




TRANSFORMATION OF DIGITAL INNOVATION IN EDUCATION IN THE POST-COVID ERA: AN EXPLORATION CENTERED ON DRONES AND VIRTUAL REALITY

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Abstract

The relevance of this study is underscored by the significant shifts in traditional methods of teaching software disciplines in the post-COVID era. The widespread adoption of remote learning and the integration of innovative technologies have necessitated a re-evaluation of educational practices. The purpose of this study is to explore the impact of modern innovative technologies on the effectiveness of education and the quality of learning in the post-COVID period. The primary method employed in this study was a survey, through which questions related to the use of drones and virtual reality (VR) technologies in the educational process were posed to students and educators. The results obtained during this study indicate a high level of acceptance by modern students and their educators of the role of drones and VR technologies in the educational environment of contemporary educational institutions. Participants in the surveys positively assessed the trends of transformation of innovative technologies in the educational environment, which applies to almost all groups of students and educators without exception, regardless of their specialties. Respondents highlighted multiple positive effects of integrating drones and VR technologies into the educational space of educational institutions, including a high level of comfort when using these technical devices, improvement in the perception of educational material, enhancement of the quality of mastering software disciplines. Both educators and students view the emerging prospects of practical use of drones and VR technologies in the educational space of educational institutions positively, particularly in the post-COVID period and beyond.

Keywords: Advanced Technical Solutions, Modern Technologies, Optimization of the Teaching Process, Remote Assessment, Systematic Learning



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INTRODUCTION

In the post-COVID era, conventional methods of teaching and learning are undergoing noteworthy challenges. The popularity of distance and blended learning requires the education sector to shift towards more engaging and interactive education (Kusuma, 2020; Suwarni, 2021; AL-Momani et

al., 2024). Digital innovations, such as drones and virtual reality (VR), seem to offer solutions to this challenge. However, the ways of effectively integrating these technologies into education and assessing their effectiveness are not fully explored, defining the problem of this scientific work as the need to explore real possibilities for studying the impact of digital technology transformations in education in the post-epidemiological period. This implies the search for new opportunities for the use of digital innovations in the modern education system to enhance student engagement in the educational process and improve the overall clarity of presenting the curriculum (Asmororini, Kinda, & Şen, 2023; Azis & Clefoto, 2024; Cadiz et al., 2024; Fernande, Sridharan, & Kuandee, 2024). In addition, the use of drones and VR technologies in the educational space of a modern educational institution opens up additional opportunities to increase the level of technological literacy of both students and teaching staff, which is very relevant in the era of global digital transformation of modern society. In this context, the working hypothesis of the study is the high degree of acceptance by teachers and students of modern educational institutions of drones and VR technologies as effective tools for improving the overall level of teaching software disciplines.

In the study by Thomas et al. (2021), which examines the possibilities of technological advancements in ensuring the development of digital innovations in various fields in the post-pandemic period, it is noted that digital technologies themselves are not a final solution but tools for solving specific problems. According to the authors, the application of drones and VR technologies for data collection and processing substantially enhances the efficiency of the educational process, providing evidence in favor of the idea of their refinement and use in the future. However, potential problems that may arise from the use of these systems were not addressed in the study.

Gong and Ribiere (2021) note that the processes of digital innovation transformation have become crucial in assessing the quality of changes in various aspects of modern society, one of which is the field of education. In the post-pandemic era, the popularity of distance learning technologies, particularly VR, has sharply increased, opening additional opportunities to enhance the overall level of modern education (Pavliuchenko, 2023; Bilyk, 2024). Nevertheless, the study does not illuminate the real benefits of the practical application of the considered technologies in organizing the educational process.

Moreover, Mora et al. (2021), in a study addressing issues of the accessibility of modern digital technologies and the prospects for their application in various areas of contemporary society, draw attention to the circumstance that the transformation of digital innovations in the education sector after the completion of the COVID-19 pandemic opens up broad opportunities for improving the existing education system. In particular, according to the researchers, the use of drones allows the exploration of terrains, obtaining crucial information that can be subsequently used in the exploration of various academic disciplines. However, this study does not address the issue of eliminating possible errors that may arise when using drones for data collection.

In the study by Schiopu et al. (2022), various problematic aspects of the practical application of drones and VR technologies in different sectors, including education and tourism, are considered. The opinion is expressed that the pandemic has had a noteworthy impact on these industries, leading to a decrease in the flow of clients for tourism companies and forcing educational institutions to switch to a distance learning system. In the post-pandemic conditions, the expansion of the scope of VR technologies and drones offers new opportunities in tourism and education, allowing an increase in the level of customer service for tourism firms and the quality of service in the education system (Tamar et al., 2023; Hysa, 2024; Zakiyah, Boonma, & Collado, 2024). Nonetheless, the study did not examine the expansion of these systems' prospects in education within the context of their interaction (Zhao & Wu, 2022; Suroso, Solaiman, & Fanani, 2023; Yohanie et al., 2023; Banali et al., 2024; Fitriana & Waswa, 2024).

Zhao et al. (2022) explored the issues of applying modern innovative advancements in digital education in the post-COVID era. Scientists draw attention to the fact that digital education in schools, utilizing artificial intelligence, big data technology, and VR, contributes to the enhancement of teaching effectiveness and promotes teaching progress. The opinion is expressed that the introduction of corresponding social responsibility into the values system of digital education will contribute to the sustainable development of the educational system as a whole, as well as the improvement of literacy across all segments of the population regarding the application of digital innovations. However, this study does not address the problematic issues of organizing the interaction of the considered technological innovations in their complex use.

Despite the growing recognition of the benefits of drones and VR technologies in education, there remains a significant gap in understanding how these innovations can be systematically integrated into diverse academic disciplines, particularly in the post-COVID era. Most existing studies have focused on the general advantages of digital technologies but have not thoroughly examined the specific educational contexts (Gopika and Rekha, 2023; Pela et al., 2023; Asrial et al., 2023; Asamoah et al., 2024; Asrial et al., 2024; Habibi, Jiyane, & Ozsen, 2024). Additionally, limited research has been conducted on the challenges educators face in adopting these technologies, such as the need for proper infrastructure, training, and pedagogical adjustments. This study aims to fill these gaps by exploring the practical applications of drones and VR technologies across multiple fields of study, assessing not only their immediate educational benefits but also the barriers to widespread implementation.

The purpose of this study is to examine the process of integrating VR technologies and drones into the educational system in the post-COVID era, including various aspects of their impact on increasing the overall effectiveness of the educational process.

RESEARCH METHOD

The research approach in this study is based on surveying students and teachers of an educational institution on various aspects of the application of drones and VR technologies in building the educational process. The theoretical foundation of this study consists of the results of several studies aimed at examining key aspects of the application of drones and VR technologies in various processes within the modern education system.

The survey method involved 752 Peking University students in their junior year undergoing training in various specialties. The data from these specialties were considered when processing the results obtained during the survey. A more detailed description of the students in the categories under consideration is presented in Table 1.

Table 1. Categories of students who participated in the survey

Specialty	Age and quantity	
	Men	Women
Information technology	72 (20.44±0.56)	55 (19.25±0.46)
Construction and architecture	68 (19.45±0.34)	50 (18.25±0.65)
Journalism	59 (20.12±0.52)	48 (19.65±0.35)
Agricultural industry	74 (20.21±0.44)	41 (19.22±0.56)
Mechanical engineering	69 (19.86±0.49)	60 (18.11±0.52)
Ecology	82 (19.56±0.62)	74 (18.98±0.35)
Total	424 (19.94±0.49)	328 (18.91±0.48)

Classes with students were held in the 1st semester of the 2022-2023 academic year; in total, there were 4 training scheduled classes using drones and 3 classes using VR technologies during the week for students of each specialty. Such models of flying drones as: Autel Evo Nano+, Autel Evo Lite+, DJI Phantom 4 Pro V2.0, DJI Mini 3 were used in the classes. During the classes on the study of VR technologies, head-mounted devices were used, while specially equipped laboratories of the university were used for conducting classes. The duration of each lesson using drones and VR technologies for each of the participants in the experiment was 2 academic hours. After the educational experiment was completed, students were asked to fill out a questionnaire to assess their level of perception of the practical application of drones and VR technologies in the educational process of the university. The results of the survey and the questions offered to students in the questionnaire are presented in Table 5. The survey participants were asked to use a 5-point rating system when answering questions. They completed several tasks using drones and VR technologies. A list of tasks of this kind is presented in Table 2.

Table 2. Tasks were proposed for the students and teachers who participated in the survey using drones and VR technologies

Specialty	The purpose of using drones	The purpose of using VR technologies
Information technology	Using various programming languages to calculate the trajectory of a drone	Cybersecurity, troubleshooting network problems, creation of virtual laboratories, new technologies
Construction and architecture	Aerial photography of construction sites, study of building structures, 3D modelling	Creation of virtual models of construction objects, creation of virtual presentations.
Journalism	Collecting news stories	Virtual editing, creation of virtual reports.
Agricultural industry	Overview of the agricultural area	Modelling the development of individual branches of agriculture
Mechanical engineering	Examination of design features of engineering facilities	Professional training remotely, remote design
Ecology	Aerial photography of natural landscapes	Building virtual models of natural objects and their examination, analysis of climate change

The survey conducted in this study was anonymized, ensuring that participants' identities were not disclosed, allowing them to provide honest and unbiased feedback. During the survey, students and teachers were asked to complete questionnaires for the appropriate forms. The survey results are presented in Tables 3 and 4. The survey was conducted after the students completed all the tasks set for them during the experiment. The survey results were processed using quantitative, statistical, and comparative analysis methods. Technology Acceptance Model was developed: To assess the acceptance of teachers and students towards this technology (1, 2):

$$U = \beta PEU + \beta 2PU, \tag{1}$$

$$BI = \beta 3U + \beta 4PEU + \beta 5PU, \tag{2}$$

where U – Usage Intention of educators and students to use VR and drones; PEU – Perceived Ease of Use of Technology; PU – Perceived Usefulness of Technology; BI – Behavioral Intention to Use; β – the extent to which each variable influences the outcome.

RESULTS AND DISCUSSION

For apparent age estimation, the ϵ -Error, also known as the Normal Score, serves as a crucial metric, providing a quantitative measure of predicted age accuracy relative to the ground truth. The average absolute error between estimated age and the chronological age of a person is the Mean Absolute Error (Rothe, 2015). The ideal value of MAE is ‘Zero’ but in real time it is not possible but a better model shows MAE near to ‘Zero’. The MAE is evaluate using eq. (4).

The coronavirus pandemic has largely determined the sequence of introduction and application of digital technologies in educational processes in the course of studying various disciplines and has also given rise to a rethink in the organization of education in general. Conventional learning models have prevailed for centuries, but they are characterized by certain limitations, and after the pandemic, they had to change substantially (Mutmainnah et al., 2023). The advent of VR and artificial intelligence technologies forces a change in approaches and methods of learning at different levels. Using digital resources brings substantial changes that can complement traditional learning to develop students' skills of independent orientation in the digital space and use various opportunities to improve their knowledge and skills (Lu et al., 2023; Zhu et al., 2023).

At the University of Beijing, during 1 academic semester, training sessions were conducted with students in junior year to analyze the effectiveness of the practical use of drones and VR technologies in teaching students of different specialties. After completion of all planned classes, a survey of students and teachers of this educational institution was conducted to understand the degree of satisfaction of the participants with the results of the sessions.

During the training sessions, models of flying drones, Autel Evo Nano+, Autel Evo Lite+, DJI Phantom 4 Pro V2.0, and DJI Mini 3 were used. Students of various specialties were invited to try out the skills of controlling drones and using them to obtain information about the condition of several ground objects, the examination of which was included in the curriculum plan. A specific description of

the goals and objectives provided for in drone classes for students of various specialties is presented in Table 2. A general view of the quadcopter Autel Evo Nano+ is shown in Figure 1.



Figure 1. Quadcopter Autel Evo Nano+

Quadcopters of this type are miniature but at the same time high-tech. Ease of control is ensured by the presence of an obstacle recognition system. The maximum flight range is 10 kilometers. The maximum battery capacity allows for continuous flight for 28 minutes, which is a record for quadcopters of this class. The maximum weight of the device is 250 grams, it is so miniature that it can fit in the palm of your hand. This model is equipped with a professional video camera containing light filters red, yellow, yellow, and blue (RYYB). The noise reduction system allows you to obtain high-quality images when shooting video in low-light conditions. The presence of an automatic focusing system makes it possible to shoot fast-moving objects while maintaining the necessary detail. Smooth video shooting is ensured by a built-in network stabilizer.

Classes using VR technologies were conducted with students in specially equipped laboratories using head-mounted devices. The tasks assigned to students during lessons using VR technologies are also presented in Table 2. According to the results of the classes, the participants were asked to take a survey. The results are presented in Table 3.

Table 3. A survey of students about their attitude to the use of drones and VR technologies in the educational process

Criteria and questions	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
PU	3.84±0.43	4.01±0.41	3.85±0.46	4.08±0.47	3.91±0.41	3.95±0.62
PU-1	3.85±0.45	4.02±0.46	3.65±0.34	3.78±0.35	3.98±0.68	3.97±0.11
PU-2	3.68±0.66	4.13±0.37	3.75±0.66	4.55±0.35	3.75±0.65	3.67±0.28
PU-3	4.05±0.55	3.95±0.45	3.96±0.37	3.98±0.44	4.03±0.47	4.04±0.48
PU-4	3.76±0.35	3.87±0.55	4.03±0.25	3.96±0.43	3.77±0.75	4.08±0.55
PEU	4.01±0.45	4.04±0.48	3.9±0.97	3.93±0.35	4.04±0.36	3.97±0.54
PEU-1	4.02±0.55	4.02±0.45	3.96±0.55	4.02±0.42	3.87±0.35	4.12±0.33
PEU-2	3.98±0.44	3.97±0.33	3.77±0.52	3.66±0.64	4.17±0.46	3.96±0.46
PEU-3	3.76±0.55	3.88±0.45	3.99±0.41	3.88±0.53	4.06±0.35	4.03±0.54
PEU-4	3.69±0.33	3.78±0.54	3.86±0.38	4.04±0.32	3.98±0.54	4.01±0.55
SE	3.93±0.59	4.02±0.55	3.92±0.56	3.99±0.28	3.87±0.56	3.97±0.45
SE-1	3.98±0.36	4.01±0.53	3.96±0.12	3.97±0.36	4.01±0.64	3.93±0.44
SE-2	3.76±0.62	3.98±0.45	3.88±0.35	3.95±0.62	3.99±0.55	4.02±0.36
SE-3	3.58±0.26	3.97±0.44	3.69±0.36	3.94±0.42	3.98±0.52	4.03±0.42
PS	3.96±0.42	3.95±0.43	3.92±0.44	3.98±0.46	3.87±0.55	4.12±0.45
0,55PS-1	3.95±0.65	3.91±0.42	3.94±0.56	3.97±0.45	3.69±0.45	3.76±0.55
PS-2	3.91±0.49	3.96±0.49	3.97±0.46	3.99±0.44	3.78±0.55	4.55±0.56
PS-3	4.05±0.48	4.06±0.52	4.07±0.62	4.04±0.44	4.09±0.59	3.89±0.69
PS-4	4.01±0.36	4.05±0.5	4.08±0.39	4.09±0.55	4.11±0.45	4.06±0.46
PCR	3.87±0.69	4.04±0.56	3.96±0.55	3.88±0.46	3.87±0.39	3.88±0.56
PCR-1	3.78±0.55	3.99±0.48	3.93±0.44	3.96±0.45	3.94±0.34	3.96±0.43

Criteria and questions	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
PCR-2	3.68±0.49	3.87±0.55	3.95±0.55	3.92±0.43	3.97±0.37	3.97±0.49
PINT	4.03±0.56	4.01±0.42	3.66±0.42	3.88±0.45	3.92±0.55	3.98±0.41
PINT-1	3.97±0.45	3.96±0.45	3.87±0.39	3.89±0.38	3.91±0.44	3.97±0.42
PINT-2	3.95±0.38	3.88±0.69	3.94±0.46	3.86±0.44	3.95±0.41	3.98±0.44
PINT-3	4.01±0.45	3.77±0.43	3.97±0.48	3.79±0.37	3.96±0.46	4.01±0.47
PINT-4	4.04±0.45	3.76±0.42	3.99±0.51	3.78±0.36	3.97±0.48	4.04±0.49
BI	4.01±0.56	4.04±0.45	3.96±0.53	3.98±0.52	3.88±0.46	3.89±0.48
BI-1	4.02±0.48	4.02±0.46	3.98±0.52	3.97±0.44	3.87±0.45	3.87±0.46
BI-2	3.99±0.37	4.06±0.52	4.01±0.46	3.96±0.47	3.85±0.44	3.85±0.49
BI-3	3.97±0.45	4.07±0.48	4.08±0.37	3.99±0.45	3.92±0.45	3.89±0.44

Note: PU – Perceived Usefulness; PEU – Perceived Ease of Use; SE – Satisfaction Evaluation; PS – Perceived Satisfaction; PCR – Perceived Cyber Risk; PINT – Personal Innovations in Technology; BI – Behavioral Intention.

The results of the conducted survey on the testing of the studied technologies in the educational process after the pedagogical experiment vividly demonstrate a high level of perception by students of different specialties, as well as the absence of substantial statistically significant differences in the perception rating of technologies among different groups of students. The experiment, involving the use of drones and VR technologies in the educational process for students of different specialties, clearly demonstrated the following aspects. First, there was virtually no statistically significant difference in the ratings of usefulness, simplicity, and a range of other factors among students of different specialties. Secondly, a positive perception of the use of drones and VR technologies in the educational process was identified among students of the specialties that participated in the conducted experiment (Lee et al., 2023; Szóstak et al., 2024).

To assess the overall effectiveness of the practical application of drones and VR technologies in the educational space of the educational institution, an author's questionnaire was developed to survey teachers about their experience using these tools. Based on the results of the conducted survey, it can be concluded that teachers, in general, positively perceive the integration of drones and VR technologies into the educational process. However, attention should be paid to the fact that certain aspects of implementing such technologies will need further improvement. The results of the survey are presented in Table 4. The results of the survey of students demonstrate that they positively assess the level of their comfort and interest shown in classes involving drones and VR. In addition, students indicate that the use of drones in the educational process contributes to the improvement of communication skills and team interaction skills in the learning space. Furthermore, the use of drones increases the level of theoretical knowledge and perception of practical scenarios. According to the performed statistical calculations, there was no substantial difference between the grades of students of different specialties.

Table 4. The results of a survey of teachers on the use of drones and VR technologies in teaching students of various specialties

	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
General perception and understanding	3.54±0.86	3.32±0.64	3.85±0.55	3.3±0.66	3.86±0.52	3.25±0.43
The degree of pedagogical influence	4.25±0.35	3.65±0.75	4.11±0.58	3.86±0.45	4.12±0.25	3.89±0.63
The effectiveness of using drones and VR technologies in the learning process (in relation to a specific specialty)	3.55±0.25	4.01±0.65	4.04±0.36	3.76±0.65	4.08±0.36	3.88±0.2
Opportunities to increase the level of	3.84±0.22	3.62±0.56	3.89±0.75	3.66±0.54	3.33±0.55	3.65±0.45

	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
perception of educational material through the use of drones and VR technologies						
Professional	3.73±0.45	3.68±0.56	3.64±0.75	3.86±0.25	3.66±0.42	3.77±0.52
development prospects						
The problems of introducing drones into the education system	3.87±0.55	3.78±0.62	3.86±0.44	3.67±0.39	3.65±0.44	3.44±0.33
Student engagement and improved communication between them	3.99±0.86	3.65±0.45	3.83±0.77	3.65±0.56	3.98±0.56	3.97±0.52
Features of the use of drones and VR technologies in the educational process of individual specialties	2.65±0.42	2.98±0.37	3.11±0.23	2.89±0.22	2.77±0.43	2.65±0.11
Updating and improving the practical application of drones and VR technologies in the educational process	2.29±0.21	2.33±0.25	2.68±0.37	2.58±0.44	2.65±0.37	2.88±0.45
Prospects for solving the problems of practical application of drones and VR technologies in the education system	2.86±0.2	2.99±0.32	2.66±0.44	2.99±0.62	3.02±0.54	2.88±0.33

The results of the survey conducted among teachers show that they positively assess aspects such as the use of drones and VR technologies in the modern education system. These aspects include the overall perception, the impact on the purely pedagogical nature of the educational process, the effectiveness of the practical application of the technologies in the learning process, the potential to enhance the success of studying a particular specialty, and the possibilities to improve the perception of the presented educational material through the use of drones and VR technologies. In addition, the survey highlights the qualitative impact on the level of professional development of students, their engagement in the learning process, and interaction with students. However, teachers gave a relatively low assessment of the prospects for the practical application of drones and VR technologies in the educational process of certain specialties (Özacar et al., 2023; Lu et al., 2024).

Table 5 presents the survey results of the experiment participants regarding specific aspects of the application of drones and VR technologies in the university’s educational space. Respondents were asked to answer questions using a 5-point rating scale (1 – lowest score, 5 – highest score). As indicated by the data presented in Table 5, students who participated in the experiment highly evaluated various aspects of the use of drones and VR technologies in the educational space of a modern educational institution. In particular, students from all 6 specialties rated the comfort level of operating a drone during a study session ranging from 3.56 to 4.05 on average. The level of interest in learning about the properties and capabilities of drones was assessed by the experiment participants in the range of 3.72 to 4.04 points. Agreement among the participants that the use of drones and VR technologies contributes to better assimilation of the educational material was recorded in the assessment range of 3.56 to 4.04 points. The advantages of employing these technologies in educational sessions over conventional

methods of delivering material were rated slightly lower, ranging from 3.45 to 4.01 points on average. The aspect of stimulating classes with drones and VR technologies to enhance group efficiency and assimilation of educational material was rated in a slightly broader range, from 3.45 to 4.04 points. The practical effectiveness of conducting classes with the use of drones and VR technologies was rated by students in the range of 3.55 to 4.05 points. Questions regarding stimulating students' interest in studying other program disciplines through the use of drones and VR technologies in the educational process of the institution were assessed in the range of 3.65 to 4.11 points. When asked about their opinion on how much conducting practical sessions with drones and VR technologies contributes to a better understanding of theoretical knowledge in a practical dimension, students responded on average in the range of 3.64 to 4.04.

Table 5. A survey of students on certain aspects of the use of drones and VR technologies in the educational process

Questions	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
Were you comfortable flying the drone during the class?	3.56±0.45	3.77±0.26	3.88±0.35	4.05±0.55	3.89±0.25	4.01±0.65
How interested were you in studying the properties and capabilities of drones?	3.78±0.45	4.04±0.25	3.85±0.65	3.76±0.28	4.02±0.36	3.72±0.45
Do you agree that the use of drones and VR technologies in the educational process helps to improve the perception of program material?	3.56±0.25	3.78±0.56	4.04±0.36	3.88±0.65	3.98±0.45	3.96±0.55
Do you think classes using drones and VR technologies have advantages over conventional presentation of the material?	3.45±0.68	3.45±0.58	3.55±0.65	3.98±0.65	3.99±0.65	4.01±0.28
Do classes using drones and VR technologies stimulate an increase in group effectiveness and the assimilation of program material?	3.45±0.66	3.68±0.85	3.65±0.45	4.05±0.52	3.89±0.55	3.92±0.45
How effective, in your opinion, are classes using drones and VR technologies in practical terms?	3.55±0.42	3.65±0.64	3.78±0.55	3.75±0.44	4.02±0.33	4.05±0.55
Do you think that conducting training sessions using drones and VR technologies stimulates students' interest in studying software disciplines?	3.65±0.65	3.77±0.45	3.89±0.26	4.11±0.38	3.88±0.55	3.75±0.25
Does conducting	3.64±0.45	3.88±0.62	4.04±0.35	3.86±0.25	3.99±0.35	3.79±0.42

Questions	IT	Journalism	Construction and architecture	Agricultural industry	Mechanical engineering	Ecology
practical classes using drones and VR technologies contribute to the better assimilation of theoretical knowledge in a practical plane?						

Thus, the practical benefits of using drones and VR technologies in the educational space of a modern educational institution were rated quite highly by experiment participants. This should be considered in the future when organizing sessions using these technologies in educational institutions with students from different faculties and specialties. According to the Technology Acceptance Model, the degree of user intention of teachers and students to use VR technologies and drones in the educational process is equation (1):

$$U = \beta_{PEU} + \beta_{2PU} = 0.35 \times 3.98 + 0.35 \times 2 \times 3.94 = 4.15 \quad (1)$$

Behavioral intention to use equation (2):

$$BI = \beta_{3U} + \beta_{4PEU} + \beta_{5PU} = 0.35 \times 3 \times 4.15 + 0.35 \times 4 \times 3.98 + 0.35 \times 2 \times 3.94 = 12.68 \quad (2)$$

Students' high assessment of the practical effectiveness of using drones and VR technologies indicates a significant optimization of the educational process through the use of these technologies. According to students, the use of these technologies during training sessions helps to increase the level of involvement in the educational process, which ensures the achievement of a high level of mastery of program disciplines. Optimization of the educational process when using technologies of the type under consideration is achieved due to such properties as a high degree of mobility of the received educational information and completion of tasks, increased motivation of students for learning of this type, giving the educational process an individual focus, increasing the visibility of educational materials, prompt feedback between the teacher and students, as well as the ability for students to get instant access to the results of their completed assignments.

The use of drones and VR in education makes it possible to improve the quality of user experience when studying software disciplines (Chen et al., 2023; Unal et al., 2020). 2 different tracking methods are effective: vision-based and GPS-based. These techniques are used to combine drone images with computer-generated 3D models.

The practical implications of the results for education indicate that the integration of drones and VR technologies can significantly enhance the learning experience by increasing student engagement, improving the assimilation of complex concepts, and providing hands-on experience with cutting-edge tools (Kravtsov et al., 2020). These technologies offer unique opportunities to simulate real-world scenarios, which is particularly beneficial in fields such as engineering, architecture, and agriculture, where practical application of knowledge is critical. By making learning more interactive and immersive, drones and VR can bridge the gap between theoretical knowledge and practical skills, fostering better understanding and retention of course material. Furthermore, the study highlights the potential for these technologies to enhance communication and collaboration among students, as well as improve problem-solving skills in group settings.

The study's findings show that students and educators from different specializations have a high level of acceptance and a favorable opinion of drone and VR technologies. Using these tools in the classroom has been found to improve comfort, engagement, and learning quality, according to survey participants. Students from a variety of disciplines, including mechanical engineering, agriculture, and information technology, all expressed a generally favorable experience, and there were no appreciable variations between the groups when it came to how beneficial and simple these technologies were to use. Teachers recognized the potential of drones and VR to improve learning outcomes, as well as the pedagogical benefits. However, they also pointed out areas that needed improvement, especially in the

methodological framework and technological support. The post-COVID era's overall efficacy in education was thought to be enhanced by the incorporation of these digital advances, which were seen to improve the practical application of theoretical knowledge, boost student motivation, and optimize the educational process (Suryani et al., 2024).

In the course of this study, results were obtained indicating that teachers and students from the educational institutions surveyed regarding the prospects of using drones and VR technologies positively assess these prospects and generally approve the integration of such technologies into the educational process. Students from various specialties had a positive attitude toward the application of such technologies in the educational environment of the educational institution in the future.

Dong et al. (2022) explored the main areas of development of online education platforms in the post-pandemic era, and noted that in the conditions of the digital economy, the current transformation of the education sector towards the informatization of education, quality education, and professional education can become the flagship of a new era. The conclusion was formulated that, to meet various needs of future society in talents and address the issue of social employment, the development of VR technologies is necessary, as the most progressive digital innovations in the modern education system. The conclusion expressed in the study aligns with the results obtained in this paper, as it emphasizes the need for the transformation of digital technologies in education, serving as a driver of progress in this field.

Moreover, in the study of Nermend et al. (2022), a wide range of problematic aspects of evaluating the decision to change the paradigm in the system of modern education through digital transformation were considered. It was noted that technological transformation, with the introduction of drones and VR technologies, has become one of the key goals of modern educational institutions in recent years. The conclusion was drawn about the final decision on the stated problem, as the world is in a stage of transformation primarily due to digital development and diversification. Higher education is also transforming due to the forced change of methodological approaches and requires an evaluation of decision-making criteria, taking into account the realities of the ongoing process and its justification (Titova et al., 2021; Nestulya & Shara, 2023; Karuku, 2023; Mariesi, Vakili, & Chalabi, 2023). Such conclusions appear controversial, as digital development and diversification are not the only nor primary driving factors of the transformation of today's surrounding world.

In the study by Hussain (2021), a series of issues related to the paradigm of technological convergence and digital transformation in the context of creating a structure based on sustainability principles after the COVID-19 pandemic were discussed. The author noted that, during the global pandemic, special attention was given to the development of remote communication platforms, widely used in the field of education. According to the study, innovations in the implementation of cutting-edge educational technologies have a substantial impact on real business process changes in various sectors. The conclusion was drawn that, in the context of the development of digital transformations in modern society, there will be further improvement of education system technologies based on digital innovations. Such conclusions require appropriate verification over time, as the consequences of digital transformations in contemporary society are fully unpredictable.

In turn, Allal-Cherif (2022), in a study aimed at exploring the principles of using augmented reality, VR, and artificial intelligence in various fields, including education, emphasizes that the COVID-19 pandemic has greatly complicated communication, making it necessary to introduce new technologies for data transmission. The researcher concludes that the application of VR technologies in various areas of life has a great future, as it opens up new possibilities for communication between individuals and the transmission of information over long distances, which has significant prospects when used in the modern education system. The researcher's conclusions generally align with the results obtained in this study, despite the fact that the improvement of the information transmission process at a distance through VR technologies is still unpredictable and may lead to numerous discoveries and innovations.

A broad range of problematic aspects of sustainable technological and innovative development in the post-COVID-19 pandemic period is discussed in the study by Bortoló et al. (2023). The opinion is expressed that the pandemic has contributed to the evolution of big data processing technologies and innovations in the digitization sphere. The researchers note that tracking key trends in the development of this process will contribute to the discovery of additional opportunities for studying the prospects of applying VR technologies in education and other areas. The authors' opinion coincides with the results obtained in this study since the process of transforming digital innovations in education is closely

related to new opportunities that arise when using VR technologies at all stages of the educational process.

Varadarajan et al. (2022) examined the principles of implementing digital innovations in various areas of modern life. The authors noted that over the past few decades, technological innovations based on the application of digital technologies have firmly established themselves in everyday life. VR technologies are particularly effective in the educational sphere, as they open up new possibilities for data demonstration, while the use of drones contributes to expanding the possibilities of collecting this data (Symonenko et al., 2020; Aviv et al., 2021). This opinion fully corresponds to the results presented in this study, as it reflects the interrelation of VR technologies and the use of drones in organizing the educational process of educational institutions.

de la Peña et al. (2022) examined current trends in the modern education system. According to the researchers, to ensure universal education on a solid scientific basis, it is necessary to meet the needs of the industry and adapt content, methodologies, and tools to the continuous social and technological changes of the present time. Among such changes is the gradual integration of VR technologies into education, as well as a range of other technologies that provide opportunities for effectively addressing a wide range of educational tasks. Such an opinion corresponds to the results of this study, but it requires clarification, as universal education implies a harmonious combination of VR technologies with other methods of conducting classes.

Zhang et al. (2023) considered a complex of problematic aspects related to expanding data based on modelling the virtual electromagnetic environment for drone signal identification when used in the modern education system. It was noted that the efficiency of using drones to obtain various types of data is due to the fact that drones operate in unlicensed frequency ranges, where there are many devices operating on the same frequency. This poses a serious problem for conventional methods of signal identification. In such scenarios, due to the complexity and significant dynamics of the electromagnetic environment, a large volume of data is required for reliable neural network identification of drones, reflecting various conditions of drone signal propagation. This, in turn, is substantial for using such devices to implement educational programs. Figure 2 shows a block diagram of a drone identification algorithm for its use in a modern education system.

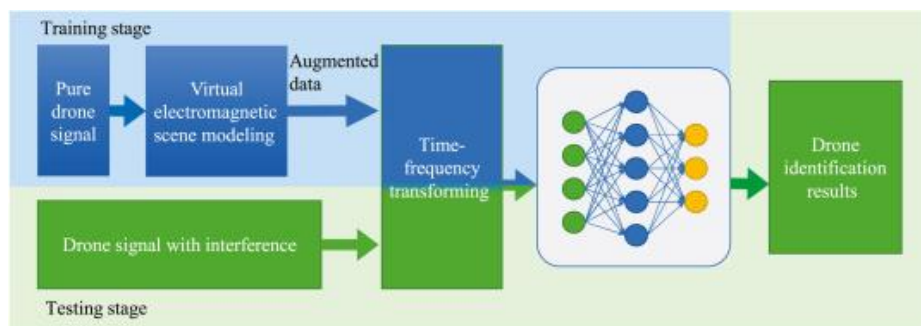


Figure 2. Drone identification algorithm flowchart

Source: Zhang et al. (2023).

On their part, Luo et al. (2023) addressed a range of problematic aspects related to the development of VR to support dissertation writing meetings, using the example of a Sino-British international college in China. The researchers highlight that the outbreak of the pandemic necessitated the implementation of remote synchronous interaction for supervising research, requiring the application of new and more modern technological solutions. According to the authors, VR technologies provide such an opportunity as they optimally meet the requirements for sessions set by both educators and students. This opinion is supported by the results obtained in this study, as it reflects the interrelation among all participants in the educational process when implementing VR technologies (Fraune et al., 2021; Németh et al., 2022).

Figure 3 shows a model for conducting training sessions in different rooms with the participation of a teacher and a student. The lesson is conducted using VR technologies, which allows the teacher to control the educational process without direct contact with the student.



Figure 3. Teacher and student in different rooms during the educational process

Source: Luo et al. (2023).

In light of the data results obtained, it is evident that the use of drones and VR technologies in the educational process was positively received by both students and teachers. This finding is consistent with previous studies, such as Hussain (2021) and Dong et al. (2022), which emphasized the transformative potential of digital tools in enhancing student engagement and learning outcomes. The novelty of this study lies in its focus on the practical application of these technologies across multiple disciplines, offering a broader understanding of their versatility in education. However, the study has several limitations. The sample size, limited to a single institution, may reduce the generalizability of the findings, and the short-term nature of the data collection does not allow for conclusions regarding the long-term impact of these technologies on learning retention and performance. Additionally, reliance on self-reported data may introduce biases, as individual experiences with technology can vary significantly. Despite these limitations, the implications of the findings are significant. The integration of drones and VR technologies has the potential to revolutionize the educational landscape, offering immersive learning experiences that bridge the gap between theoretical knowledge and practical skills. It is recommended that further studies expand on this work by exploring long-term impacts and including a wider range of institutions to validate these findings across different educational environments. Moreover, the development of a robust technological and methodological framework is essential for the seamless incorporation of these innovations into mainstream education.

CONCLUSION

The study established that the integration of VR and drone technologies into the educational process of modern educational institutions has a positive effect. Regardless of specific specialties, students equally assessed their effectiveness in the learning process. The use of VR technologies allows students to better understand the interconnection of complex concepts in the subjects they study, providing numerous opportunities to examine various phenomena from different perspectives. This creates conditions that are closer to real-world practical scenarios, enabling a deeper understanding of the nuances of the study material and the educational process as a whole. This contributes to increasing students' interest in the learning process, making it engaging, expanding their opportunities to develop various skills and practical abilities, and leading to a better understanding of the essence of their future profession. In the post-COVID-19 era, such skills become increasingly important for preparing future professionals and are required to enhance their professionalism. In addition, this contributes to increasing the level of digital literacy among students and educators and their ability to apply various technologies in their future professional activities.

The results of the study are a vivid demonstration of the universality of the practical application of drones and VR technologies in the educational space of modern educational institutions. Improving the quality of practical experience in observing specific phenomena, developing architectural projects, and many other advantages contribute to the effectiveness of students' acquisition of practical skills, which will be needed in their future professional activities. The student survey clearly demonstrates their positive attitude towards the use of drones in the educational process, as well as a high assessment of the real effectiveness of the application of these technological solutions in education. The survey results from teachers show a similar attitude; however, they strive to make improvements in the methodological base, technological support, and other components of the educational process.

It is recommended that teachers incorporate these technologies into educational sessions to boost student engagement and clarify challenging concepts. This study offers a valuable foundation for policymakers and researchers to assess and further develop the use of innovative digital tools in education. The prospects for further related studies are determined by the possibility of their use in the implementation of new, more advanced VR technologies and various digital innovations in the educational space of modern educational institutions, with the aim of raising the overall level of the education system.

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AUTHOR CONTRIBUTIONS

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CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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