Incorporating contemporary technologies into higher education pedagogy: Exploring mastery and innovative implementation

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Abstract Currently implementation of modern computer technologies, such as devices of virtual, augmented reality, etc., plays a crucial role in the motivation of today’s students. Online education causes the enhancement of new technologies introduced into the educational process. In its turn, it forced teachers of different specializations to deal with new computer technologies to be in trend, because in a majority of Ukrainian universities, the implementation of new computer technologies was poor. Now the level of use of modern technologies in pedagogical practice is higher in comparison with the state of it before the COVID-19 pandemic. The work aims to analyze modern scientific data on the use and implementation of new computer technologies in the modern process of education. Scientific articles of the last decade were used for providing this analysis. It was settled that the integration of new computer technologies including virtual and augmented realities in the educational process is aimed at solving a variety of issues such as the transformation of the organization of the educational process of cognition due to its shift toward systemic thinking; effective organization of cognitive activity of students in the course of training; the need to form an open and accessible education system; orientation of the educational process on the individual; improvement of the professional competence of students.

Keywords: virtual reality, augmented reality, higher education, computer technologies, pedagogical process

1. Introduction

Today, the implementation of innovative technologies in the educational environment is considered a mandatory component of improving the quality of the educational level. The integration of modern pedagogical and information-communication technologies in higher education is the most important factor for the transition of the educational system to a new level, improving the quality of teaching disciplines, increasing student motivation, and stimulating the development of students’ information competencies. Due to the changing requirements of the labor market, it has become necessary to develop learning technologies in the educational sphere. The current priority goal of education is the preparation of qualified graduates who are capable of professional problem solving in an ever-changing environment. The peculiarity of higher education today is the rapid increase in the volume of information, which is a fundamental factor that necessitates changes in the organization of the educational process. The transformation of education should be carried out through radical changes taking into account the modern level of educational technology development. The integration of modern technologies, including pedagogical, computer and communicative technologies, leads to the need for effective interaction between the subjects of the educational process and is focused on dynamism and flexibility (Akimov et al., 2021). New technologies can significantly accelerate the transfer of knowledge and are aimed at the faster adaptation of students to social changes. Modern information technologies form new pedagogical and educational methods and strategies based on the use of gadgets and different information processing systems. The implementation of modern information technologies in the educational and pedagogical process is an obvious condition for the modernization of the education system.

Unfortunately, in modern Ukrainian higher education institutions, teaching is currently carried out mainly by traditional methods, which include the presentation of material, its processing by students and testing of the acquired knowledge. In applied fields, including medicine and architecture, an important aspect is the practical mastery of the material, the development of techniques, and the acquisition of experience. In particular, in medical education, the acquisition of practical skills and their development and consolidation are very important because the quality and quantity of their implementation affect the
qualifications of future doctors, paramedics and nurses. Teaching many basic disciplines, including medical ones, at the proper level requires the demonstration of visual material, which is necessary for the best assimilation of knowledge (Kamphuis et al., 2014). Improvements and optimization of computer systems have made it possible to widely use virtual and augmented reality technologies in various fields of education, including medicine (Joo-Nagata et al., 2017). The digital competence of all participants in the educational process, including both teachers and students, helps to find, analyze, evaluate and use a variety of (including voluminous) digital content in practice. The creative use of digital technologies drives the process of self-improvement and development. The use of immersive technologies can significantly improve the process and quality of learning, as well as prepare future doctors, paramedics and nurses for various situations that may arise during real operations or manipulations with patients in real time. The introduction and use of computer technologies in the educational process do not require significant financial costs, and if effective simulations are developed, it allows for a reduction in the number of hours spent in practical classes on familiarization with the peculiarities of working with different situations or a significant amount of material and, accordingly, to devote more time to developing practical skills and acquiring competencies. The use of immersive technologies in the educational process is a visual and interesting way to study different disciplines in one room. Augmented and virtual realities are high-quality replacements for tables and models. Learning processes involving the acquisition of new knowledge and competencies based on immersive technologies motivate and organize (Kovalchuk et al., 2020). Immersive virtual and augmented reality technologies cannot completely replace other types of teaching, but their combination with classical pedagogical approaches significantly improves student performance, which may be due to both the diversity of object visualization and the growing interest in the learning process.

The first virtual system in medicine was introduced in 1965 by Robert Mann to facilitate the perception of educational material for orthopedists. In the late 1980s, there were already attempts to introduce VR visualization into clinical practice. In recent years, VR technology has changed significantly: improved technical support and new engineering solutions have improved the quality of visualization and reduced the negative effects of VR (nausea, dizziness, temporary visual impairment, etc.) (Kovalchuk et al., 2020). In addition, global trends in education are focused on humanistic ideals, which also impose certain restrictions on the availability of materials for educational purposes. Modern education must be safe and conducted in compliance with recognized and legally approved ethical standards (Kamphuis et al., 2014).

The use of virtual and augmented reality-based simulations to teach students of medical specialties who require perfect mastery of invasive techniques allows them to familiarize themselves with the peculiarities of working in aseptic conditions and demonstrate the algorithm of interventions. The direct participation of each student in the educational process is important, as is the ability to independently perform a large number of manipulations with the simulation of the latest equipment individually.

The use of augmented and virtual reality technologies allows doctors with different specializations to master basic surgical procedures, which is extremely important since, for example, future family doctors do not undergo professional surgical practice. At the same time, students who want to choose specialties based on manipulations (surgical interventions, examinations such as colonoscopy, gynecological examinations, etc.) can learn and improve their skills faster with the help of simulations, reducing the risk of complications associated with the inexperience of the intern. The use of virtual reality allows you to visualize the complexity of the area to be operated on and provides the opportunity to repeat the process as many times as necessary, which is impossible to do in real life. A study by Seymour et al. showed that doctors trained using virtual reality techniques performed operations 29% faster than those trained using traditional methods (Kovalchuk et al., 2020). Thus, modern educational technologies can offer a safe, effective, and profitable curriculum thanks to the introduction of virtual and augmented reality (Herron, 2016; Pottle, 2019). VR is the use of software to simulate the environment. Unlike traditional user interfaces with screens, visualization in VR is carried out using a special helmet-shaped display (HMD) and certain sensors (manipulators, gloves, styluses) that allow the user to interact with the environment and virtual characters and objects as if they were real (Hamacher et al., 2016). Augmented and virtual realities have many technical aspects in common, but augmented reality differs from virtual reality because its essence is not to create a completely artificial environment but to overlay a computer-generated image on the user's real environment (Kamphuis et al., 2014; Abhari et al., 2015). Tablets, mobile phones, AR glasses, and other optimized devices can be used as hardware to run augmented reality applications. AR is widely used in clinical practice and provides additional information for doctors during interventional procedures. Augmented reality complements the real surgical field with a virtual overlay of visualized results of examinations such as thoracography, angiography and ultrasound (Valdés et al., 2016).

2. Literature review

Today, in Ukraine, there is already some experience in implementing virtual and augmented reality technologies in the educational process for students. VR technologies in education are educational tools that use computer technology to create three-dimensional (3D) images or environments that can interact with real or physical environments. VR is a broad concept that has many different tools and programs. There are three main categories of VR, namely, on-screen VR, immersive VR environments, and virtual worlds (Haowen et al., 2021). One of the rapidly developing areas in the field of medical educational technologies is the use of immersive virtual, augmented and mixed reality technologies to reproduce the environment and
objects in the form of complex computer images (McBride & Drake, 2018). Experience suggests that Virtual and Augmented Reality simulators should have quality standards suitable for educational purposes.

However, even if these standards are met, the effectiveness of this method of learning, as well as classical teaching methods, primarily depends on student motivation. With the use of the latest and most unusual, but at the same time state-of-the-art, technologies, the opportunity to work in the digital space can also serve as an additional incentive for student motivation in acquiring digital competencies. Several published studies have tested virtual and augmented reality simulators in specific educational institutions to study their validity and transfer of acquired skills to real-life situations (Barsom et al., 2016; Pelargos et al., 2017; Kuehn, 2018). It has been shown that in higher education medical institutions, VR is adequate for learning practical skills in laparoscopic surgery, neurosurgery, catheterization methods and endoscopic procedures. We will consider in more detail the prospects for using virtual/augmented reality in various areas of medical education.

2.1. Anatomy and physiology

Anatomy and physiology are classic fundamental subjects for which virtual/augmented reality is used (Faria et al., 2016). For the first time, an application for studying human anatomy using virtual reality was created in 1991 based on CT/MRI data and contains more than 7000 digital anatomical images. When studying the discipline of human anatomy, augmented reality programs based on tablets/smartphones, which project three-dimensional information, visual three-dimensional structures, and links to traditional pages of textbooks and atlases, are also used.

Today, it is possible to model dynamic processes at different levels of the organization of biosystems. In teaching physiology, modeling the work of cell membranes, particularly neurons, and organ systems should be considered relevant, focusing on the most informative parameters, for example, for the cardiovascular system, including heart rate, blood pressure, contractility, and vascular resistance, in such an active model.

2.2. Surgery

Immersive technologies are useful in the study of several disciplines in surgical specialization, including laparoscopy, endoscopic procedures, and neurosurgery. Accuracy and realism are extremely important elements for manipulation to maximize the reproduction of real stressful conditions in a doctor’s practice. For example, modern VR laparoscopic simulators are “hybrids” because they consist of real surgical instruments and a virtual working field and are equipped with evaluation systems that measure different parameters, such as errors made during surgery and ergonomic movements of the surgeon (Badash et al., 2016). They are especially useful when intensive feedback from the instructor is actively used (Paschold et al., 2013).

Similarly, the main application of augmented reality in surgical training is telemetry: the instructor can teach the student by indicating the correct surgical movements, paths, and features of manipulations on the screen. Virtual and augmented reality modeling has great potential for practising complex procedures such as mastoidectomy (Andersen et al., 2015).

The use of immersive technologies improves learning outcomes and the consolidation of skills necessary for successful surgery (Andersen et al., 2016). In neurovascular surgery, augmented reality can be used to visualize the vascular architecture, which can help a specialist make decisions, reduce operating time, and improve accuracy.

The combination of medical tools enriched with preoperative indicators using AR during a real surgical operation helps both experienced doctors and novice surgeons improve their spatial understanding of anatomy to determine the most nontraumatic approach.

2.3. General practice

Several simulations, such as 3D lung dynamics visualization using augmented reality, allow real-time visualization of 3D organ dynamics superimposed directly on a mannequin or a patient in the operating room. This system can also be used to recreate specialized clinical training scenarios, such as ectopic pregnancy (Moro et al., 2017).

For higher medical education, one computer-based learning technology that is being actively implemented in the educational process is the Anatomage Table, which contains full-size images of 4 frozen bodies and sections made in three planes, according to the principle of cuts of frozen corpses proposed by the outstanding Ukrainian anatomist N.I. Pirogov. This computer system makes it possible to obtain 3D images of organs and systems. At the same time, the growing role of 3-D visualization in the study of morphology has made it possible to prepare higher education students to work with modern methods of medical research: ultrasound, computed and magnetic resonance imaging (Kovalchuk et al., 2021). The Anatomage Table is actively used in teaching human anatomy. This device allows you to learn not only the structure of organs and neurovascular trunks but also their topography to control the level of input and output knowledge. It also makes it possible to determine the layered structure of the human body, which is necessary for further study of clinical anatomy. The provided images of histological preparations of organs, which can be displayed on the monitor screen simultaneously with the image of the organ, allow higher education students to become accustomed to the holistic approach to studying the structure of
structures and use this approach in the future. When working on the Anatomage Table, students also learn the principles of analyzing CT and MR images, which is necessary for specialists of any specialization (Kovalchuk et al., 2021).

Virtual/Augmented Reality simulators have several advantages: minimal cost of use, simplification of several ethical points, and safety in comparison with training on real patients. Moreover, these simulators can be used to obtain a greater variety and complexity of procedures. Unlike an anatomical laboratory or clinic, modern computer-based learning technologies allow students to study at their convenience, regardless of the availability of cadaveric material or patients. The value of VR in the context of training is that this approach offers an environment that is as similar as possible to real-life scenarios. Conducting operations in virtual reality allows individuals to acquire the necessary psychomotor skills to master invasive techniques (Herron, 2016; Khan et al., 2018; Oda et al., 2019). As a result, medical students’ learning outcomes improved, as shown in a study of the success of neuroanatomy learning using immersive and interactive virtual technologies (Ekstrand et al., 2018).

However, the introduction of new methods into the education system has several difficulties. These include, first, difficulties in assessing the effectiveness of the use of virtual and augmented reality in education, including medical education (Chan & Zary, 2019). In addition, today, VR and AR teaching methods are not structurally included in the educational process and are not systematically applied (Sánchez-Cabrero et al., 2019). For simulators to be valuable, they must provide realistic feedback that allows the user to apply this training in a real situation (Kirkman et al., 2014). The comparison between VR and real-life simulations is a subject of debate, as trainees do not receive physical feedback when interacting with real objects. Virtual reality has been shown to be a less effective method for training compared to tactile simulations such as those involving cadaveric materials and physical models. One of the advantages of this technology is the cost of purchasing and maintaining virtual reality equipment (Moro et al., 2017). However, such technologies help to save teachers' time and classroom space: one installation usually does not occupy more than 2x2 m but allows a variety of simulation activities to be performed when VR modeling takes place. In addition, different immersive systems help to create default curricula tailored to specific purposes. Moreover, these systems can generate a variety of representative data (Kovalchuk et al., 2020), which is useful for ensuring consumption, encouraging learner comprehension, and revealing students, who can obtain more from further learning through other methods. In addition, the introduction of digital technologies requires continuous improvement in the digital competence of academic staff, who will be able to take advantage of immersive technologies. It should also be noted that given the interest of software and hardware manufacturers in the healthcare market, as well as the demand and growing competition in modern digital industries (Khor et al., 2016), we should expect an increasing availability of immersive technologies and, as a result, the economic feasibility of their implementation in medical education today. Studies have shown that medical students' learning outcomes, for example, in neuroanatomy, improve with the use of immersive and interactive virtual technologies (Zaderei et al., 2016).

The purpose of this study is to analyze modern scientific data on the use and impact of immersive technologies in modern education.

3. Materials and methods

For a comprehensive search, we searched for relevant studies in the ERIC Database and Web of Science Database over the past decade. To remove a large number of irrelevant papers during the manual search, a selection of terms was created: "pedagogical process/new technologies", "pedagogical process/virtual reality", "pedagogical process/augmented reality", "virtual reality/educational process", or "augmented reality/educational process". The current literature review includes works that aim to address the problems of implementing and introducing new technologies, including virtual and augmented realities, into pedagogical and educational processes.

4. Results

With the integration of pedagogical technologies, we understand the process and the result of combining pedagogical technologies into a certain integrity, accompanied by the densification of links between its components. The result of this integration is an innovative pedagogical technology. Information technology is understood as an integrated process based on a set of methods and means of collecting new quality information and its processing, storage and transfer of educational information to the learner. Information technologies also imply the interactive interaction of all subjects of the educational process among themselves or program means and the control of students' knowledge through testing. Due to the introduction of new methods of activity and various tools in the process of implementing modern pedagogical technologies, the penetration of information and communication technologies into the learning process has occurred. Computer classes, digital microscopes, interactive whiteboards, interactive testing systems, tablets, various program complexes, etc., can be used (Popov et al., 2022). Different forms of training organizations are formed based on this integration. Media conferences, virtual laboratories, webquests, etc., can be defined. The implementation of information and communication technologies in the educational process of higher education institutions is provided by media technologies, network information resources, and electronic aids. This occurs due to the implementation of these courses in the educational process.
New information and communication technologies may be involved in the realization of problem, discussion, game and group learning technologies whose peculiarity is the obvious inclusion of all members in the interactive process; however, the implementation of information and communication technologies promotes individualization of learning, taking into consideration the needs and abilities of any student. The implementation of new technologies is aimed at improving the educational process—volume of learning material, pace, time of learning, etc. This integration makes the educational process flexible, elective, and complex. Integration can be represented by project-action technology, the basis of which is the development of students’ creativity, critical thinking, orientation skills in the information space, and independence. This integration allows the use of creative nonstandard tasks. Project-activity technology is aimed at integrating the skills, knowledge and skills of students from different areas, as well as realizing different teaching methods (Aleinikova et al., 2020). An example can be the technology of webquests, problem situations or tasks with elements of role-playing games, for which it is necessary to use information and communication resources such as the internet.

The peculiarity of modular technology is the creation of a target individualized program in terms of content, tempo, rate of learning, methods, variants of self-control, etc. The aim of problem-modular technology is the formation of students’ independent activities: scientific research, creative work, etc. This kind of technology allows any student to study the material by their level of abilities and theoretical background. Teachers upload learning materials according to the curriculum. The realization of such technology is facilitated by different platforms, including the "Moodle" system, which includes several blocks, and modules on different disciplines of the course, each of which includes a structured system. Students can study or repeat the material in different versions: abbreviated, in-depth and full (Semenets-Oriova et al., 2022). The course material may be presented in the form of structured blocks, where the electronic platform contains test tasks to test knowledge, self-control, setting of scientific problems, analysis of possible difficulties and errors that arise when solving tasks and studying the material, setting of the main problem with the formulation of goals and objectives of the course, the main teaching material, final generalization of the content, and additional material of increased complexity. The result of integration can be the technology of distance learning, the source material for the creation of which are interactive resources and systems, remote access technologies, problem-module technology, and a wide range of new information, telecommunication technologies and technical means. This is the highest level of integration obtained by merging information and communication technologies and education of new technologies. Distance learning technologies enhance the educational process and make it more dynamic and person-oriented. In higher education, distance learning significantly extends educational opportunities for all students regardless of their level. Such technology can be used in distance olympiads, creative competitions, scientific projects, educational chat discussions, and educational courses and conferences (Kryshtanovych et al., 2022).

The model of integral pedagogical technology is a structure that includes the following functional blocks and their components: a) key tasks (capabilities) of pedagogical technologies oriented to the goals and objectives of modern professional education and b) a didactic subsystem containing components that represent the integration of the corresponding components of the constituent technologies. Integrated components are formed based on technology differentiation into components and their integration. The managerial subsystem provides management of the technology itself and the learning and cognitive activity of students. The managerial subsystem contains conceptual principles, foundations and methods of learning management. The main purpose of integrating pedagogical technologies is to improve the quality and effectiveness of the pedagogical process, which is carried out based on the total realization of all pedagogical capabilities of the constituent technologies (Popov et al., 2021). Therefore, in integral pedagogical technology, first, the following should be maximally realized: differentiation, individualization and personal orientation of learning; activity and independence of students; and active and full use of computer tools. Integral technology includes all the best of its component technologies, motivates students, realizes differentiation and individualization of learning, and provides an opportunity to form individual trajectories of learning and development for students.

It is possible to substantiate the following conceptual provisions of integral technology: the integration of pedagogical technologies is an important condition for improving the effectiveness and quality of the pedagogical process in a professional school, and the design and implementation of managed integral pedagogical technologies allow us to create mechanisms for the sustainable and continuous self-managed development of a professional educational institution. The proposed models of flexible integral pedagogical technologies have been widely approved for use in the professional activities of several educational organizations.

5. Discussion

Computer-based training demonstrations are gradually becoming an important means of presenting information during lectures, when there is a spectacular opportunity to illustrate phenomena and various processes during the lecture with the help of flexible and visual computer dynamic models, with flexible control of the parameters of the models directly during the presentation of the material. According to a number of scientists, the combination of computer and television systems provides new rich didactic opportunities for lecturers to increase the effectiveness of lectures, especially since currently, the number of ready-made programs is constantly increasing. Some scientists emphasize that new information and communication technologies make it possible to put into practice the real integration of academic disciplines, to find points of contact between general and special disciplines and, thus, to realize the idea of interdisciplinary links. The conclusions of the cited scientists
confirm the results of the current study, particularly in terms of prioritizing the formation of visibility with the help of flexible and visual computer dynamic models with adaptive control.

In the innovative format, according to Pottle (2019), the emphasis in education should be on the methodological preparation of the student not only for each discipline but also on their integration using information and communication technologies. Scientists (Ekstrand et al., 2018; Kovalchuk et al., 2020; Oda et al., 2019) have pointed out that the recent development of computer equipment and technologies has led to important changes in the understanding of the role of information processes in the life of society and the possibilities of using computer tools in education.

It is obvious that the field of application of computer technologies in education is constantly expanding: from the use of computer and related information technologies as an object of study of the subject of informatics, the emphasis is shifted to its wide use as a means of intensifying the process of teaching general education disciplines. Andersen (2016), Chan & Zary (2019) and Haowen (2021) are convinced of this, emphasizing that the use of internet technologies in educational activities significantly increases the motivation of students to study and helps to more productively implement modern pedagogical technologies, such as personal-oriented training, project methods, the development of integrative approaches, and training in practice.

Modern researchers (Joo-Nagata et al., 2017; Kuehn, 2018; Barsom et al., 2016) believe that when studying certain topics, it is important to determine the form of educational activity that best corresponds to computer technologies: lectures, practical sessions, laboratories, seminar classes, independent work, control work, etc. In general, scientists offer a range of information and communication technologies that are used in the educational process:

1. Teachers read the lecture course.
2. Conducting practical and seminar classes.
3. The implementation of control checks of the knowledge and skills of students not only in class but also during examinations, defense of term papers and diploma theses, etc. When conducting knowledge control in the interdisciplinary orientation of education, interdisciplinary tests play a special role. The methodology of creating such tests should be based on the requirements of the relevant educational standard, which reveals the interdisciplinary nature of learning. Interdisciplinary tests are used to assess mastery of knowledge and skills and, in the case of difficulties, help to build or adjust the tactics of studying the discipline. The effectiveness of the organization lies in a special means of self-diagnosing knowledge and skills, presented in the form of an interdisciplinary test and allowing independent correction of the tactics of studying disciplines.
4. Traditional and network variants of scientific and methodical seminars are carried out with students and teachers in the educational system, as well as various kinds of conferences and exhibitions aimed at improving students' scientific and professional qualifications.
5. Independent study of training courses by students, as well as the use of distance learning methods, has become increasingly widespread in recent years. Learning computerization is an independent type of learning activity that has the greatest efficiency and effectiveness. This is all the more important because the modern trend of education is aimed at reducing the number of classroom classes and thus increasing the hours devoted to self-study. Both partial and full use of computer technology are possible in students' independent work.

The above conclusions of the scientists synergize with the results of the current study, while the effect of mutual complementarity is observed in terms of priority information and communication technologies for the modern educational environment.

A number of scientists (Zaderei et al., 2016; Sánchez-Cabero et al., 2019; Kirkman et al., 2014) single out pedagogical technologies that actively contribute to this, in particular:

1) a deepening of knowledge, consolidation of skills and abilities;
2) systematic training of actions with technological tools;
3) consolidation of socially significant forms and skills of behavior;
4) The development of technological thinking, the ability to algorithmize, and the ability to standardize cognitive activity.
Modern pedagogy defines such organizational stages of technologized learning:
1) analysis of the authentic activity of the student;
2) Determination of the content of learning at each stage of work;
3) Check the degree of students' workload and calculate the time necessary for learning;
4) Choose the most effective organizational forms of teaching and education;
5) Preparation of materials for motivation to learn;
6) Development of a system of training exercises based on the algorithm of the activity of the student.

Considering the integration of modern technologies in the pedagogical activity of a teacher of a higher school in the national educational space, with proposals regarding the selection of pedagogical technologies, it is possible to agree in a partial format based on the realities of the social environment of Ukraine today.
6. Conclusions

The integration of modern pedagogical information and communication technologies in the educational process can solve several problems, such as the transformation of the organization of the educational process of cognition due to its shift toward systemic thinking, the effective organization of the cognitive activity of students in the course of training, the need to form an open and accessible education system, the orientation of the educational process to the individual, and the improvement of the professional competence of students.

Virtual reality/augmented reality in immersive technologies are primarily tools that are used to achieve a specific set of learning outcomes. The need to introduce augmented and virtual reality technologies into the educational process is due to the widespread use of these new technologies in practice. From the above, the following conclusions can be drawn about the prospects for the use of virtual and augmented reality in education: motivating and ensuring the improvement of digital competencies of all participants in the educational process; simultaneous combination of practical and theoretical knowledge; the possibility of training students with a wide range of practical skills and abilities; and expansion of the methodological arsenal of scientific and pedagogical staff.

Ethical considerations

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Conflict of interest

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