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IMPACT OF IMMERSIVE LEARNING TOOLS ON STUDENT MOTIVATION AND ACADEMIC PARTICIPATION

IMPACTO DE LAS HERRAMIENTAS DE APRENDIZAJE INMERSIVO EN LA MOTIVACIÓN ESTUDIANTIL Y LA PARTICIPACIÓN ACADÉMICA

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ABSTRACT

This study examines how virtual (VR) and augmented reality (AR) technologies can enhance engagement and interaction in higher education by creating immersive experiences for students. Using a multidisciplinary approach that combines cloud computing, interactive design, and gamified learning tools, the project implemented web-based AR applications to support university open days and admissions processes. The integration of these technologies promoted active learning through visual and experiential interaction, improved communication between applicants and educators, and strengthened digital competence. The results confirm that immersive tools contribute to higher motivation and understanding of educational content while enhancing institutional innovation and transparency. The study concludes that adopting VR/AR technologies within the educational ecosystem supports experiential, inclusive, and digitally oriented learning models essential for modern universities.

Keywords:

Virtual reality, augmented reality, higher education, student engagement, experiential learning, digital competence.

RESUMEN

Este estudio examina cómo las tecnologías de realidad virtual (RV) y aumentada (RA) pueden mejorar la participación y la interacción en la educación superior mediante la creación de experiencias inmersivas para los estudiantes. Mediante un enfoque multidisciplinario que combina computación en la nube, diseño interactivo y herramientas de aprendizaje gamificado, el proyecto implementó aplicaciones web de RA para apoyar las jornadas de puertas abiertas universitarias y los procesos de admisión. La integración de estas tecnologías promovió el aprendizaje activo mediante la interacción visual y experiencial, mejoró la comunicación entre solicitantes y docentes y fortaleció la competencia digital. Los resultados confirman que las herramientas inmersivas contribuyen a una mayor motivación y comprensión del contenido educativo, a la vez que promueven la innovación y la transparencia institucional. El estudio concluye que la adopción de tecnologías de RV/RA en el ecosistema educativo promueve modelos de aprendizaje experiencial, inclusivos y digitales, esenciales para las universidades modernas.

Palabras clave:

Realidad virtual, realidad aumentada, educación superior, participación estudiantil, aprendizaje experiencial, competencia digital.

INTRODUCTION

Modern education actively applies technologies that help organize the educational process effectively. The educational process involves many interactions, particularly those with large groups of people: organizing open days at universities and accepting documents from applicants (Agape et al., 2024; Sapfirova, 2025). These processes are characterized by large numbers of interested young people who want to receive urgent consultations, familiarize themselves with documents, submit personal files, and perform other procedures. A characteristic feature of such events is typically a shortage of university staff, difficulty in organizing quick interaction, and slow data processing.

In modern higher education, immersive technologies are increasingly viewed not merely as technical tools but as pedagogical instruments that reshape the learning environment (Babina & Utusikov, 2024). Integrating virtual and augmented reality into educational practice promotes experiential learning, allowing students to interact with complex concepts through simulation, visualization, and game-based tasks. For prospective students, such experiences also serve as an introduction to the university's digital culture, fostering early engagement and a sense of belonging within the academic community (Samigullina et al., 2024).

Therefore, in our research we aimed to focus on the technical aspects that could enhance the effectiveness of working with university applicants. These technical aspects include QR codes,

1. QR codes have become one of the most widely used tools for activating augmented reality due to their simplicity (Bhattacharya & Singla, 2024; Online Tool Center, 2024). QR codes work on any device with a camera and are supported by all modern operating systems (iOS, Android, Windows), making them a perfect solution for mass use. Additionally, QR codes are a commonplace solution for modern users; they evoke associations with interactive elements.

QR codes are easy to create, distribute, and scan since they do not require specialized equipment or complex configurations. Markerless technologies, such as SLAM (simultaneous localization and mapping), which is a spatial orientation technology based on environmental objects, require significant computational resources and may not be available on "thin" devices. For example, the game Pokemon GO uses SLAM technology, creating a real-time map of the surroundings and identifying the device's position to make virtual objects appear natural. The popularity of the game is attributed to complete immersion in the virtual space.

2. Augmented Reality (AR) is a technology that overlays virtual objects on the real world. AR technologies can be divided into marker-based and markerless depending on the AR content activation method. QR codes are one type of marker, but other approaches exist, each with its own features in terms of functionality.

To activate AR content, marker-based AR technologies use predefined visual markers. Markers can be simple (e.g., QR codes) or complex (e.g., images or objects). For example, in the IKEA Place app, the user scans a QR code on a product or in the catalog, and the app launches an AR scene with a 3D furniture model from the IKEA catalog. Vuforia, one of the most popular platforms for developing AR applications, uses images as markers to activate AR content. Sometimes, physical objects such as product packaging or architectural elements are used as markers.

Markerless AR technologies do not require predefined markers, instead, they use data from the camera, sensors, and computer vision algorithms to overlay virtual content onto the real world. For example, Snapchat uses neural networks to recognize faces and apply AR filters (Andreeva & Pronina, 2024).

3. The main technical component of our optimization solution of the university admission campaign and open day events was a mobile robotic system, which ensures the security of information resources and prevents potential threats and negative consequences for personal data and applicants' documents (e.g., data loss, illegal profiling, distortion, blocking etc.). This system defines the input parameters and conditions for selecting an effective strategy for conducting the admission

Using cloud technologies for educational mobile robots

One of the possible (and most promising) ways to provide services with mobile robots is using a unified platform that includes cloud computing and cloud storage. In this approach, the robot (or group of robots) connects to the cloud via an API, opening up broad opportunities for accessing software services, storage, and data analysis (Katkov et al., 2016).

Cloud technologies, in addition to the standard advantages (automatic resource distribution for completing tasks, prompt processing of incoming information, and good impressions after the robot's chat with the user), also allow rethinking the possibilities of interaction with a cluster of homogeneous robotic objects. For example, the data exchange when processing a large number of user documents (applications, certificates, etc.) or the cooperative decomposition of a general task into smaller sub-tasks can be simplified using a centralized system, which generally has greater computational capabilities, providing robots with a better "understanding" of their purpose and saving a significant number of resources (energy, financial, and computational). Thus, the robot ends up in a specific location, analyzes the area (for example, the room where the admission campaign is taking place) using sensors, and sends the obtained data to the cloud to recreate the map of the area and store this information. The second robot, which will either come on the next shift or begin performing other functional duties later, will gain access to the centralized system where the area information is stored, allowing it to save time on conducting similar analysis and immediately proceed with work (Ryabchikova et al., 2025).

It should be considered that robots can perceive information differently and thus process it differently while still not disrupting the logic of their operation. Therefore, it is crucial to set certain rules in advance, which will regulate the robots' behavior within a centralized architecture, justifying the potential of the described approach. These include: a secure cloud environment, constant internet access, an efficient system for searching for information in a database with high-speed access, and adherence to rules and mobile robots designing standards.

Usually, the robot's service account must be managed via the Identity & Access Management (IAM) interface in order to access the private Cloud Storage container. For example, when considering the process of connecting a robot to cloud storage via Google Cloud, Cloud Robotics (the technology of cloud computing integration with robotic systems) identifies the robot, allowing secure connection without additional setup.

The purpose of this article is to examine the pedagogical potential of integrating virtual and augmented reality technologies into university practice to enhance interactive learning, strengthen student engagement, and improve communication processes within the educational environment, particularly during outreach and admission activities.

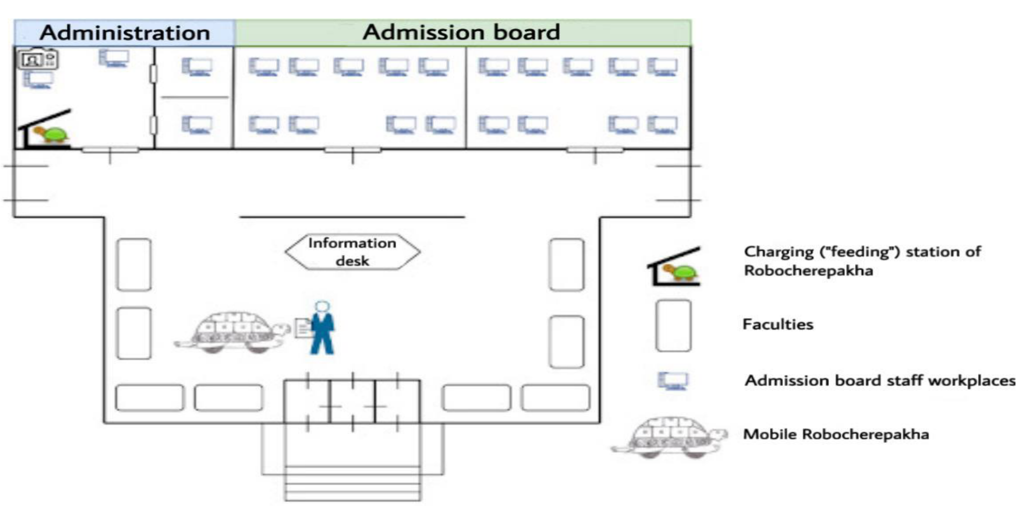
MATERIALS AND METHODS

Our research conducted in 2024 at Moscow Polytechnic University applied virtual and augmented reality technologies as well as cloud platforms for data processing during document submission for prospective students (Figure 1) and during open day events.

We used a mobile Robocherepakha, an autonomous device equipped with a camera, speakers, and a microphone, allowing it not only to read and process data but also to interact with users in real-time. Owing to its built-in SIM card module, it stays online even in remote locations without stable Wi-Fi, ensuring uninterrupted information transmission and processing. However, mobile service and constant internet access require a multi-level security system to prevent data leaks and unauthorized access.

A 3D model of the mobile robot was developed and optimized for integration into the AR scene. Interaction with users was carried out through QR codes that activated AR content. Special attention was given to information security: encryption methods, biometric locks, and browser sandboxing were used.

Fig. 1: Robocherepakha's functioning scheme within admission campaign



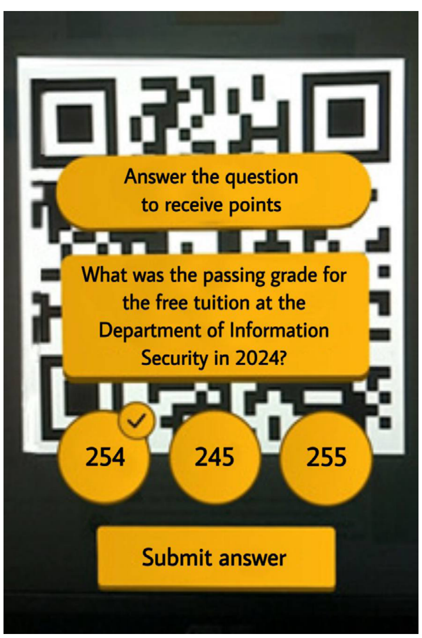
Source: Authors' own elaboration

It is essential to correctly define the hardware and software implementation of all its required components in order to enable the mobile robotic platform to collect questionnaires and transmit them to the university's database. For Robocherepakha, a safe with a code lock is proposed as the container for collecting applications, while its main body, equipped with a camera with machine vision, sensors, secure Wi-Fi for communication, and a "feeding station" for recharging the battery at the end of the workday, should be made of resistant to damage, durable and lightweight materials capable of withstanding significant loads (achieved by 3D printing).

For additional information, QR codes are placed on the 'turtle's' shell, leading to the university's website, the news feed, or the device owner's website. The QR codes also ensure ventilation of the internal equipment by creating through-holes along the contours of the codes, thus reducing the likelihood of equipment overheating. The robot finishes with the applicant and enters standby mode.

The specifics of interacting with prospective students during an open day can be seen in the example of an AR object using VR technology (QR codes). When the camera is pointed at the QR code, a 3D Robocherepakha model appears in augmented reality with a question for the applicant. The question provides three answer options. If the applicant answers correctly, the following message appears: "Congratulations! You answered correctly!" The applicant can then approach the volunteers during the open day and show the photo with the correct answer to receive points for their portfolio. Figure 2

Fig. 2: Dynamic AR-object demonstration.



Source: Authors' own elaboration

The experiment was structured as a practice-oriented educational project within the framework of digital transformation courses at Moscow Polytechnic University. Students participated in the design and testing of AR content, QR code integration, and visualization elements, gaining hands-on experience in educational technology development. This approach not only bridged theory and practice but also demonstrated how interdisciplinary collaboration uniting IT, design, and pedagogy can enhance professional readiness and critical thinking.

RESULTS AND DISCUSSION

First, a concept was developed within which the style of Robocherepakha was defined as futuristic, retro, cartoonish, or realistic. We chose the style of a stylized humanoid combining elements of a traditional biological turtle and modern technologies. Sketches were created to determine the Robocherepakha's construction, basic shapes, proportions, and design details, such as the placement of engines, sensors, and other elements.

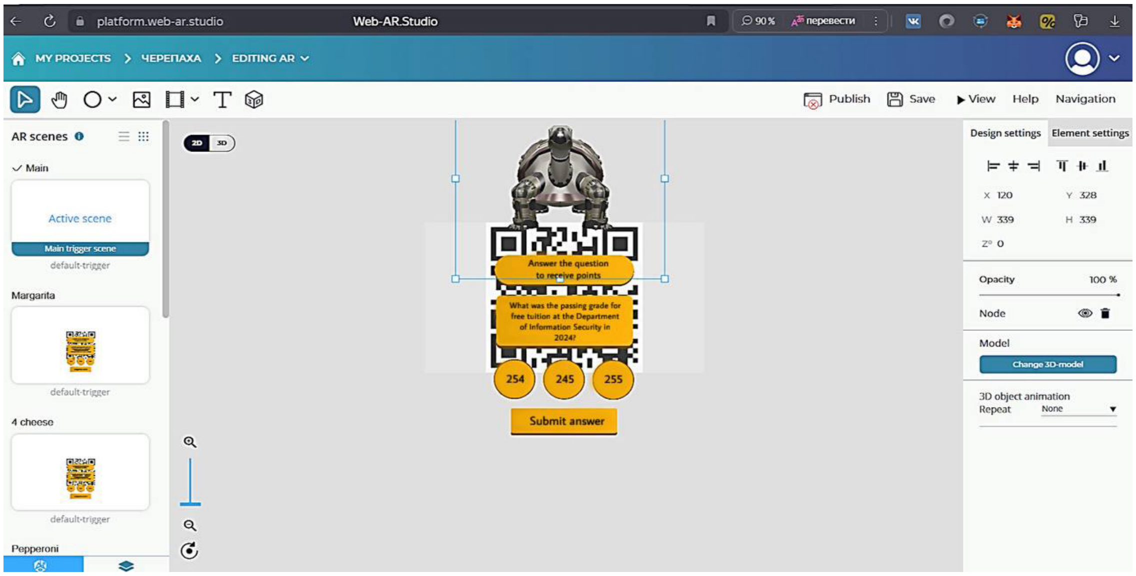
The 3D model was created using Blender software. In the first stage of the process, basic shapes were formed using the basic templates (primitives) of the program (cubes, spheres, cylinders, etc.), which were then gradually modified and connected to form the main parts of Robocherepakha: the shell, body, and limbs. Special attention was given to anatomical correctness, with smooth transitions between parts and the natural limbs curvature, etc.

In the detailing stage, small-sized details were added to the model: textures and colors. The developers aimed for a balance between detail and performance, as overly complex models could cause rendering issues in AR applications on devices with limited resources. All details were carefully worked out to ensure a realistic and attractive appearance.

To add realism to the model, textures were created. Developers used Photoshop™ to create maps for diffuse reflection, normals, roughness, and metallic shine. This allowed them to convey the peciliarities of materials such as metal, plastic, and other. Various techniques were used to achieve the desired level of detail and visual appeal.

Before exporting, the model underwent optimization for AR usage, including reduction of the number of polygons, simplifying the geometry, and optimizing textures for the best balance between quality and performance. Various export formats were tested to find the best format for the target AR application platform. The final model was exported in the glb format, compatible with the chosen Web-AR. Studio™ constructor (Figure 3). The model was then imported into the AR application and integrated into a gameplay or for interactive experience.

Fig. 3: Turtle integration into WebAR.Studio.



Source: Authors' own elaboration

Creating a Robocherepakha 3D model for AR is a multi-step process that requires professional 3D modeling skills and an understanding of AR technologies. The key factors for successful integration of the model into an AR application are proper optimization and format selection.

WebAR.Studio is a cloud-based constructor that allows creating interactive AR scenes that work directly in a browser without the need to download a separate app. Its key feature is the ease of use, allowing even non-technical users to create AR projects for marketing, education, or entertainment.

In this case, the final 3D model was prepared in the glb format, which is optimal (convenient) for web implementations, as it combines geometry, textures, and animations in one compressed file. After exporting, the model is uploaded into the WebAR.Studio editor, where it can be integrated into the scenario, whether it's a game, virtual fitting, or educational interactive activity.

The platform supports two main approaches to augmented reality: marker-based (when AR content appears upon recognition of a specific image) and markerless (using SLAM technologies to place objects on real surfaces). Depending on the task, the model can be tied to a QR code, geolocation, or simply activated when opening a link. In this case, the model was linked to a QR code.

Beyond its technical efficiency, the project revealed clear educational benefits. Students and visitors engaged in interactive AR sessions reported increased motivation, better understanding of digital interfaces, and higher satisfaction with the learning environment (Chávez et al., 2025; Chernova et al., 2025). The immersive, game-like format encouraged curiosity and self-directed exploration core elements of constructivist learning theories. These outcomes support the broader use of VR/AR as instruments for improving digital literacy and participatory learning within higher education.

Protection of Robocherepakha

First, physical access protection for Robocherepakha should be considered – a biometric lock that allows access only to authorized users, combined with a sheet-fed scanner, provides an additional level of physical security for the device. These measures will reduce the risk of unauthorized access and interference with the robot's operation. To increase security in case of unauthorized access, Robocherepakha will emit sound signals, drawing attention to attempts of hacking and recording instances of illegal actions.

An important aspect of the protection system is the regular update of Robocherepakha's software, which helps prevent vulnerabilities and increase the overall security of the device and transmitted data. Each update must be tested to identify vulnerabilities and implement fixes. Robocherepakha collects data and interacts with people: it uses speakers to announce instructions or answer questions, while its camera allows it to recognize users and adapt communication scenarios. In case of emergency situations (e.g., theft attempt, damage), the device sends a signal to the control center and takes defensive actions.

Browser Sandbox and its role in ensuring AR content security in Education Environment

A browser sandbox is a security mechanism that restricts web applications and content from accessing system resources on the device. In the context of augmented reality (AR), especially when using QR codes to activate AR content through WebAR, the browser sandbox plays a key role in minimizing attack vectors and protecting user data. The browser sandbox operation principle is shown in Table 1.

Table 1. Browser Sandbox operation principle.

Stages	Description
Restricting access to system resources	The browser sandbox restricts web applications' access to the operating system and hardware resources of the device. WebAR content running in the browser cannot directly access the file system, installed applications, or other critical elements of the device.
Permission control	The browser requests the user's permission to access resources such as the camera, microphone, or geolocation. These permissions are temporary and can always be revoked. Unlike native AR apps that often require constant access to these resources, WebAR content operates in a more restricted mode.
Process isolation	Modern browsers use isolation processes for each open website or web application. This means that even if an attacker manages to inject concurrent code into one website, they won't be able to access other browser tabs or processes.

Source: Authors' own elaboration

Steps of Working with the Sandbox Environment in WebAR are given in Table 2.

Table 2. Steps of working with the Sandbox environment in WebAR.

Steps	Description
Step 1	The user puts on AR glasses or uses a smartphone/tablet to interact with the WebAR content. With WebAR, the user scans a QR code, which redirects them to the WebAR platform through a browser.
Step 2	The browser or AR glasses request permission to access the camera and other necessary sensors (e.g., gyroscope, accelerometer) to activate AR functionality. The user must explicitly allow the access to proceed.
Step 3	After receiving permissions, the WebAR content (such as a 3D model, animation, or interactive object overlaid on the real world through the device's camera) loads and starts visualizing in the browser or AR glasses sandbox environment. Depending on the device, the user can interact with AR objects using gestures, voice commands, or touch input (e.g., rotate, move, or activate additional features).
Step 4	The information streams from the camera and sensors are processed locally on the user's device. In WebAR, processing occurs within the browser, ensuring data isolation and protecting it from being sent to third-party servers without the user's explicit consent. The user can close the app or browser at any time, which stops the AR content and ends access to the camera and sensors.

Source: Authors' own elaboration

The implementation of VR/AR technologies through deep content immersion not only attracts users with its unique functionality but also establishes a close connection between the user and the generated content, allowing it to be evaluated on all levels of perception (from theoretical to material).

The result of implementing VR/AR technologies is the feedback from users, characterized primarily by the necessity to interest the company's management by showcasing the benefits of utilizing and integrating the presented technologies into the ongoing business process, creating the necessary and high-quality content, and developing ergonomic software with gamification elements (such as intuitive, user-friendly interfaces, interactions in a quiz format, point accumulation, or a humorous voice guide). System effectiveness evaluation and reports based on the test results with recommendations for further development are necessary to be organized.

The implementation of the mobile Robocherepakha into the university's infrastructure helped solve a number of tasks related to its "smart" interaction with users and the attraction of applicants based on the use of gamification elements, a set of basic information-communication rules and the university's educational technologies, where one of the most relevant and modern approaches is the application of virtual and augmented reality technologies (VR/AR technologies). The positive result of implementing the mobile robot, aimed at interacting with people (clients, applicants, etc.), is always their evaluation and positive feedback, so the proposed technical solution must have scalability (automatic allocation of required resources), security, and reliability (fault tolerance). Let's inquire into these tasks in more detail.

From a technical point of view, one of the main advantages of WebAR.Studio is the built-in interaction templates. For example, a 3D object can respond to touches, trigger animations when the camera gets closer, or engage in simple game mechanics. All of this is configured visually without the need to write a code, although the mechanics can be extended via JavaScript if desired. The finished project is published on the platform's cloud or exported for self-hosting. Analytics are available: how many users launched the AR scene, how long they interacted with it, and which elements caused the most interest. In the case of Robocherepakha, the project was published in the platform's cloud.

Despite the advantages described, the solution has limitations. For instance, complex scenes with high-polygon models may lag on "thin" devices, and the free version limits the number of projects and adds watermarks. It may be wiser to resort to more flexible frameworks (A-Frame or Three.js) for custom scenarios with unique mechanics Nevertheless, if the goal is to quickly launch an AR campaign with minimal effort, WebAR.Studio proves to be a convenient tool, reducing the way from concept to working prototype.

The pedagogical dimension of immersive technologies lies in their ability to transform passive information consumption into active participation. By involving learners in simulation and visualization processes, universities can bridge abstract knowledge and real-world application. Moreover, VR/AR environments contribute to inclusion and accessibility, enabling students with different learning styles to interact with educational material in multisensory ways. The findings suggest that educational institutions adopting immersive technologies not only strengthen recruitment but also cultivate the digital competence and engagement of their students.

CONCLUSIONS

The integration of virtual and augmented reality technologies into university environments demonstrates significant pedagogical potential beyond their technical applications. When effectively implemented, VR/AR tools serve as catalysts for transforming traditional teaching into an interactive, student-centered process grounded in experiential learning. Their use enables students to visualize complex concepts, participate in simulated problem-solving, and engage in collaborative digital spaces that mirror real professional contexts.

In addition to enriching classroom experiences, immersive technologies contribute to digital competence development and interdisciplinary collaboration among students of engineering, design, and education programs. The university thus becomes a dynamic ecosystem where innovation, creativity, and applied learning converge. The inclusion of AR-supported open days and interactive admission activities illustrate how education and communication can be seamlessly integrated to strengthen institutional identity and accessibility.

Ultimately, the educational value of VR/AR lies in their ability to cultivate curiosity, critical thinking, and autonomy skills essential for lifelong learning in a digital society. By aligning technological innovation with pedagogical objectives, universities can ensure that immersive learning environments foster not only engagement but also meaningful knowledge construction and professional readiness for the challenges of the future.

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