KAPITEL 4 / *CHAPTER 4* [4]
PRACTICE OF ARTIFICIALLY CONTROLLED ENVIRONMENT AT THE PHYSICAL EDUCATION PROCESS OF HIGHER EDUCATION STUDENTS

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Introduction.

The 21st century has ushered in a profound transformation across global educational systems, driven by an unprecedented pace of technological advancement and widespread digitalization. This imperative for modernization extends significantly into physical education within higher education institutions (HEIs), where traditional pedagogical approaches are challenged to meet contemporary demands for personalized, accessible, and engaging learning experiences. In response, the concept of an Artificially Controlled Environment (ACE) has emerged as a pivotal solution, fundamentally redefining the educational process by integrating intelligent platforms, adaptive training systems, and real-time monitoring devices to foster individualized physical development.

The urgency and relevance of implementing ACE are acutely felt within the Ukrainian educational landscape. HEIs here operate under immense pressure from geopolitical challenges, including ongoing martial law, which necessitates robust solutions for ensuring educational continuity and flexibility. Moreover, the enduring effects of the global pandemic have solidified the need for effective distance and blended learning modalities. In this complex and dynamic environment, ACE is not merely an innovation but a vital tool for ensuring that physical education remains accessible, impactful, and aligned with the critical needs of students navigating unpredictable circumstances.

The operational foundation of ACE rests upon a sophisticated integration of diverse digital components. This includes the widespread use of mobile applications and fitness gadgets for personalized tracking of activity and progress, empowering

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students with self-monitoring capabilities. Interactive platforms and video lessons serve as the backbone for structured synchronous and asynchronous learning, facilitating virtual instruction. Crucially, Virtual and Augmented Reality (VR/AR) technologies introduce immersive training experiences, allowing for the simulation of sports scenarios and skill practice in controlled digital environments. Complementary to these, online physical activity diaries centralize data collection, enabling comprehensive analysis for tailored feedback and program adjustments.

The value proposition of ACE in physical education is multifaceted, offering unparalleled personalization by adapting training programs to individual needs, and significantly boosting student motivation and engagement through interactive and gamified elements. ACE facilitates objective and continuous monitoring of physical activity, providing data-driven insights for timely pedagogical interventions. However, the implementation is not without its complexities. It faces internal weaknesses such as a high dependence on technical equipment and a need for student self-discipline, alongside external threats like economic constraints, cybersecurity risks, and instability under martial law. The integration also necessitates specialized faculty training and addresses resistance to change, highlighting the need for strategic management.

This chapter aims to provide a comprehensive and rigorous analysis of the implementation of Artificially Controlled Environments in physical education within Ukrainian higher education institutions. Drawing upon a synthesis of current research and strategic frameworks, it seeks to delineate the intricate interplay of influencing factors, evaluate the system's inherent capabilities and limitations, and assess the feasibility of its objectives. Ultimately, this exploration endeavors to offer actionable insights and potential strategies for optimizing ACE integration, thereby contributing to the modernization and resilience of physical education in Ukraine's dynamic educational landscape.

4.1. Artificially controlled environment at physical education: main components and their functionality

The current stage of education development in Ukraine, marked by the challenges of digitalization, the spread of distance learning and the conditions of martial law, necessitates a radical transformation of the process of physical education in higher education institutions. In response to these realities, active modernization is taking place, the central element of which is the integration of technologies that form an artificially controlled environment (ACE) (Figure 1).

Figure 1. Distribution of keywords of information sources by research topic

An artificially controlled environment (ACE) in the context of physical education in higher education institutions is defined as a holistic, technologically rich and interactive system designed for optimal management and personalization of physical activity of higher education students. Its main goal is to ensure effective management of students' physical activity, adaptation to their individual needs and provision of prompt feedback, regardless of physical or geographical limitations. This environment allows maintaining continuity and high quality of the educational process even in difficult and non-standard conditions (Table 1).

Table 1 - Comparative analyze of artificially controlled environment components

Characteristic	Mobile Applications & Fitness Gadgets	Interactive Platforms & Video Lessons	Virtual & Augmented Reality (VR/AR)	Online Physical Activity Diaries
Primary Function	Collecting objective data on physical activity, monitoring health indicators.	Creating a virtual learning space, conducting classes, sharing materials.	Immersing or overlaying virtual objects for simulation, training, rehabilitation.	Collecting and analyzing individual data on workouts, well-being, nutrition.
Examples	Strava, MyFitnessPal, Apple Watch, Fitbit.	Zoom, Google Meet, Moodle, Microsoft Teams, YouTube.	VR headsets for sports simulators, AR apps for virtual trainers.	Google Forms, specialized modules on university platforms, web-based workout logging services.
Role in "Control"	Enable personalized control through data; allow instructors to remotely adapt assignments.	Create a structured space for monitoring presence/activity; ensure standardized delivery of content.	Create an immersive, controlled environment for skill practice; allow adaptation of simulation parameters.	Are a central element for monitoring progress; enable instructors to continuously adjust the learning process.
Impact on Student	Increased motivation for independent practice, self-monitoring of progress.	Ensured access to learning, structured information reception.	Enhanced engagement and motivation through novelty and interactivity, safe practice of complex movements.	Fosters self-analysis, discipline, awareness of personal development dynamics, personalization of the program.
Key Link to ACE	Source of objective data for personalization and analysis.	Foundation for remote organization and methodological provision.	Creation of a controlled virtual space for imitation and training.	Means of progress monitoring and feedback for adaptation.
Benefits for Instructor	Remote monitoring, program adaptation, objective data.	Class organization, centralized communication, material standardization.	Ability to model complex situations, increased student motivation, data collection on interaction.	Continuous monitoring, individual correction, progress tracking, adaptation for special groups.
Challenges / Limitations	Data accuracy, need for student self-discipline, gadget cost.	Technical requirements, internet stability, maintaining attention remotely.	High equipment cost, potential physical/psychological impact, need for specialized content.	Requires diligent student input, subjectivity of well-being data.

The effectiveness of the Physical Education System is ensured by the interaction of a number of key technological components, each of which performs specific functions and has a significant impact on the quality of physical education.

Mobile applications and fitness gadgets. These technologies are a fundamental component of the Physical Education System, as they form a personalized managed environment by collecting and analyzing objective quantitative data on the student's physical condition and activity. Fitness gadgets automatically record key indicators, such as the number of steps, calories burned, heart rate, sleep quality, and GPS tracking of motor activity. Mobile applications, in turn, analyze this data, provide instant feedback through visualization of progress, and offer individual training programs or reminders. Such integration allows the teacher to remotely monitor student activity, promptly adapt tasks and provide personalized recommendations based on real data, which significantly increases motivation for independent study.

Interactive platforms and video lessons. These components create a virtual learning space and provide a methodological basis for the SCS. Interactive platforms (such as ZOOM, Google Meet, Moodle) serve as a means for conducting synchronous and asynchronous classes, exchanging educational materials, organizing testing and effective communication between participants in the educational process. Video lessons are a critically important element, as they allow you to demonstrate the technique of performing exercises, conduct training in recording or in real time, and also provide detailed methodological recommendations. These elements provide the structure and consistency of the educational process in a remote format, allowing the teacher to monitor the presence, activity of students, provide individual tasks and check their completion, as well as standardize the presentation of material and provide the necessary visual component of training.

Virtual and augmented reality (VR/AR). Virtual (VR) and augmented (AR) reality technologies provide immersive and engaging guided environments that significantly increase student engagement and motivation for physical activity. VR immerses the user in a fully simulated virtual environment where sports games, training, or rehabilitation exercises can be simulated, allowing for safe practice of complex motor

skills and simulated competitive situations. AR, by overlaying virtual objects on the real world, allows for interaction with them, such as providing a virtual trainer or real-world markings. These capabilities are particularly valuable for rehabilitation programs or high-precision training, and the instructor can control the parameters of the virtual environment and receive detailed data on the student's interaction with it.

Online physical activity diaries. Digital online diaries are a central element for collecting and analyzing individual student data, often integrating with mobile applications or web platforms. In them, students record their training, well-being indicators, nutrition and other data related to physical activity. These tools allow the teacher to constantly monitor the dynamics of physical development and promptly adjust the educational process. They provide personalized feedback and help adapt programs, especially for students of special medical groups, which is an integral element of an innovative strategy for ensuring the quality of physical training in the face of modern challenges.

The successful functioning of the Artificially Controlled Environment in the physical education of students of higher education institutions largely depends on the interaction of numerous internal and external factors. This system, designed to personalize and optimize the training process using modern technologies, has significant potential. However, its full implementation requires a deep understanding of both its inherent advantages and disadvantages, as well as the influence of the broader educational, social and economic context.

Internal factors include the inherent characteristics of the ACE and the resource capabilities of the educational institution. Its strengths include a high level of personalization of programs that adapt to the individual needs of students through the use of mobile applications and fitness gadgets. This provides effective monitoring of progress, increases motivation and makes physical education flexible and accessible. At the same time, internal weaknesses include significant dependence on technical equipment and infrastructure, high implementation costs, the need for qualified teachers, and a high level of student self-discipline, without which the system may be ineffective. Internal factors are elements under the direct or indirect control of the HEI

(Higher Education Institution) and/or directly related to the design and functioning of the ACE (Artificially Controlled Environment) (Table 2).

Table 2 - Internal factors influencing the functioning of the Artificially Controlled Environment in physical education of students of higher education institutions

Specific Aspect	Impact on ACE (Description)	Examples of ACE Components/ Activities	Strategic Impact
Personalization and Adaptability	ACE allows for deep adaptation of training programs to individual needs, fitness levels, and health status of students	Mobile apps, fitness gadgets, online diaries, AI-algorithms for program adaptation	Increased individual effectiveness, reduced risks, increased student satisfaction
Measurability and Monitoring	Systematic collection of objective data ensures constant monitoring of progress and the possibility of prompt process adjustment	Heart rate sensors, GPS trackers, automatic activity logging, analytical dashboards for instructors	Justified decisions, rational use of resources, timely correction
Flexibility and Accessibility	Ensures continuity of physical education regardless of physical location and time, which is critical in conditions of distance learning and instability	Cloud platforms, online services, 24/7 availability, synchronous and asynchronous classes	Preservation of educational quality in crisis conditions, expanded reach, inclusiveness
Increased Motivation and Engagement	Interactive elements, gamification, visualization of achievements, and VR/AR make classes more attractive and dynamic	Virtual competitions, reward systems, VR sports simulators, AR enhancements for training	Increased activity, reduced dropout rates, formation of a positive attitude towards physical education
Objectivity and Data Quality	Automated collection of quantitative data provides a reliable basis for analyzing effectiveness and making decisions; video lessons standardize methodology	Automatic trackers, structured databases, high-quality methodological video materials	Increased reliability of assessments, unification of educational materials, process transparency
Resource Costs	Significant initial investments in equipment procurement, software development/licensing, and infrastructure creation	Procurement of VR helmets, servers, licenses for specialized platforms, development of unique content	Limited scalability, financial burden on the HEI budget, dependence on external financing

Specific Aspect	Impact on ACE (Description)	Examples of ACE Components/ Activities	Strategic Impact
Dependence on Technological Infrastructure	Necessity of stable high-speed internet access and compatible devices for all students	Home internet, Wi-Fi quality in dormitories, availability of smartphones/PCs for students, their relevance	Creation of "digital inequality" among students, disruptions in the educational process due to technical problems
Staff Qualification	Physical education instructors require special training and professional development for effective use and administration of ACE	Training on software use, VR/AR courses in education, training in fitness tracker data analysis	Need for additional training costs, potential resistance to change, reduced ACE effectiveness due to incompetence
Need for Student Self-Discipline	The success of ACE largely depends on the level of self-organization and internal motivation of students for regular independent studies	Lack of direct teacher control during independent study, procrastination, low level of responsibility	Decreased overall program effectiveness, low engagement of individual students
Quality/Subjectivity of Certain Data	Some indicators (e.g., well-being, fatigue level) can be subjective; data accuracy from various gadgets may vary	Data from well-being questionnaires, uncertified/uncalibrated fitness trackers, user errors	Potential erroneous conclusions, need for additional verification, limitations in decision-making
Potential Reduction in "Live" Communication	Excessive technological mediation can reduce direct social interaction between participants in the educational process	Limitations of group games, lack of direct emotional contact, social isolation	Impact on the formation of social skills, teamwork, and emotional well-being of students

External factors create opportunities that can accelerate the development and implementation of ACE. These include the global trend towards digitalization of education, which makes technological solutions increasingly integrated into the educational process. The spread of distance learning, especially in wartime conditions, emphasizes the relevance of ACE as a means of ensuring the continuity of education. The continuous development of technologies, such as artificial intelligence and virtual/augmented reality, opens up new horizons for improving the functionality of the system, and the growing public awareness of the importance of health increases the demand for innovative methods of physical education (Table 3).

Table 3 - External factors influencing the functioning of the Artificially Controlled Environment in physical education of students of higher education institutions

Specific Aspect	Impact on ACE (Description)	Examples of ACE Components/ Activities	Strategic Impact
Trends in Education Digitalization	The global and national trend towards integrating digital technologies into the educational process creates a favorable environment for ACE	State programs "State in a smartphone," "Digital education," HEI adaptation to online formats	Creation of a favorable environment for innovation, facilitation of ACE integration and adoption
Proliferation of Distance Learning	The growing need for distance and hybrid educational forms (especially under martial law) makes ACE a vital tool	Introduction of distance learning in schools and universities due to the pandemic and military actions	Increased relevance and demand for ACE solutions, justification of investments in technology
Technological Progress (AI, VR/AR)	Rapid development of new technologies constantly opens up opportunities for improving ACE functionality, creating more immersive and adaptive solutions	Appearance of new AI trainers, more accessible VR devices, development of new sports trackers	Expansion of ACE capabilities, increased efficiency, competitive advantages
Growing Awareness of Health Importance	Public demand for a healthy lifestyle, physical activity, and disease prevention contributes to the development of ACE as an innovative approach	Growing popularity of fitness clubs, health applications, increased attention to preventive medicine	Increased student interest in physical education, support from parents and society
State Support and Grants	Opportunity to receive funding and participate in national/international programs for education and sports infrastructure modernization	National digitalization projects, grants from international funds for the development of educational innovations	Additional sources of financing, reduced burden on the HEI budget
Globalization of Educational Services	Successful implementation of ACE can increase the attractiveness of HEIs for foreign students and contribute to integration into the international educational space	Cooperation with foreign universities, exchange of experience, participation in international scientific projects	Increased prestige of the HEI, expansion of the partner network
Instability and Security Challenges	Martial law, power outages, internet disruptions, and the need for displacement complicate the uninterrupted functioning of ACE	Military actions, power outages, infrastructure damage, forced migration of the population	Interruption of the educational process, inability to fully use online resources, logistical difficulties
Cybersecurity	Storing and processing large	Hacker attacks on	Loss of student and

Specific Aspect	Impact on ACE (Description)	Examples of ACE Components/ Activities	Strategic Impact
Risks	volumes of personal student data in ACE creates threats of leakage, unauthorized access, and cyberattacks	educational systems, phishing, leakage of user data from online services	parent trust, legal consequences, financial losses from cyber incidents
Economic Constraints	Budget deficits in the state and HEIs can hinder full funding of ACE implementation, support, and scaling	Reduced state funding for education, inflation, decline in HEI solvency	Insufficient equipment updates, outdated software, inability to expand ACE functionality
Resistance to Change	Conservatism of some instructors who are not ready to master new technologies, as well as resistance from students or parents	Instructors' refusal to use new platforms, low student engagement due to unwillingness to adapt	Sabotage or low implementation effectiveness, slowdown in ACE development rates
Legal and Ethical Imbalances	Lack of clear regulatory norms regarding the collection/use of personal data and ethical aspects of constant monitoring	Uncertainty regarding the confidentiality of fitness tracker data, issues of student privacy control	Legal risks, ethical conflicts, need for rapid policy development
Technological Inequality	Unequal access to modern technologies and stable internet among students (especially from regions with limited access or low socioeconomic status)	Lack of personal computer/smartphone, expensive internet, living in remote areas	Creation of academic inequality, limitation of ACE coverage, social exclusion

However, the external environment also carries certain threats that can restrain or complicate the functioning of ACE. These include the unstable situation under martial law, which can lead to disruptions in infrastructure and communications. There are also serious cybersecurity risks associated with the protection of students' personal data. Insufficient funding for education and potential resistance to change from conservative academics or students themselves can be significant obstacles. In addition, the problem of technological inequality among students can deepen the gap in access to quality education through ACE.

The functioning of an ACE in the physical education of higher education students is determined by a complex interplay of internal advantages and limitations with external opportunities and threats. The inherent strengths of ACE, such as a high degree of personalization, flexibility, and accessibility, along with its capacity for objective monitoring and increased motivation, establish a strong foundation for an innovative

and effective educational process. However, these benefits are somewhat offset by internal weaknesses, including high resource costs, dependence on technological infrastructure, the need for qualified staff, and the requirement for high student self-discipline, which can limit the system's full potential.

At the same time, the external environment presents significant opportunities for ACE's development, such as the global trend towards digitalization of education and the widespread adoption of distance learning, making this system highly relevant. Technological advancements in AI and VR/AR constantly open new prospects, and the growing public awareness of the importance of health creates favorable demand. Nevertheless, there are also serious threats, including instability in the context of martial law, cybersecurity risks, economic constraints, and resistance to change, all of which require systemic attention and strategic management. The effective implementation and scaling of ACE will necessitate a balanced approach that maximizes its strengths and opportunities while minimizing the impact of weaknesses and external challenges.

4.2. International practice of artificially controlled environment at the physical education process of higher education students

In the 21st century, physical education in higher education is undergoing significant changes due to digitalization and the introduction of artificially controlled environments into the educational process. The relevance of the study is due to the need to adapt traditional physical education methods to new technological and social challenges. As noted by Kopp et al. (2019), an innovative educational environment contributes to increasing student motivation and their involvement in the educational process, which is of particular value in the process of physical education [5].

According to OECD (2021), more than 65% of higher education institutions in developed countries are implementing digital educational technologies to improve the quality of education, in particular in physical education. In this context, the concept of “artificially controlled environment” includes intelligent platforms, adaptive training

systems, virtual simulators and physical activity monitoring devices that provide real-time feedback [9].

In the context of the COVID-19 pandemic and the massive transition to distance learning, the role of digital technologies in physical education has increased significantly. Research by Varea & González-Calvo (2020) shows that 84% of students in the EU and North America have encountered the need to use digital platforms during physical education classes. This has set the task of rethinking traditional forms of physical education for scientists [4].

Artificially guided environments (AGEs) allow to automate the process of collecting data on the student's condition, individualize the workload, and integrate physical activity into hybrid or fully remote educational models. According to a study by Li et al. (2022), the introduction of intelligent systems into education increased the overall level of physical activity of students by 23% compared to traditional forms [8].

According to Tapia-Serrano et al. (2023), artificially guided environments have the potential to compensate for the limitations of traditional physical education, especially in universities where attendance is low. They prove that gamification and digital fitness trackers contribute to improving students' discipline and their regular involvement in physical activity [12].

In the international context, successful examples of the implementation of SHCS in the USA (the "Smart PE" programs at UCLA, Stanford), Great Britain (AR technologies at the University of Bristol), and Japan (biometric modules at the Tokyo University of Physical Education) are. These initiatives demonstrate the synergy of physical, digital, and educational components [2, 10].

Thus, studying the experience of leading countries in the field of digitalization of physical education allows us to identify effective approaches to the formation of a modern educational model. The literature review aims to synthesize these practices, determine their potential for adaptation in the conditions of the Ukrainian educational system, and justify the need to create an innovative physical education infrastructure.

Modern world scientific thought is actively exploring the possibilities of implementing artificially controlled environments (ACEs) in physical education of

higher education students, which we have revealed through bibliographic analysis and content analysis.

Thus, the work of authors Bellhäuser, Wampfler, Ifenthaler, (2018) presents a study of the integration of mobile learning analytics in higher education, focusing on assessing the usability of the prototype of the MyLA mobile application, including in the practice of physical education classes. The main emphasis was on how mobile applications can support students' self-regulated learning and provide feedback for self-control. The results of the study confirmed the potential of mobile learning analytics to support self-regulated learning, allowing students to monitor their progress and use this data as a means of self-control [1].

Chinese researchers Li, H., Hu, R., Wang, Z., Xu, G., (2024) aimed to identify the main factors influencing university students' intention to continuously use fitness apps and propose effective strategies for developing and promoting them in organized physical activity practices. The study also aimed to contribute to the understanding of how fitness apps can improve physical activity and health among university students. The results of a survey of 522 Chinese university students showed that the perception of the usefulness and ease of using fitness apps had a significant positive impact on attitudes towards them, and habit played a crucial role in the transition from intention to actual continuous use [7].

The study by Soria-Barreto K., Ruiz-Campo S., Al-Adwan A.S., Zuniga-Jara S. (2021) was devoted to studying the intentions of university students to continue using online tools and digital learning technologies during and after the COVID-19 pandemic, including in the process of physical education. The work focused on factors influencing sustained interest in this process, and was conducted among university students in three countries: Spain (Europe), Chile (Latin America) and Jordan (Asia). The results revealed a modified Expectations Confirmation Model for the use of online tools and digital technologies in learning, which consisted, according to the authors, of three new concepts: self-management of learning, computer activity and the formation of a permanent habit. Self-management of learning was identified as a key concept that has a significant positive impact on the intention to continue using online tools for all

three countries, especially in Jordan [11].

The works related to the implementation of virtual reality in the process of physical education and sports training of higher education students present (Table 4):

- integration of virtual reality technologies into the process of physical education - virtual reality as a promising technology for improving the learning experience in physical education, offering immersive environments and interactive simulations to increase student engagement and motivation, allowing to practice skills in virtual environments with instant feedback (Kuleva M., 2024) [6];

- the impact of metaverse technologies, virtual reality and gamification on students' motor skills in the process of their physical education - virtual reality and exergames (games with physical activity) to create a comfortable learning environment on the example of a developed and tested program to improve students' coordination skills (Utamayasa I.G.D., Kusuma A.I., Ariani L.P.T., 2025) [13];

- combining virtual reality and gamification with the practice of forming motor skills in students - gamification techniques are effective in the processes of forming motor skills and consolidating motor skills in various content physical education programs for higher education students (Fernández-Vázquez D.; Navarro-López V.; Cano-de-la-Cuerda R.; Palacios-Ceña D.; Espada M.; Bores-García D.; Delfa-de-la-Morena J.M.; Romero-Parra N., 2024) [3];

- application of virtual reality technologies in the practice of sports-oriented physical education of students - virtual reality offers many opportunities for visual support for the study of technical techniques, especially in complex coordination sports (Witte K, Bürger D, Pastel S., 2025) [14].

The study by Hu X., Li J., (2024) presented the concept of an integrated solution for physical education based on a “smart campus” and focused on improving the physical education experience for students through the integration of smart physical fitness monitoring through contact devices; interactive fitness equipment and gamification; mobile applications and individual digital training plans; smart objects and indoor navigation. The results emphasize that the integration of technologies such as smart sensor devices and mobile applications allows for the effective collection

Table 4 - Systematization of Research on Artificially Controlled Environments in Higher Education Physical Education

Research Area / Technology	Authors & Year	Main Goal / Focus	Key Findings / Impact on ACEs	Unifying Characteristics / Connection to ACEs
Mobile Learning Analytics	Bellhäuser, Wampfler, Ifenthaler (2018)	Assessing usability of the MyLA mobile app prototype for self-regulated learning and self-control in PE.	Confirmed potential of mobile analytics to support self-regulated learning and progress monitoring.	Sensor-based Reading & Activity Monitoring: Apps collect data for feedback and self-control. Adaptive Exercises & Personalization: Data used for monitoring and adaptation.
Fitness Apps	Li, H., Hu, R., Wang, Z., Xu, G. (2024)	Identifying factors influencing university students' continuous use intention of fitness apps and proposing effective promotion strategies.	Perceived usefulness, ease of use, and habit significantly impacted continued use.	Sensor-based Reading & Activity Monitoring: Data collection on physical activity. Adaptive Exercises & Personalization: Personalized training plans. Gamification & Interactivity: Motivation through game elements.
Online Tools & Digital Learning Technologies	Soria-Barreto K., Ruiz-Campo S., Al-Adwan A.S., Zuniga-Jara S. (2021)	Studying university students' intentions to continue using online tools and digital learning technologies during and after the COVID-19 pandemic, including in PE.	Revealed a modified Expectations Confirmation Model with new concepts: self-management of learning, computer activity, and formation of a permanent habit. Self-management identified as key.	Adaptive Exercises & Personalization: Self-management of learning impacts the use of tools for personalization. Integrated "Smart" Platforms: Online tools as part of a controlled environment.
Virtual Reality (VR)	Kuleva M. (2024)	Integration of VR technologies into the physical education process.	VR enhances the learning experience by offering immersive environments and interactive simulations to boost student engagement and motivation.	Immersive & Simulated Spaces: Creation of artificial, digital environments that simulate real conditions, with full control over parameters.
Metaverse, VR & Gamification	Utamayasa I.G.D., Kusuma A.I., Ariani L.P.T. (2025)	Impact of metaverse, VR, and exergames on students' motor skills.	Created a comfortable learning environment to improve coordination skills through a developed and tested program.	Immersive & Simulated Spaces: Using VR to create a controlled environment. Gamification & Interactivity: Game elements for motivation and directing behavior.
VR & Gamification	Fernández-	Combining VR and	Gamification techniques are	Gamification & Interactivity:

for Motor Skill Development	Vázquez D. et al. (2024)	gamification with motor skill practice.	effective in forming and consolidating motor skills in various PE programs.	Artificially created stimuli that controllably influence user motivation and engagement, guiding efforts.
VR in Sports-Oriented PE	Witte K, Bürger D, Pastel S. (2025)	Application of VR technologies in sports-oriented physical education.	VR offers many opportunities for visual support in learning technical techniques, especially in complex coordination sports.	Immersive & Simulated Spaces: Visual support and simulation within a controlled environment.
Integrated "Smart Campus" PE Solution	Hu X., Li J. (2024)	Concept of an integrated PE solution based on a "smart campus," focusing on smart monitoring, interactive equipment, mobile apps, and individual digital training plans.	Effective data collection on fitness, personalized feedback, adaptable training plans, increased student motivation and satisfaction.	Sensor-based Reading & Activity Monitoring: Data collection via contact devices. Adaptive Exercises & Personalization: Adapting training based on collected data. Gamification & Interactivity: Interactive equipment. Integrated "Smart" Platforms: Combining all technologies into a single, artificially designed infrastructure.

of data on students' physical fitness results, providing them with individual feedback, and adapting training plans. This leads to increased motivation and satisfaction of students with the educational process, as well as improving their overall physical fitness. Interactive teaching methods based on these technologies are recommended by the authors for implementation in educational practice [7].

The comparative analysis and data systematization method we conducted allowed us to establish the unifying characteristics of the scientific works presented by us:

1. All studies directly or indirectly relate to the field of physical education, sports training or physical activity, in the educational space of higher education institutions.

2. The central theme is the study, implementation and assessment of the impact of the latest digital technologies, such as virtual reality, metaverse, gamification, contact devices, artificial intelligence and complex "smart" platforms and environments.

3. The common goal of these studies is to improve various aspects of the student experience and learning outcomes by increasing students' involvement and motivation for physical activity; improving motor skills, physical fitness and sports performance; enriching the learning experience; solving challenges associated with traditional methods (for example, space limitations, equipment, lack of motivation, etc.).

4. The research reflects current trends and challenges, such as adapting to distance learning (particularly during the COVID-19 pandemic), using data to personalize learning, and making physical activity more engaging in the digital age.

5. The advantage of technology in providing personalized training, real-time feedback, and adaptive exercises, which is difficult to implement in purely traditional settings, is often emphasized.

We also identified aspects that connect the works we reviewed with the concept of "artificially controlled environment":

- Immersive and simulated spaces (virtual reality, metaverse): the use of virtual reality and metaverse technologies creates artificial, digital environments that simulate real conditions (e.g., virtual sparring, sports scenarios). These environments are fully controlled and programmed, allowing for fine-tuning of training parameters, level of

complexity, environment, and interaction. This is a direct embodiment of an artificially controlled environment for learning in the practice of physical education for higher education students.

- Sensory reading and activity monitoring: integration of contact devices and biosensors to collect data on movement, physiological indicators, and physical activity of students. These data are used for precise monitoring, assessment of physical fitness, and tracking the effectiveness of physical education programs. The collection and analysis of this data is a key element of "control" in such an environment, as it allows the system to "understand" the user's state.

- Adaptive exercises and personalization: Based on the data collected by sensors and using algorithms (often with elements of artificial intelligence), platforms can adapt exercises, adjust the load and provide personalized feedback in real time. This creates a dynamic, "guided" environment that responds to the individual needs and progress of each student, optimizing the learning and training process.

- Gamification and interactivity: The introduction of game elements (scores, levels, awards, competitions) and interactive interfaces into virtual or "smart" platforms. These elements are artificially created stimuli that controllably affect the motivation and engagement of users, directing their behavior and efforts towards the implementation of the assigned learning tasks.

- Integrated "smart" platforms (e.g. Smart PE): The idea of a "smart campus" or Smart PE-type platforms combines all digital technologies (biosensors and contact devices; virtual reality; artificial intelligence; mobile applications) into a single, integrated system. This system is an artificially designed infrastructure that purposefully collects, processes data and provides guided interventions to optimize the physical education process.

Thus, these scientific works demonstrate how technologies are used to create, monitor, adapt and manage teaching and training processes in physical education, which is the essence of an "artificially guided environment".

This innovative approach, encompassing intelligent platforms, adaptive training systems, virtual simulators, and real-time monitoring devices, is crucial for adapting to

new technological and social demands. ACE is shown to significantly enhance student motivation, involvement, and overall physical activity levels, addressing limitations of traditional methods, especially in contexts of low attendance or remote learning. Successful international implementations highlight ACE's potential to individualize workloads, automate data collection, and seamlessly integrate physical activity into hybrid or fully remote educational models, demonstrating a powerful synergy of physical, digital, and educational components.

Modern scientific literature actively explores the multifaceted possibilities of ACE in higher education physical education. Research highlights the utility of mobile learning analytics for self-regulated learning, factors influencing the continuous use of fitness applications, and student intentions to engage with digital learning tools. Furthermore, studies extensively demonstrate the integration of virtual reality and metaverse technologies to create immersive, interactive, and gamified environments that enhance motor skills and engagement, offering personalized training and real-time feedback. These scientific works collectively illustrate how digital technologies are strategically employed to create, monitor, adapt, and manage teaching and training processes in physical education, encapsulating the very essence and defining characteristics of an Artificially Controlled Environment.

4.3. Elements of artificially controlled environment in the practice of physical education of students of higher education institutions of Ukraine

The relevance of studying the modern experience of Ukrainian higher education institutions (HEIs) in introducing elements of an artificially controlled environment (ACE) into the process of physical education is due to sharp changes in the educational process in the conditions of war, post-pandemic times. And taking into account the consequences of the spread of COVID-19, the problem of taking this experience into account (distance/blended learning) is becoming more relevant in the educational process [16].

In the context of modern globalization and information challenges, the

digitalization of education appears not simply as a technical innovation, but as a deep transformation that requires rethinking the content and organization of the educational process. As noted by Sysoeva S (2021), this process includes the transfer of educational and methodological materials into digital format, the creation of publicly available knowledge bases, the active use of mobile and cloud technologies, as well as the implementation of intelligent learning management systems. At the same time, digital transformation, despite the expansion of the educational space and the diversification of teaching methods, generates a number of risks, in particular, the potential loss of basic cognitive skills and the need to preserve the fundamentals of the classical education system. This emphasizes the critical importance of forming digital competence of all participants in the educational process and conducting targeted pedagogical research to ensure the quality of education in new realities [24].

In the modern information society, where the integration of innovative approaches is gaining particular importance, their application is fundamental for all areas of education, including physical education. As Tsaban H., Lavrin G., Angeliuk I. (2023) emphasize in their work, the use of modern information technologies in physical education significantly increases the efficiency of the educational process, acting as a powerful tool for cognition and learning. These technologies perform generalizing, research, developmental, educational and control-corrective functions, contributing to the solution of a wide range of tasks. In particular, their use in professional and applied physical training allows to improve the pedagogical process, significantly increase the efficiency of educational and training sessions, provide operational access to current knowledge and form a new quality of professional training of specialists, which is key to adapting to the requirements of the information society [26].

The digitalization of physical education in higher education institutions contributes to the formation of a new quality of professional training of physical education specialists by means of digitalization. In this perspective, Shukatka O. (2020) notes that operating with digital information technologies allows to form a component of professional competencies, and the use of digital innovative scientific and methodological environments determines strategic approaches to updating the content,

means, methods of training and professional development of pedagogical specialists in the context of education reform [29].

The use of digital technologies as a result of the modernization of the educational process in physical education opens up wide opportunities for individualization of learning. According to Efremenko A., Kolokolova V., Pozdnyakova M., Pyatysotskaya S. (2025) the introduction of these technologies into higher education makes teaching methods more flexible, allows students to be involved in the learning process and personalize the educational process. Recently, such digital innovations as virtual and augmented reality have been rapidly used in physical education [17].

Hajovich E., Rozlutska G. (2024) in their work determine that digital technologies play a key role in shaping both current and future educational trends, ensuring multimodal learning, increasing the flexibility of the educational process and the involvement of students. The use of digital tools promotes asynchronous learning, overcomes geographical barriers and personalizes access to educational resources, which fundamentally changes the perception of information, develops critical thinking and creativity. Thus, digital innovations are an integral part of transformational processes in modern education, determining its further development [15] (Table 3).

Thus, the introduction of elements of an artificially controlled environment into the process of physical education of university students is a relevant and necessary step in the context of the digitalization of higher education. This allows ensuring the continuity of the educational process, increasing its efficiency, and adapting it to new challenges of modernity.

The process of physical education in Ukrainian higher education institutions is currently being actively modernized through the integration of technologies that create an artificially controlled environment, which is a response to the challenges of modern digitalization, the spread of distance learning and the conditions of martial law.

This environment is a structured, technologically mediated system that allows teachers to effectively manage students' physical activity, adapt it to individual needs and provide feedback, despite physical limitations.

Table 3 - Key Elements and Technologies of the Artificially Controlled Environment (ACE) in Ukrainian Higher Education PE

ACE Element / Technology	Description & Functionality	Key Research & Contributions	Impact on Physical Education & ACE Characteristics
Mobile Applications & Fitness Gadgets	• Create a personalized controlled environment allowing students to track physical activity (steps, calories, heart rate, sleep quality), training progress (strength, running), nutrition, and hydration. • Provide instant feedback, data visualization, and results comparison. • Gadgets collect objective physical data; apps analyze it, offer individual training programs, and reminders.	Petrenko Yu., Petrenko Yul. (2022): Mobile apps increase student motivation by allowing self-tracking of general physical fitness, nutrition, and hydration. Mostetska O., Lavrin H. (2022): Crucial for controlling student physical health and assessing sports achievements; systematize learning materials and introduce modern information flows. Sapegina I. (2023): Enhance educational process effectiveness and material absorption in distance learning.	Personalization & Adaptation: Enable remote instructor control, task adaptation, and recommendations based on real data. Motivation & Self-Control: Boost student motivation for independent exercise. Data Collection & Analysis: Form the foundation for an ACE by gathering granular student performance and health data.
Interactive Platforms & Video Lessons	Interactive platforms (e.g., ZOOM, Google Meet, Moodle) create virtual spaces for classes, material exchange, testing, and communication. Video lessons are key for demonstrating exercises, conducting recorded or live training, and providing methodological guidance. Ensure structure and sequence in distance learning.	Mozolev O. (2022): Fitness technologies for distance learning rely on platforms like ZOOM, Google Meet, Viber, Telegram for effective feedback, methodological assistance, exercise control, and physical development testing. Mozolev O.; Khmara M. (2025): Interactive technologies change teaching methods, tools, and organizational forms, considering distance education and personalization needs. Shavel H., Kotenji L., Sokolenko L. (2024): Confirm successful adaptation of traditional PE methods for distance platforms in Ukraine, maintaining student interest and learning effectiveness despite physical space/technical challenges.	Structured Learning Environment: Provide a framework for remote PE. Instructor Control: Allow monitoring of presence, activity, and individual task completion. Standardization & Visual Learning: Standardize material delivery and provide essential visual components. Adaptability: Essential for quality and effectiveness in modern educational spaces.

Virtual & Augmented Reality (VR/AR)	• VR immerses users in simulated environments for sports games, training, or rehabilitation. AR overlays virtual objects onto the real world (e.g., virtual coach, markings). • Create an immersive and engaging controlled environment that boosts student engagement and motivation.	• Chepeliuk A., Hrushko V., Fedorenko A. (2024): VR transforms PE methods, adapting to individual needs, effective in rehabilitation (safe problem imitation) and high-performance training (specific scenario replication). • Yefremenko A., Kolokolov V., Pozdniakova M., Piatysotska S. (2025): VR/AR games increase engagement, motivation, and improve motor skills across age groups, including students. Challenges include high cost, program development expertise, potential physical/psychological impact.	• Enhanced Engagement & Motivation: Leverage immersive experiences to make PE more appealing. • Skill Development & Safety: Allow safe practice of complex motor skills and competitive simulations, valuable for rehabilitation or precise training. • Controlled Parameters: Instructors can manage virtual environment settings and gather interaction data.
Online Physical Activity Diaries	• Digital tools (often integrated into apps or web platforms) where students record workouts, well-being indicators, nutrition, and other physical activity data.	• Kolb M., Solovei A. (2023): Discuss new PE methodologies and strategies adapted to martial law challenges, emphasizing innovative approaches for continuity and effectiveness. • Yazlovetska O., Babenko A. (2025): Highlight the importance of implementing innovative approaches for continuous and effective physical activity during martial law.	• Data Collection & Monitoring: Central for gathering and analyzing individual student data. • Personalized Feedback & Adaptation: Enable continuous monitoring and correction of the learning process, helping identify physical development dynamics and adapt programs, especially for special medical groups. • Innovation & Resilience: Crucial for maintaining PE quality amid active educational environment development and global challenges.

Mobile applications and fitness gadgets. These technologies create a personalized controlled environment, allowing students to track their own physical activity (steps, calories, pulse, sleep quality), progress in training (strength indicators, running) and even nutrition and water balance. They provide instant feedback, data visualization and the ability to compare results. Fitness gadgets collect objective data about the student's physical condition, and mobile applications analyze them, offer individual training programs and reminders. This allows the teacher to remotely monitor the activity of applicants, adapt tasks and provide recommendations based on real data, increasing students' motivation for independent studies [20, 22, 23].

The study by Petrenko Yur., Petrenko Yul. (2022) highlights the significant advantages of using mobile applications, as they increase students' motivation to engage in sports, allowing them to track their level of general physical fitness through various types of motor activity (walking, running, strength training), as well as control nutrition and water balance [22].

Similarly, Mostetska O., Lavrin G. (2022) in their analysis of the possibilities of using modern devices and mobile applications in sports emphasize their critical importance for monitoring students' physical health and assessing their sports achievements. These technologies open up new prospects for the systematization of educational materials and the introduction of modern information flows into the process of physical culture [20].

For her part, Sapegina I. (2023) emphasizes the role of sports mobile fitness applications as an important tool of digital developments. Their implementation significantly increases the efficiency of the educational process and the quality of material assimilation by higher education students in distance learning conditions. Thus, mobile applications and fitness gadgets not only stimulate physical activity and help monitor progress, but are also an integral part of the digital transformation of the educational process, adapting it to modern challenges and requirements [23].

Interactive platforms and video lessons. Interactive platforms (e.g., ZOOM, Google Meet, Moodle) create a virtual space for conducting classes, exchanging materials, testing, and communicating. Video lessons are a key component that allows

you to demonstrate the technique of performing exercises, conduct training in recording or in real time, and provide methodological recommendations. These elements provide the structure and consistency of the educational process in a distance format. The teacher can control attendance, activity, provide individual tasks, and check their completion through the platform. Video lessons allow you to standardize the presentation of material and provide a visual component of learning, which is especially important in the process of physical education [19, 25]. As noted by Mozolev O. (2022), fitness technologies for distance learning of students are based on the use of such interactive online platforms as ZOOM, Google Meet, Viber, and Telegram, which provide effective feedback, methodological assistance, control of exercise performance, and testing of physical development [19].

In a joint study by Mozolev O.; Khmara M. (2025) expand on this topic by analyzing the features of the implementation of interactive technologies that change the methods, means and organizational forms of student education. These technologies take into account the spread of distance education and the need for personalization of the educational process [25].

At the same time, Shavel H., Kotendzhi L., Sokolenko L. (2024) explore the possibilities of adapting traditional physical education methods for effective use on distance education platforms in Ukraine. Their research confirms the success of such modifications, which allow maintaining students' interest in physical activity and ensuring a high level of learning efficiency, despite such challenges as limited physical space and technical problems. Thus, interactive platforms and video lessons are an urgent need and a key element in the process of modifying physical education, ensuring its quality and effectiveness in the conditions of the modern educational space [28].

Virtual and augmented reality (VR/AR). Virtual reality (VR) immerses the user in a fully simulated virtual environment, where it is possible to simulate sports games, training or rehabilitation exercises. Augmented reality (AR) superimposes virtual objects on the real world, allowing interaction with them (e.g., virtual trainer, marking in real space). VR/AR create an immersive and exciting controlled environment that increases student engagement and motivation for physical activity [17]. This allows for

safe practice of complex motor skills, simulation of competitive situations and adaptation of training to individual needs, which is especially valuable for rehabilitation or high-precision training [27]. The teacher can control the parameters of the virtual environment and receive data on the student's interaction with it.

As noted by Chepelyuk A., Grushko V., Fedorenko A. (2024), VR creates significant opportunities for the transformation of physical education and training methods, providing tools that adapt to the individual needs of users, in particular, it is effective in rehabilitation through safe simulation of problems and in high-performance sports training due to the reproduction of specific scenarios [17].

At the same time, Efremenko A., Kolokolov V., Pozdnyakova M., Pyatysotska S. (2025) in their review of the effectiveness of using VR/AR gaming technologies in physical education confirm the relevance of implementing these technologies for different age groups, including students. Their main advantages are increased engagement and motivation for learning, as well as improved motor skills. Despite the potential, the integration of VR/AR into the process of physical education faces such challenges as the high cost of equipment, the need for special knowledge for program development, the potential physical and psychological impact on users, which, according to the authors, requires a balanced approach to fully realize their significant potential during the transformation of the educational process [17].

Online physical activity diaries. These are digital tools, often integrated into mobile applications or web platforms, where students record their training, well-being indicators, nutrition and other data related to physical activity. Online diaries are a central element for collecting and analyzing individual student data, which allows the teacher to continuously monitor and correct the educational process. They provide personalized feedback, help identify the dynamics of physical development and adapt programs, especially for students of special medical groups [21].

In the study, Kolb M., Solovey A. (2023) consider new methods and strategies for organizing physical education, adapted to the challenges caused by martial law. The article highlights the importance of implementing innovative approaches to ensure the continuity and effectiveness of students' physical activity in complex modern realities

[18]. Given the current challenges of modernizing physical education, which are analyzed by Yazlovetska O., Babenko A. (2025) emphasize the importance of implementing innovative approaches to ensure the continuity and effectiveness of physical activity in martial law conditions [30]. Thus, online diaries are an integral element of an innovative strategy that helps to maintain the quality of physical training in conditions of active development of the educational environment and global challenges.

The integration of Artificially Controlled Environments (ACE) into physical education in Ukrainian higher education institutions is highly relevant and necessary, driven by the profound changes brought about by war, post-pandemic challenges, and the broader digitalization of education. This transformation moves beyond mere technical innovation, fundamentally rethinking the content and organization of physical education to ensure continuity, enhance efficiency, and adapt to modern demands. ACE, as a technologically mediated system, enables educators to effectively manage student physical activity, personalize learning experiences, and provide crucial feedback despite physical limitations, ultimately contributing to a new quality of professional training for physical education specialists and fostering students' professional competencies and digital literacy.

Key elements of this modern ACE include mobile applications and fitness gadgets for personalized tracking and motivation, interactive platforms and video lessons for structured distance learning and standardized content delivery, virtual and augmented reality (VR/AR) for immersive and engaging simulations of sports and training, and online physical activity diaries for continuous monitoring and data-driven adaptation of programs. These components collectively form a cohesive, structured, and dynamically controlled environment that leverages advanced digital tools to significantly increase student engagement, improve motor skills, and ensure the effectiveness and continuity of physical education in the face of contemporary global challenges.

4.4. Strategic analysis of artificially controlled environment implementation in higher education physical education and goal formulation

Based on the analysis of internal and external factors influencing the functioning of the artificially controlled environment (ACE) in the physical education of students of higher education institutions, as well as taking into account the experience of implementing an artificially controlled environment in the practice of foreign and domestic higher education institutions, we conducted a comprehensive strategic analysis, the first tool of which was the *SWOT analysis*. This analytical tool allows us to systematize the strengths and weaknesses of the ACE concept itself, as well as to identify external opportunities and threats that it faces in the conditions of the modern educational and social context of Ukraine (Figure 2).

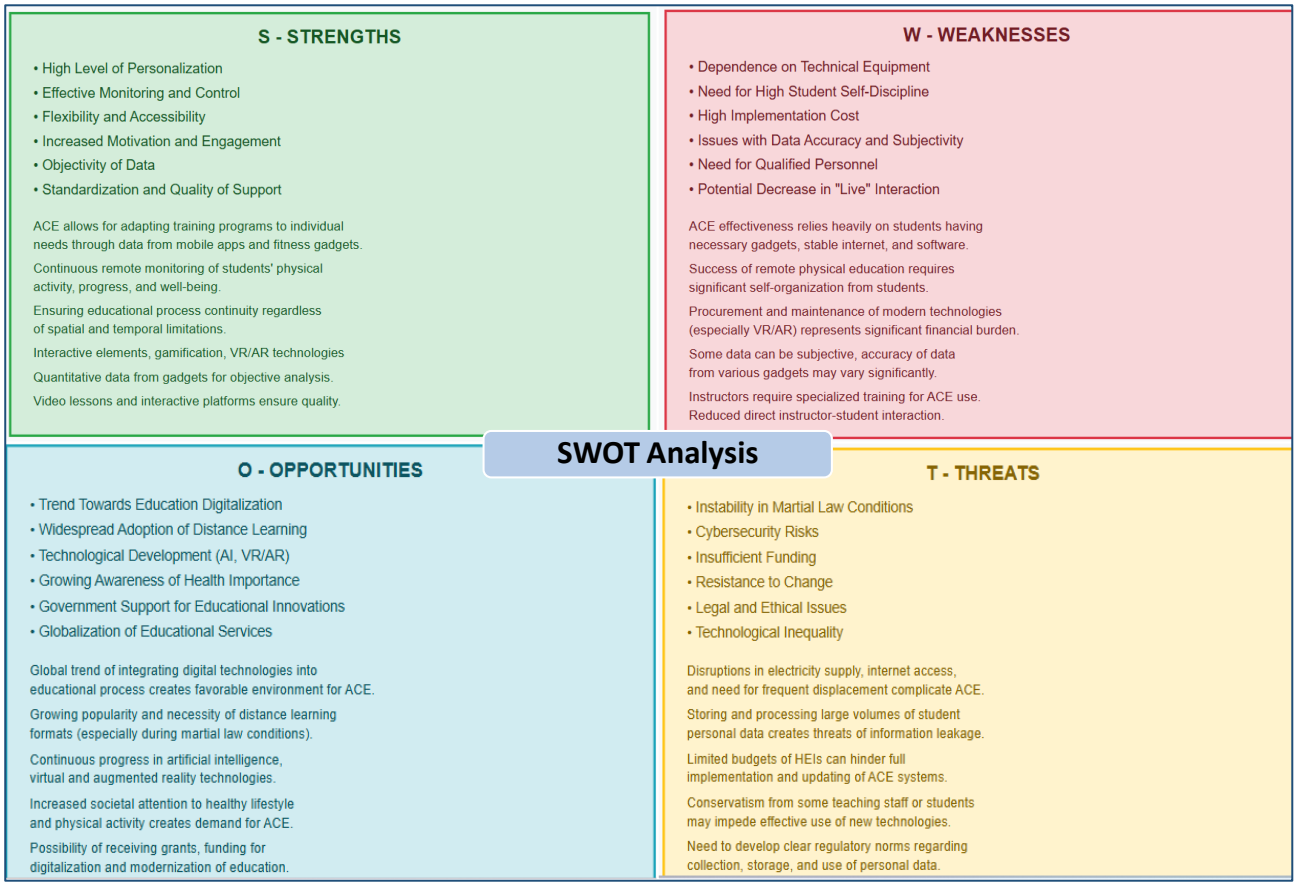

Figure 2 - SWOT-analysis of implementing artificially controlled environment in higher education physical education

The implementation of ACE in the practice of physical education in higher

education demonstrates significant potential, based on a number of its inherent advantages. The strengths of the ACE include its ability to achieve a high level of personalization of the educational process, which is achieved through the integration of mobile applications, fitness gadgets and online diaries, which provide the collection of individualized data on the student's physical activity and health status. This allows for effective monitoring and control of the dynamics of physical development, providing the teacher with tools for prompt adjustment of programs. A key advantage is also the flexibility and accessibility of the ACE, which guarantees the continuity of physical education regardless of space-time restrictions, which is especially relevant in the conditions of distance learning and the challenges of wartime. The use of interactive elements, gamification and virtual/augmented reality technologies significantly increases student motivation and engagement. An important strength is the objectivity of automatically collected data and the possibility of standardizing methodological support through the use of video lessons and interactive platforms.

Despite significant advantages, the ACE also has certain weaknesses that require attention. One of the main ones is the dependence on technical equipment from both the HEI and the students, which includes the availability of gadgets, stable internet and appropriate software. This can lead to high costs of implementing and maintaining a ACE, especially for VR/AR technologies. In addition, the effectiveness of the ACE largely depends on the high self-discipline of students, without which the potential of the system may not be fully realized. There are also challenges related to the accuracy and subjectivity of data (for example, self-assessment of well-being) and the need for qualified personnel among the teaching staff to effectively manage the new system. A potential decrease in "live" communication cannot be ruled out, which can affect social interaction in the educational process.

The external environment creates a number of opportunities for ACE. First of all, this is the trend towards the digitalization of education and the spread of distance learning, which create favorable soil for the integration and development of ACE as a response to current needs. The constant development of technologies (artificial intelligence, VR/AR) opens up horizons for improving functionality and creating new,

more adaptive and immersive solutions. Growing public awareness of the importance of health is generating demand for effective and affordable methods of physical education. There is also potential for state support for innovation and expanding cooperation within the framework of globalization of educational services.

At the same time, there are threats that may hinder or complicate the implementation of the ACE. These include instability in conditions of martial law, which may lead to disruptions in the operation of the infrastructure, cybersecurity risks associated with the protection of personal data. Insufficient funding for HEIs can become a serious obstacle to the full deployment and updating of the system. It is also important to consider resistance to change from the conservative part of the academic community or students, as well as legal and ethical issues related to the collection and use of data. Finally, the problem of technological inequality among students can deepen the gap in access to quality education.

In summary, the successful implementation of the Physical Education System requires not only the use of its internal advantages, but also an effective response to external challenges and opportunities. Strategic planning should be aimed at minimizing weaknesses and threats, while simultaneously using strengths and existing opportunities to form a sustainable and adaptive system of physical education in higher education.

The implementation of an ACE in physical education within higher education institutions in Ukraine is a multifaceted process influenced by a range of interconnected macro-environmental factors. These influences can be systematically analyzed using *the PESTLE methodology*, allowing for a comprehensive assessment of the political, economic, social, technological, legal, and environmental factors that shape the conditions for the successful implementation and functioning of ACE.

From a political perspective, a key driver is the national and global trend towards the digitalization of education, supported by government programs and initiatives. These policies create a favorable environment for the introduction of innovative solutions like ACE, and also facilitate the adaptation of the educational process to challenges related to distance learning and conditions of martial law. The political will

for international integration of Ukrainian education can also enhance the attractiveness of HEIs utilizing advanced technologies (Figure 3).

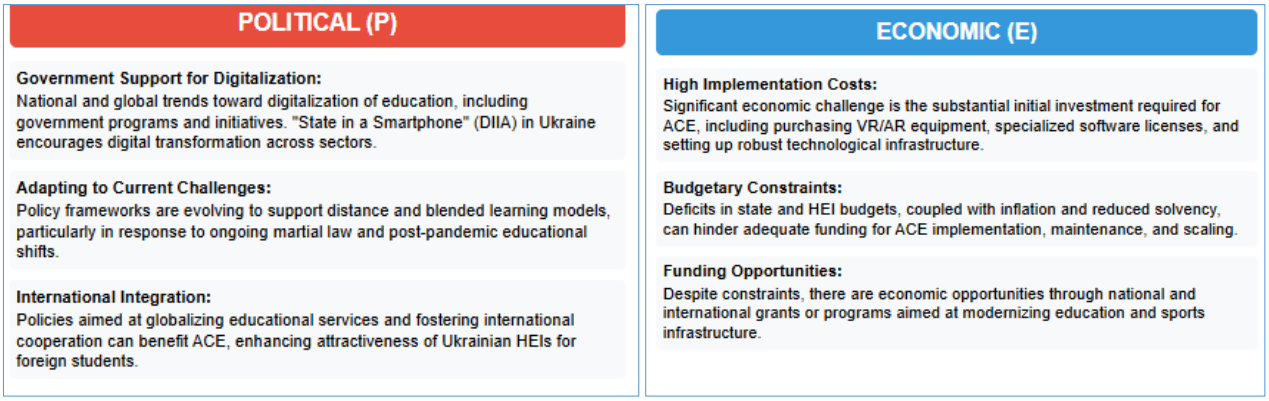

Figure 3 - PESTLE-Analysis: implementing artificially controlled environment in physical education for higher education institutions (Political & Economic factors)

Economic factors present significant challenges and opportunities. The high cost of implementing and supporting ACE, including the acquisition of VR/AR equipment and specialized software, represents a substantial financial burden for HEI budgets, especially amid limited state funding and inflation. At the same time, the availability of national and international grant programs and projects for educational modernization can serve as a vital funding source, reducing the economic load and facilitating accelerated ACE implementation.

The social dimension impacts ACE through several aspects. Growing public attention to healthy lifestyles and physical activity creates increased demand for effective and accessible physical education methods, contributing to student acceptance and engagement with ACE. However, the system's success largely depends on the level of student self-discipline, as reduced direct supervision requires high self-organization. The potential decrease in "live" interaction within a technologically mediated environment may negatively affect the development of social skills. There is also a risk of deepening technological inequality among students, which could limit the accessibility and effectiveness of ACE for all categories of learners (Figure 4).

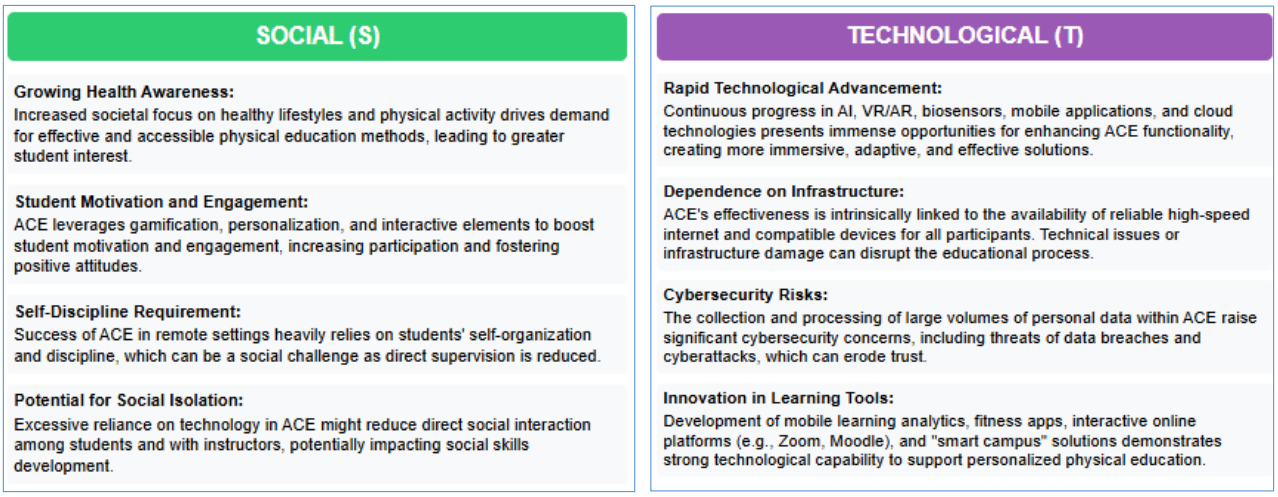

Figure 4 - PESTLE-Analysis: implementing artificially controlled environment in physical education for higher education institutions (Social & Technological factors)

Technological progress is a fundamental basis for ACE's development. The rapid advancement of artificial intelligence, virtual and augmented reality, biosensors, mobile applications, and cloud technologies constantly expands ACE's functional capabilities, making it more immersive, adaptive, and interactive. However, ACE's effectiveness critically depends on the availability and stability of relevant technological infrastructure and devices for both students and HEIs.

Simultaneously, technological advancements also give rise to legal and ethical challenges, particularly concerning the collection, storage, and use of large volumes of student personal data. This necessitates the development of clear regulatory norms and policies to ensure data confidentiality and security, as well as addressing ethical dilemmas related to continuous monitoring and privacy implications.

Finally, contextual (Environmental) factors create unique conditions for ACE implementation in Ukraine. The ongoing martial law is a significant destabilizing factor that can cause disruptions in electricity supply, internet access, and forced population displacement, complicating the system's uninterrupted functioning. The experience of the COVID-19 pandemic and the mass transition to distance learning have also shaped a new educational environment where ACE plays a vital role in ensuring the continuity and quality of physical education (Figure 5).

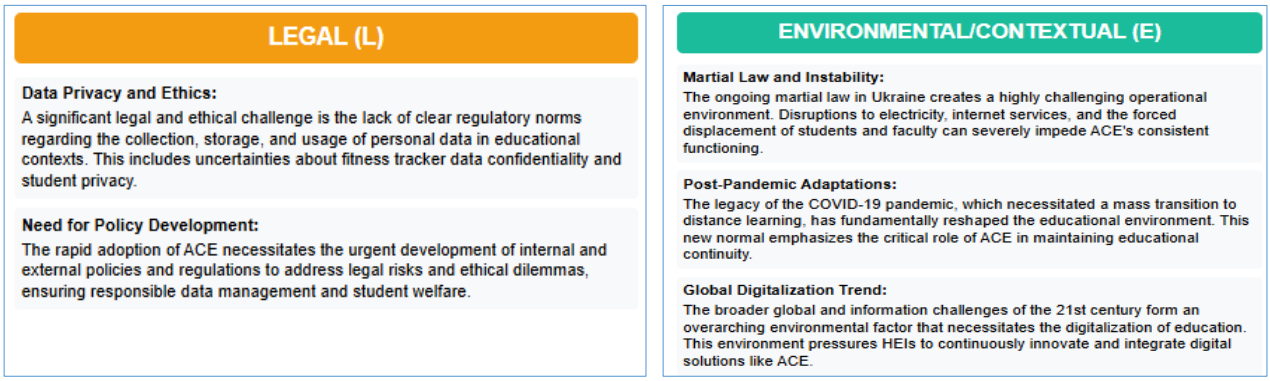

Figure 5 - PESTLE-Analysis: implementing artificially controlled environment in physical education for higher education institutions (Law & Environmental factors)

Global digitalization trends and the constant challenges of the modern information society create a general backdrop that urges HEIs to continuous innovation and adaptation.

Thus, the successful implementation of ACE requires a comprehensive approach that considers the dynamics of all these PESTLE factors. Only a deep understanding and strategic management of these influences will allow for the maximum realization of ACE's potential in enhancing the effectiveness of physical education and adapting to the demands of modernity.

SMART-analysis systematically evaluates the proposed objectives for integrating an Artificially Controlled Environment (ACE) into physical education within Ukrainian higher education institutions, ensuring alignment with the principles of Specificity, Measurability, Achievability, Relevance, and Time-boundness.

The implementation of an Artificially Controlled Environment in physical education at Ukrainian universities is driven by clearly defined and precise objectives. Firstly, it aims to boost student motivation and engagement by making physical activity more appealing and interactive, thereby overcoming challenges such as low attendance or lack of interest often associated with traditional formats. This objective is to be achieved through the strategic application of gamification, immersive technologies (e.g., VR/AR), and interactive feedback mechanisms. Secondly, ACE seeks to improve the individualization of the training process by adapting physical education programs

and recommendations to meet each student's unique needs, fitness levels, and health status. This personalization is facilitated by systematic data collection from mobile applications, fitness gadgets, and online diaries, enabling highly customized workouts and health guidance. Finally, a key objective is to optimize the control and monitoring of physical activity. This involves establishing continuous, often remote, oversight of students' physical activity, progress, and well-being. Such monitoring ensures objective, data-driven insights for instructors, allowing them to provide timely feedback and make real-time adjustments to training plans, even in distance learning scenarios. A critical aspect, particularly given current conditions in Ukraine, is ensuring the continuity of the educational process despite spatial or temporal constraints (Figure 6).

Figure 6 - SMART-analysis of artificially controlled environment implementation in physical education at higher education institutions

The effectiveness of integrating digital technologies into physical education will be evaluated using specific, quantifiable metrics. Student engagement levels will be measured by active participation rates in online sessions, consistent use of ACE platforms and applications, completion rates of assigned tasks, and engagement with interactive content. Surveys will also be utilized to gauge perceived motivation and satisfaction. Physical activity indicators will be assessed using concrete data from fitness gadgets and mobile applications, including average daily steps, calories burned, heart rate zones during exercise, and adherence to personalized training plans. Previous research indicates potential for significant increases in overall physical activity levels

(e.g., a 23% increase compared to traditional forms). Furthermore, the utilization of advanced technologies will be tracked by monitoring the frequency and duration of student engagement with specific ACE components, such as VR/AR sessions, virtual simulations, and interactive video lessons. Academic performance and skill development will be evaluated through improvements in specific motor skills, physical fitness tests, and academic achievements related to physical education courses. Lastly, feedback and adaptation cycles will be monitored by assessing the frequency and quality of personalized feedback provided by instructors based on collected data, along with the subsequent adjustments made to student programs.

Recognizing the existing resource limitations within Ukrainian higher education institutions, the implementation of ACE elements is designed to be realistic and achievable through a phased approach. While challenges like high implementation costs, dependence on technical infrastructure, and the need for qualified staff exist, these are counterbalanced by several strategic considerations. The approach advocates for gradual integration, starting with foundational and more accessible elements like mobile applications and online diaries before progressing to more resource-intensive technologies like VR/AR. This strategy also emphasizes leveraging existing infrastructure, utilizing widely available interactive platforms such as ZOOM, Google Meet, and Moodle for synchronous and asynchronous learning. Opportunities for government and international support through grants and funding from national and international programs aimed at digitalizing education are crucial for alleviating financial burdens. Moreover, investing in teacher training and professional development is vital to equip physical education instructors with the necessary digital competencies, ensuring effective management and utilization of the ACE. Despite potential initial resistance to change, continuous professional development can foster acceptance and proficiency.

The integration of digital innovations in physical education is highly relevant to the broader context of Ukrainian education and societal needs. This relevance is underscored by its direct alignment with the nationwide strategy for educational digitalization, as confirmed by regulatory documents from the Ministry of Education

and Science of Ukraine, ensuring institutional backing and long-term sustainability. ACE directly addresses the urgent need for flexible and accessible physical education, particularly in the context of martial law and post-pandemic distance learning, thereby ensuring continuity and quality of instruction under challenging circumstances. Furthermore, it provides innovative solutions for limitations often associated with traditional physical education, such as attendance issues, lack of personalization, and limited access to diverse training environments. Crucially, ACE contributes to the formation of 21st-century skills, including digital competencies and self-management skills among students, which are essential for success in the modern information society.

The implementation and continuous refinement of technologies within physical education are planned within clear temporal frameworks, specifically aligning with the academic year and its cycles. While the provided text did not specify rigid deadlines, the nature of educational programming implies a structured rollout. A phased rollout strategy will see the introduction of new ACE components planned over specific academic semesters or years (e.g., piloting mobile apps in Semester 1, introducing VR elements in Semester 2 of the following year). Curriculum integration of new methodologies and technologies will occur at defined stages, allowing for faculty training and student onboarding before the start of relevant academic periods. Lastly, regular evaluation of performance metrics for ACE implementation (as outlined in the "Measurable" section) will be conducted at the end of each academic semester or year to assess progress, make necessary adjustments, and set new goals for subsequent cycles. This iterative process ensures continuous improvement and adaptation to evolving needs and technological advancements.

A Value Chain Analysis offers a granular examination of an organization's internal processes to pinpoint where value is generated and how it can be amplified. In the context of integrating an Artificially Controlled Environment into physical education within Ukrainian Higher Education Institutions, this analysis elucidates how novel technologies contribute to value creation across each stage, potentially yielding a competitive advantage, optimizing costs, or enhancing overall efficiency (Figure 7).

Figure 7 - Value Chain Analysis: implementing artificially controlled environments in physical education at Ukrainian higher education institutions

Primary activities —those directly involved in the creation and delivery of physical education services and the "product" of student physical development—are profoundly impacted. Inbound logistics, traditionally encompassing student enrollment, physical facilities, and basic equipment, are transformed by ACE to include digital onboarding, management of ACE platform access, acquisition of specialized software licenses (VR/AR, analytics), integration of data from student-owned fitness gadgets, and ensuring stable internet connectivity, thereby automating data intake, streamlining content delivery, and personalizing resource allocation.

Operations, the core of service delivery and training execution, evolve from in-person classes and fixed schedules to personalized training plans via mobile apps, interactive video lessons, virtual reality simulations for skill practice, and real-time feedback through smart devices, offering increased flexibility, individualization, enhanced engagement, and data-driven instruction.

For outbound logistics, the delivery of outcomes to students, ACE shifts from observed progress and verbal feedback to continuous tracking via online diaries and fitness gadgets, automated performance reports, personalized insights, and accessible historical data, providing objective, quantifiable progress and empowering students with self-monitoring tools.

Marketing and sales are bolstered as ACE features become unique selling propositions, showcasing personalized learning benefits and leveraging data on engagement and outcomes to promote program effectiveness, thus enhancing attractiveness and potentially increasing enrollment and retention.

Finally, service —post-delivery support and continuous improvement—moves beyond traditional office hours to continuous remote feedback, automated alerts, online support forums, and adaptive program adjustments based on data analysis, enabling proactive support and continuous improvement of student well-being.

Support activities, which indirectly contribute to the overall value of ACE-integrated physical education, are equally transformed. Firm infrastructure evolves to include strategic planning for digital transformation, securing funding for tech investments, developing cybersecurity protocols for student data, and integrating ACE into the HEI's broader digital ecosystem, leading to enhanced organizational efficiency and strategic alignment. Human resource management shifts to specialized training for physical education instructors on ACE platform utilization, data interpretation, virtual coaching, and new pedagogical approaches, increasing faculty competence and instructional quality. Technology development expands from basic equipment updates to research and development into new ACE components (e.g., AI algorithms), continuous software updates, maintenance of digital infrastructure, and integration of emerging technologies like advanced biosensors, ensuring continuous innovation and sustained competitive advantage. Lastly, procurement transitions to strategic acquisition of ACE software licenses, compatible hardware (VR headsets, fitness trackers), cloud computing services, and cybersecurity solutions, ensuring cost-effective access to cutting-edge technologies and seamless operation.

This comprehensive analysis underscores that ACE implementation not only modernizes physical education but also fundamentally redefines value creation at every stage, offering substantial benefits for both institutions and students.

Conclusions.

1. Strategic Imperative of Digital Transformation: The integration of ACE represents a fundamental and critical strategic imperative for modern physical education, directly aligning with global digitalization trends and serving as an essential response to the evolving demands for accessible, personalized, and engaging learning experiences in the 21st century.

2. Integrated Technological Ecosystem: ACE is defined by a synergistic blend of diverse digital components, including mobile applications, fitness gadgets, interactive online platforms, high-quality video lessons, immersive Virtual and Augmented Reality (VR/AR) technologies, and comprehensive online physical activity diaries, which collectively form a cohesive and adaptive learning ecosystem.

3. Enhanced Personalization and Motivation: A key value proposition of ACE is its unparalleled capacity for personalizing physical education programs to individual student needs, fitness levels, and health statuses. This, coupled with gamified and interactive elements, significantly boosts student motivation and engagement, thereby enhancing the effectiveness and appeal of physical activity.

4. Optimized Monitoring and Data-Driven Instruction: ACE provides robust capabilities for continuous, objective, and data-driven monitoring of student physical activity and progress. This enables educators to offer precise, timely feedback and make informed adjustments to training plans, fundamentally transforming instructional quality and student outcomes.

5. Ensuring Educational Continuity in Challenging Contexts: The flexibility and accessibility inherent in ACE are paramount for ensuring uninterrupted physical education, particularly critical in the Ukrainian context of ongoing geopolitical instability and the post-pandemic need for resilient distance and blended learning modalities. This is a core strategic strength providing resilience.

6. Alignment with International and National Digitalization Trends: The adoption of ACE positions Ukrainian HEIs within the broader international discourse on educational innovation and digitalization. It aligns with global best practices in

leveraging technology for improved learning outcomes and directly supports national strategies for digital transformation in education.

7. Strategic Value Chain Enhancement: ACE profoundly impacts and enhances the entire value chain of physical education delivery. From resource acquisition to service delivery and post-training support, technology integrates across primary and support activities, optimizing efficiency, enabling personalization, and creating new avenues for value addition at every stage.

8. Significant Resource and Infrastructure Demands: A major strategic challenge lies in the substantial initial and ongoing financial investments required for ACE implementation, including the acquisition of advanced hardware (e.g., VR/AR equipment), software licenses, and the maintenance of robust technical infrastructure and reliable internet connectivity.

9. Crucial Human Capital and Social Adaptation: Successful ACE integration necessitates significant investment in the professional development of physical education faculty to equip them with advanced digital competencies. Furthermore, addressing issues such as student self-discipline, potential digital inequality, and resistance to change from stakeholders is vital for widespread adoption and sustained effectiveness.

10. Navigating Legal, Ethical, and Security Risks: The collection and processing of extensive personal data within ACE environments introduce complex legal and ethical considerations, including data privacy, confidentiality, and the need for clear regulatory frameworks. Cybersecurity threats also pose a continuous risk, demanding robust security protocols and policies.

11. Leveraging Technological Opportunities for Evolution: The rapid and continuous advancements in fields like Artificial Intelligence (AI), VR/AR, and data analytics present ongoing strategic opportunities for the continuous evolution and enhancement of ACE, allowing for the integration of increasingly sophisticated and adaptive features.

12. Mandate for Phased and Adaptive Implementation: Given the multifaceted benefits and significant challenges, the successful implementation of ACE mandates a

strategic, phased, and highly adaptive approach. This involves careful resource allocation, continuous technological integration, proactive human capital development, and ongoing evaluation to ensure the system effectively responds to both current needs and future demands within the dynamic Ukrainian educational landscape.