design teachers must understand what knowledge and skills have an applied aspect in the field of design, and from this perspective adapt "medical" material to the educational process. Virtual reality allows the designer to understand and test the ergonomic requirements for designing objects and spaces (Honcharova N., 2019).

Augmented reality (AR, Augmented reality) allows combining the real world with the virtual one, in other words, the physical world is combined with digital data in order to supplement it with information about surrounding objects. It is an enhanced real-life environment that provides an image of the real world by projecting digital information onto the existing environment. The main goal of augmented reality is to transfer three-dimensional virtual objects in real time into a three-dimensional real environment. This technology differs from virtual reality technology, in which the user is able to completely immerse himself in the virtual world.

Mixed reality (MR) combines these two types; objects of the virtual world are organically integrated into the physically existing world, forming a single whole and forming a new reality. It combines the real world and digital objects into an interactive reality.

VR, AR and MR technologies allow for volumetric and surface visualisation of organs and structures of the body. AR technologies enable students to examine the intricate framework of the human body such as the skeleton and muscles, facilitating comprehension of variations in anatomical structure between adults and children (Parshukova L. et al., 2023).

Applications of VR and AR technologies in the study of anatomy. With the development of modern technologies, innovative forms and means of teaching are actively included in the educational process. The study of anatomy has long been carried out using traditional methods, such as dissection of a human corpse, the use of atlases and textbooks. Due to the insufficient supply of biological material to anatomical departments, teachers began to actively introduce modern computer technologies into the educational process: projectors, interactive whiteboards, anatomical tables. This knowledge can also be applied when educating design instructors. In the realm of education, novel interactive manuals, virtual displays, and apps are being developed, allowing for the visualisation and study of various structures, organs, and systems. For example, the anatomy application 3d4medical for iPad uses AR technology, contains a large number of high-quality illustrations and animations, and can build 3D models in front of human eyes.

An option for using AR technology to study anatomy is three-dimensional (3D visualisation) of organs and parts of the human body using an anatomical 3D table with a large touch screen the size of an adult. In recent years, quite a lot of medical atlases with 3D images for electronic devices have appeared: the human anatomy atlas Visible Body, Anatomy Learning, the Muscle Anatomy Pro application, the BoneBox™–Skull Viewer program, Skeleton. 3D Anatomy", "Visual Anatomy Free", virtual platform "BioDigital Human–3D Anatomy", "Virtual Human Body", "Human Anatomy Atlas 2019 Edition", software platform 3D Organon, 3D platform Complete Anatomy, Arteksa Virtual Anatomy and others.

The advantage of these technologies is the availability of an unlimited number of different models, the study of different levels and systems individually and as a whole, the ability to visualise and mentally manipulate 3D structures, correctly identify them and the structures associated with them is an important skill for students.

The use of VR and AR technologies during classes develops students' visual-spatial abilities during learning, enhances engagement, increases the memorability of the material and its understanding, and expands communication between students. The results of foreign studies on the effectiveness of studying structural anatomy using VR or AR technologies show great prospects for the use of virtual and augmented reality as a means of supplementing the content of classes in anatomical education. AR technologies around the world were in maximum demand during the period of distance learning due to the COVID-19 pandemic, which allowed students to receive high-quality knowledge with access to all the necessary resources anytime and anywhere.

Discussion

The study uncovered that future design teachers have limited utilisation of modern technologies when it comes to teaching anatomy. This concerns, first of all, the presentation of visuals. This issue has been studied in detail in the professional training of specialists in the field of medicine. In the field of art education, visual aids are represented mainly by images on a plane or in the form of sculptural models, which are used in art classes as staged objects.

The novelty of this study is a comprehensive analysis of methods and means of visualisation when studying anatomy by artistic specialists. An important aspect is taking into account the nuances of using the acquired knowledge in the real practice of teaching design. This is the basis for the nature of the proposed options for using visualisation and identifying their potential.

The findings address the area of artistic training, in contrast to most studies that address visualisation issues in anatomy teaching in general (Suárez-Escudero J. C. et al., 2020; Silén C. et al., 2021).

The results of the study by Ha T.M. are relevant. et al. (2023) in the context of the interdisciplinarity of the subject of anatomy. The solutions proposed by the team of authors correspond to our concept of visual support for the training of design teachers.

To expand the visual didactic range, the results of the work of Triepels C.P.R. can be used. et al., (2020), Ye Z. et al. (2020), Chytas D. et al. (2020), which provides an in-depth look at the various 3D digital visualisations used to study anatomy.

This work is limited to general recommendations and rather represents the potential of using modern means and methods of visualisation in teaching anatomy to future design teachers, taking into account the specifics of design. Therefore, further research in the subject implementation and adaptation of existing educational platforms and other digital materials for the study of anatomy to the specific needs of the field of art education is promising.

Conclusions and Implications

It is important to mention that the utilisation of advanced computer mannequin modeling systems enhances the effectiveness and efficiency of the ergonomic model for resolving design issues. This involves a computerised model, tools to control and manipulate the model, as well as methods for positioning the model within a three-dimensional computer setting. However, employing such systems demands high-performance hardware and specialised professionals.

Computer systems have anthropometric, postural, or biomechanical limitations. The student may have difficulty conveying the model's poses or make mistakes in controlling her movements. A computer operates with only four dimensions, and the subject environment requires a more subtle approach and can only be formed by a person, but with the participation of the most advanced technical means.

These problems are partially solved by the use of augmented, virtual, and mixed reality technologies.

Thus, the use of digital technologies in the educational process not only leads to an increase in the level of "digital maturity", but also has a positive impact on the educational process and the functioning of educational institutions as a whole. The results of the literature review indicated that VR, AR, and MR had a potential to complement anatomical teaching using traditional methods.

Working with traditional sculptural models and practicing their depiction is still important in the study of anatomy, even with the incorporation of the latest technologies. They can be a good addition, especially in remote learning situations.

Prospective teachers must understand that students should be given the opportunity use of multiple resources, which contributes to flexibility in acquiring knowledge, in other words, students' ability to apply acquired knowledge in various contexts. Teaching material and teaching style should reflect changes in the real world.

Suggestions for Future Research

Currently in Ukraine, distance learning is still considered the most appropriate method of education, which was initially implemented for safety reasons during the time of martial law. Therefore, the inclusion in the teaching process of new tools that meet the modern level of development of science and technology is a necessity. Visualisation elements have generally proven to be effective in the educational process. As for the study of human anatomy, this is an important information component that allows you to get a complete understanding of the systems of the human body and their interaction.

The emergence of an increasing number of services on the Internet that allow studying the human body in 3D format does not fully solve the issues of teaching plastic anatomy to graphic designers. Basically, all the presented developments represent anatomy for study from a medical perspective or for general development in the school curriculum.

In design education, the knowledge of anatomy is required in several aspects of design. Understanding the dimensions and movement patterns of an individual is essential in order to create objects that encompass their personal space, where essential life activities occur. What is important here is the question of the functional flow of various life processes, which require a certain organisation of space and influence its formation and objects. Which are located in it. Thus, ergonomics, which is the basis of design, is itself based on anatomy. And the most effective is the visual perception of the movement of the human body. In graphic design, one of the directions is the development of characters, so here the approach to anatomy is more pictorial. It is built on the study of ways to depict a person both statically and dynamically. The characteristics of a character can be expressed through his figure, physique, and manner of movement. Hence, we believe that it would be beneficial to focus on advancements in graphic design training that consider the specific aspects of teaching anatomical form and cater to the demand for showcasing the wider range of the body's functional abilities.

References

Brovchenko, A. I., & Tymenko, V. P. (2023). Information technologies of visualization in design. In *Digital transformations in culture* (pp. 142–162). Riga, Latvia: «Baltija Publishing». https://doi.org/10.30525/978-9934-26-319-4-9

Brumpt E., Bertin E., Tatu L. & Louvrieret A. (2023). 3D printing as a pedagogical tool for teaching normal human anatomy: a systematic review. BMC Med Educ 23, 783. https://doi.org/10.1186/s12909-023-04744-w

Chemerys, H., & Briantsev, O. (2021). Selection of software for the formation of electronic and educational environment of future designers according to distance learning. Pedahohika Formuvannia Tvorchoi Osobystosti u Vyshchii i Zahalnoosvitnii Shkolakh, (78), 261–265. https://doi.org/10.32840/1992-5786.2021.78.47

Chemerys, H., Briantseva, H., & Briantsev, O. (2021). Ways to improve design education in the context of the strategy of digital transformation of education and science of Ukraine. Physical and Mathematical Education, 32(6), 49–56.

Chytas D., Johnson E.O., Piagkou M., Tsakotos G., Babis G.C., Nikolaou V.S., Markatos K. & Natsis K., (2020). Three-dimensional printing in anatomy teaching: current evidence. Surg Radiol Anat, 42(7), 835–841.

Ebenstein J. (2020). *The exquisite and unsettling art of human anatomy*. Laurence King Publishing.

Ha, T. M., Hoang, D., Huynh, C. D., & Linh, L. (2023). LeIntegrated Educational Technology in Teaching Anatomy Using the ASIC Framework: A Case Study from VinUniversity. Advances in Medical Education and Practice:14 669–681.

Honcharova, N. (2019). Technology of augmented reality in textbooks of new generation. Problems of the Modern Textbook, (22), 46–56. https://doi.org/10.32405/2411-1309-2019-22-46-56

Modlo, Ye., Yechkalo, Y., Semerikov, S., & Tkachuk, V. (2017). Vykorystannia tekhnolohii dopovnenoi realnosti u mobilno oriientovanomu seredovyshchi navchannia VNZ [Using technology of augmented reality in a mobile-based learning environment of the higher educational institution]. Naukovi zapysky. Seriia: Problemy metodyky fizyko-matematychnoi i tekhnolohichnoi osvity, (11), 93–100. http://ds.knu.edu.ua/jspui/handle/123456789/970

Nobles M.S. (2019). Innovative instruction: learning in blended human anatomy education. Theses and Dissertations. 1040. https://digitalcommons.pepperdine.edu/etd/1040

Parshukova, L., & Parshukov, S. (2023). Augmented reality as a way of diversifying the educational process. Věda a perspektivy, (1(20), 74–83. https://doi.org/10.52058/2695-1592-2023-1(20)-74-83

Rocha D.P., Almeida da Silva K.G., Pires de Mélo I.H. & Schwingel P.A. (2021). Alternative methods for human anatomy teaching: systematic review. Research, Society and Development, 10, 16. https://doi.org/10.33448/rsd-v10i16.23641

Romand M., Dugas D., Gaudet-Blavignac C. & Rochat J. (2020) Mixed and Augmented Reality Tools in the Medical Anatomy Curriculum. Stud. Health Technol. Inform, 16. (270), 322-326.

Silén C., Karlgren K., Hjelmqvist H., Meister B., Zeberg H. & Pettersson A. (2021). Three-dimensional visualisation of authentic cases in anatomy learning – An educational design study. BMC Medical Education, 22:477, 1-15. https://doi.org/10.1186/s12909-022-03539-9

Simblet S. (2020). Anatomy for the Artist. DK (Dorling Kindersley).

Suárez-Escudero J. C., Posada-Jurado M. C., Bedoya-Muñoz L. J., Urbina-Sánchez A. J., Ferreira-Morales J. L. & Bohórquez-Gutiérrez C. A. (2020). Teaching and learning anatomy. Pedagogical methods, history, the present and tendencies. Acta Medica Colombiana-Digital, 45, 4. https://doi.org/10.36104/amc.2020.1898

Triepels C.P.R., Smeets C.F.A., Notten K.J.B., Kruitwagen R.F.P.M., Futterer J.J., Vergeldt T.F.M., Kuijk S.M.J.V. (2020). Does three-dimensional anatomy improve student understanding? 33, 1, 25-33. https://doi.org/10.1002/ca.23405

Uruthiralingam U. & Rea P. M. (2020). Augmented and Virtual Reality in Anatomical Education. A Systematic Review Adv. Exp. Med. Biol, 1235, 89-101.

Ye Z., Dun A., Jiang H., Nie C., Zhao S., Wang T. & Zhai J. (2020). The role of 3D printed models in the teaching of human anatomy: a systematic review and meta-analysis. BMC Med Educ, 20(1), 335.

Zhytienova, N. (2019). Practical aspects of using visual resources in teacher's professional activities. ScienceRise: Pedagogical Education, (6(33), 16–19. https://doi.org/10.15587/2519-4984.2019.185633