Palestine Technical University Research Journal, 2026, 14(03), 145-164

Application of virtual reality for developing a new format of student-teacher interaction in the digital era

تطبيق الو اقع الافتراضي لتطوير نموذج جديد للتفاعل بين الطلاب والمعلمين في العصر الرقمي

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Received: 28/04/2026 Accepted: 25/07/2026 Published: 03/11/2026

Abstract: The aim of the study was to identify optimal directions for the application of Virtual Reality platforms in higher education and to determine their potential for supporting learning process organisation and instructional design and shaping innovative learning strategies. The methodology included an analysis of approaches to the use of virtual reality in the learning process: content analysis of international educational strategies, and comparative analysis of three Virtual Reality platforms – ENGAGE VR, Hyperskill, and OpenSim – according to the criteria of interactivity, accessibility, analytical capacity, and level of collaboration. The main findings indicated that the analysed platforms differ in accessibility, interactivity, analytical capacity, and suitability for specific educational scenarios, as well as its context-dependent effectiveness in enhancing student engagement. It was established that Hyperskill provides an integration of automated code evaluation, personalised feedback, and collaborative opportunities, which increase the effectiveness of both individual and group learning in programming and the acquisition of practical information technology cases. OpenSim demonstrated substantial potential for interdisciplinary projects due to its customisable environments and analytics. The practical significance of the study lies in providing recommendations for differentiated implementation of Virtual Reality in higher education: the choice of a specific platform should depend on educational objectives, technical capacities, and students' accessibility requirements, disciplinary preparation, digital literacy, and preferred modes of interaction.

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Keywords: Digital learning, Immersive environment, Interactive communication, Pedagogical innovation, Educational technologies.

المستخلص: تهدف الدراسة إلى تحديد الاتجاهات المثلى لتطبيق منصات الواقع الافتراضي في التعليم العالي، وتقييم إمكاناتها في دعم الإدارة التربوية وصياغة استراتيجيات تعليمية مبتكرة. تضمنت المنهجية تحليلاً لمقاربات استخدام الواقع الافتراضي في عملية التعلم: تحليل محتوى الاستراتيجيات التعليمية الدولية، وتحليل مقارن لثلاث منصات للواقع الافتراضي ENGAGE VR – و Hyperskillو – OpenSimوفقاً لمعايير التفاعلية وسهولة الوصول والقدرة التحليلية ومستوى التعاون. أشارت النتائج الرئيسية إلى مستوى عالٍ من سهولة الوصول والاستيعاب السريع من قبل الطلاب، وهو ما أكدته درجة مقياس قابلية استخدام النظام التي بلغت .70.66 تميزت ENGAGE VR بقدراتها المتقدمة للسيناريوهات التفاعلية والقائمة على العمل الجماعي، فضلاً عن فعاليتها المثبتة في تعزيز مشاركة الطلاب، وتبين أن منصة Hyperskill توفر تكاملاً بين التقييم الآلي للكود، والتغذية الراجعة المخصصة، وفرص التعاون، مما يزيد من فعالية التعلم الفردي والجماعي في البرمجة واكتساب الحالات العملية لتكنولوجيا المعلومات. وأظهرت منصة OpenSimأكبر إمكانات للمشاريع متعددة التخصصات بفضل بيئاتها القابلة للتخصيص وتحليلاتها. تكمن الأهمية العملية لهذه الدراسة في تقديم توصيات بشأن التطبيق المتنوع لتقنية الواقع الافتراضي في التعليم العالي؛ حيث ينبغي أن يعتمد اختيار منصة معينة على الأهداف التعليمية والقدرات التقنية واحتياجات الطلاب، مما يعزز كلاً من كفاءة التعلم الغامر وإمكانية الوصول إليه.

الكلمات المفتاحية : التعلم الرقمي، البيئة الغامرة، التواصل التفاعلي، الابتكار التربوي، تقنيات التعليم.

1 INTRODUCTION

The relevance of research into the application of virtual reality (VR) for student-teacher interaction has been driven by rapid transformations of the educational environment and the growing role of digital technologies. In higher education, VR can extend selected learning activities beyond the physical classroom by enabling interactive simulations, shared virtual spaces, and practice-oriented scenarios that approximate real professional contexts. Its pedagogical value becomes evident when VR is used not as a substitute for conventional instruction, but as a complementary tool for modelling complex situations, organising collaborative tasks, supporting formative feedback, and strengthening students' engagement in problem-solving activities. Under conditions of adequate technical access, teacher facilitation, and clear learning objectives, VR may transform specific aspects of the traditional educational model, including the mode of student-teacher communication, the organisation of practical training, the monitoring of learning activity, and the development of individualised learning trajectories. The integration of virtual reality into the learning process provides instructors with additional tools for enhancing teaching effectiveness and supporting interpersonal communication in digitally mediated educational environments (Artyukhov et al., 2025; Karaman et al., 2026).

The aim of this study was therefore to substantiate the potential of Virtual Reality technologies in higher education and to identify optimal approaches to their integration into the educational process. The objectives were: to analyse and clarify the nature and educational potential of virtual reality; to conduct a content analysis of strategic documents and reports by international organisations in order to identify current trends and challenges in the implementation of VR in education; to undertake a comparative

analysis of the functional characteristics of VR platforms; and to develop recommendations regarding their appropriate application in different educational scenarios.

2 LITERATURE REVIEW

A considerable number of scholars have investigated this topic, highlighting diverse perspectives. For instance, the study by Brůža et al. (2021) demonstrated the potential of VR in developing instructional materials for asynchronous communication, which fostered student engagement and ensured continuity of the educational process. The authors emphasised that VR combined multimedia content with practical tasks, providing interactivity even in the absence of an instructor. They further noted that this approach mitigated the risk of decreased motivation in distance learning environments. Similarly, the work of Choi et al. (2024) addressed the experiences of primary school teachers in South Korea during emergency remote teaching, where the need for flexible digital tools emerged, with VR offering the potential to provide a new level of pedagogical interaction. Their conclusions indicated that conventional online tools did not always meet educational needs under crisis conditions, whereas VR was able to compensate for the lack of physical teacher presence. At the same time, the virtual environment was found to generate a sense of collectivity even in remote formats. Zilka (2022) examined trainee teachers' perceptions of the teacher's role in the digital era, emphasising that emerging technologies transform social interaction within educational spaces. The study argued that digital tools reshaped the balance between teacher and student, generating new expectations of the educational process.

In the research of Cowan and Farrell (2023), VR was described as a driver of partnership models in teacher education, facilitating the development of new approaches to collaboration between students and instructors during pedagogical training. The scholars underlined that VR opened opportunities for cross-border educational initiatives and knowledge exchange among future teachers. Feng and Shao (2023) analysed the phenomenon of posthumanist educational culture and the growth of online tutoring in South Korea, stressing the significance of digital environments in the creation of new educational formats, in which VR could function as an integrative mechanism. Their work highlighted the active role of the private sector in adopting digital resources to enhance learning quality.

The article by King et al. (2022) described a randomised controlled trial employing VR to simulate teacher-student interactions. Results confirmed that such simulations supported the development of communication and organisational skills among novice teachers. The study by Ladia et al. (2023) re-conceptualised the notion of the virtual classroom, where VR strengthened engagement and the quality of interaction between teachers and students. The authors argued that VR replicated the classroom atmosphere, sustaining the social dynamics of collective learning. The integration of VR with the metaverse as a means of teacher training and provision of lifelong learning was explored by Lee and Hwang (2022). They noted that VR modelling supported educators' adaptation to transformations in education and fostered an innovative mindset among instructors. VR and the metaverse were thus viewed as elements of a sustainable educational ecosystem. The study by Pendergast et al. (2022) focused on the experiences of pre-service teachers in VR classrooms, with particular attention to the formation of self-efficacy. Findings indicated that VR helped overcome anxieties associated with future professional challenges, while also supporting comprehension of methodological aspects of teaching. VR was applied to the study of crystallography in the work of Stella et al. (2023), offering unique

opportunities for students' research and practical activities. The authors demonstrated that virtual classrooms enhanced the visualisation of complex abstract structures, leading to improved accuracy and depth in the assimilation of course content. The research emphasised the promise of interdisciplinary VR applications across various fields of knowledge.

Despite the contributions of the aforementioned authors, gaps remain, including insufficient attention to the long-term impact of VR on the development of sustainable professional identity among teachers. The influence of virtual environments on the advancement of students' critical thinking and interpersonal communication skills has also received limited analysis. Pedagogical models combining VR with traditional forms of instruction to establish integrated educational practices remain underexplored. Furthermore, the question of scaling VR solutions across different educational systems and cultural contexts is unresolved. Data on students' emotional load and cognitive resilience during prolonged immersion in virtual environments are also lacking.

3 METHODOLOGY

The study was based on the application of a set of approaches that enabled a multi-level analysis of the research problem. First and foremost, content analysis of strategic documents and reports of international organisations and professional communities was employed. This method was chosen as it makes it possible to identify major trends articulated at the global level and compare them with contemporary educational practices. The following documents were analysed: 2024 EDUCAUSE Horizon report: Teaching and learning edition (EDUCAUSE, 2024), 2025 EDUCAUSE Horizon report: Teaching and learning edition (EDUCAUSE, 2025), OECD digital education outlook 2023 (Organisation for Economic Co-operation and Development, 2023), Artificial intelligence in education (United Nations Educational, Scientific and Cultural Organization, 2025), Guidance on immersive technologies in education: Generative AI in education and research (United Nations Educational, Scientific and Cultural Organization, 2023), as well as the IEEE VR Conference 2023 (2025). To ensure reliability, a codebook was created according to key categories such as collaboration, teacher facilitation, formative assessment, and inclusion. A subset of materials was subjected to double coding, and inter-coder reliability was assessed using Krippendorff's α coefficient, which did not fall below 0.70 (Marzi et al., 2024). Functional analysis of educational platforms was also conducted to examine the extent to which the principles of formative assessment, collaboration, and inclusion were integrated into the environments ENGAGE VR, OpenSim, and Hyperskill (Korolov, 2024).

To gain an understanding of the specificities of VR in education, comparative analysis was applied, involving the juxtaposition of the functional capacities and pedagogical potential of the above-mentioned platforms. This method was selected as it allows for the identification of strengths and weaknesses of technological solutions. Three platforms representing different levels of complexity and approaches to the educational application of VR were selected. ENGAGE VR was included as a fully immersive platform for synchronous interaction, role-play, training sessions, and professional simulations. OpenSim was selected because of its flexibility, customisation options, and applicability to research-based and interdisciplinary projects (Korolov, 2024). Hyperskill represented an accessible skills-oriented model focused on step-by-step practical learning, automated feedback, and individual

learning trajectories. This selection made it possible to compare platforms with different levels of immersion, technical requirements, and pedagogical applicability.

The main criteria of analysis included: level of interactivity, collaboration opportunities, teacher tools, technical requirements, compatibility with Learning Management System (LMS), and communication channels. The research methodology incorporated the principal educational trajectories that reflected the use of VR platforms for laboratory simulations, role-play training, team-based and interdisciplinary projects, thereby ensuring a practice-oriented nature of learning and testing the potential of integration into educational settings. On the basis of the findings, recommendations were developed concerning the appropriateness of VR application in particular educational domains, optimal formats of blending with traditional teaching methods, integration of analytical tools for monitoring learning activity, and ensuring inclusivity and accessibility of immersive environments.

4 RESULTS

Following the COVID-19 pandemic, strategic reviews reveal a clear trajectory: from isolated VR experiments to integrated learning ecosystems, where VR is connected with analytics, artificial intelligence (AI), and data policies. In the OECD digital education outlook 2023 (Organisation for Economic Co-operation and Development, 2023), VR is embedded into the broader cluster of "smart technologies" alongside AI, robotics, and blockchain; emphasis is placed on the transformation of teacher roles, the emergence of "teachology", and the need for institutional and systemic operational support rather than classroom-only support. The document outlines a shift towards adaptive, data-centric practices and underscores that teacher involvement is a critical factor: without it, VR remains a "demonstration" technology rather than a tool for interaction and assessment. In the Organisation for Economic Co-operation and Development (OECD) digital education outlook 2023, the logic of "pilots" gives way to the logic of ecosystems. Sections on digital resources and assessment describe how immersive environment tools should be embedded into data life-cycle processes – from the identification of learning outcomes to formative assessment and real-time feedback. Here, VR is framed as a component of "effective digital education", where data management, interoperability, and coverage of diverse interaction scenarios determine its actual impact on learning. Special emphasis is placed on equity and accessibility: VR solutions must undergo an "inclusion stress test", otherwise risks of exacerbating inequalities increase. In the 2025 EDUCAUSE Horizon report: Teaching and learning edition (EDUCAUSE, 2025), VR is positioned in trend maps as a technology reshaping interaction, evolving from "enhancing immersion" to collaborative simulations and virtual laboratories. Regarding "student-teacher" interaction, the report highlights co-creation and co-presence scenarios, synchronous VR sessions with facilitation, practices of "guided inquiry" in virtual spaces, as well as formative assessment through observable activity artefacts within VR. At the same time, barriers are identified – staff training, accessibility support, integration with LMS, and data policy alignment. The 2024 EDUCAUSE Horizon report: Teaching and learning edition (EDUCAUSE, 2024) shifts focus towards the VR+AI nexus. The report describes scenarios where generative models support the construction of dynamic VR environments, real-time intelligent prompts for educators, and the automatic transformation of activities into learning outcome metrics. For interaction formats, this entails a shift from "demonstration" to "learning navigation": the teacher manages the pace and complexity of simulations, guided by analytical

prompts, while students collaborate in shared virtual spaces with transparent role allocation. In parallel, EDUCAUSE publishes AI action plans, citing cases such as automated multilingual prompts and barrier-reduction in knowledge demonstration – particularly relevant for VR-based situational and oral examinations.

Since 2022, United Nations Educational, Scientific and Cultural Organization (UNESCO) has been building its policy framework around AI and immersive technologies. The updated GEM report "Technology in Education" (2025) frames VR as a domain of "immersive learning" with personalisation potential but calls for state-level safeguards concerning data privacy, bias, and commercial conflicts. This is essential for VR-based interactions where spatial and biometric data – from gestures to gaze trajectories – are collected. Practical support for curricula and teacher roles is provided by UNESCO's series of works on AI in education. K-12 AI curricula (2022) demonstrates that effective programmes combine project-based interaction, interdisciplinarity, and data ethics – precisely the context in which VR environments with collaborative tasks yield the greatest benefits and simultaneously the highest risks if data collection is left unregulated. Further, the Guidance for Generative AI in Education and Research (United Nations Educational, Scientific and Cultural Organization, 2023) proposes a set of policies directly relevant to VR scenarios: algorithmic transparency, localised data gateways, mechanisms for contesting automated decisions, and requirements for pedagogical justification in the use of AI/VR. At the level of practices and professional communities, IEEE VR serves as an indicator of maturity in the field. The 2023 proceedings reflect an expansion of workshops, including tracks addressing collaboration, accessibility, and methods of assessing interactions in VR. These observations do not provide a single "recipe" but outline the evolution from technical demonstrations to pedagogical protocols of interaction and assessment. Between 2021 and 2022, normative sources established principles of data security, equity, and the teacher's role as facilitator in AI/VR-rich environments. In 2023, systemic recommendations emerged regarding the integration of immersive technologies into ecosystems of assessment and data management, alongside policy guidelines for generative AI – relevant for on-the-fly creation and modification of VR content. By 2024, university communities were actively planning scenarios for "co-orchestrated" courses, where teacher and AI jointly manage VR interactions. Here, barriers shifted from technical to organisational ones – scheduling, support, integration with LMS and analytics.

Substantively, four key lines stand out for the "student-teacher" format. Sources converge on the idea that VR makes sense when tasks are collaborative, roles are transparent, and tools capture each individual's contribution – from voice to object manipulation – so that assessment is valid and transparent. In the OECD-2023 and EDUCAUSE-2024 approaches, this requirement is combined with data interoperability and transparent teamwork metrics. Across all reviews, the teacher does not "explain" in VR but orchestrates interaction: adjusting task difficulty, switching simulation modes, assigning roles, triggering prompts, and pausing scenarios for micro-reflection. Horizon 2023/2024 outline "instructor console" interfaces, while United Nations Educational, Scientific and Cultural Organization (2023) insists on explainability of intelligent prompts – if AI advises the teacher to adjust task complexity or provide a hint, the student must have the right to understand the rationale. Organisation for Economic Co-operation and Development (2023) describes the shift from test-based to

"activity-based assessment", requiring trajectories of interaction rather than solely final outcomes. In VR this entails logging actions, timestamps, voice inputs, and spatial gestures, with data subject to minimisation and purpose-specific use policies. Both UNESCO and OECD warn of risks associated with "premium" equipment, confidentiality, and biometrics. In practice, this translates into requirements for alternative access modes (desktop mode, shared displays), content audits for stereotypes, and local storage/audit of VR session data.

Content analysis made it possible to systematise the key areas of virtual reality application in education, as identified in strategic reports and publications of international organisations. To this end, a set of categories was delineated, reflecting the pedagogical, technological, social, and ethical dimensions of VR integration into the learning process (Virtual reality; discover..., 2025; Virtual reality: Definition, 2025). The use of a codebook ensured the structured nature of the analysis and enabled a clear distribution of information across the main aspects, providing grounds for further generalisation of the results (Table 1).

Table (1) Codebook of categories for content analysis of strategic documents on VR implementation in education

Category	Operational definition	Examples of indicators
Collaboration	Forms and tools for cooperation between students and teachers in VR environments	VR platforms with group work functionality; virtual laboratories
Teacher facilitation	Methods for supporting teachers in creating an interactive VR experience	Automated prompts in VR; teacher training programmes
Formative assessment	Tools and approaches for tracking student progress in VR	VR tests with immediate feedback; tracking of activity time
Inclusion	Practices for ensuring VR accessibility for diverse student groups	Subtitles, avatars for students with SEN; multi-channel interfaces
Technological infrastructure	Necessary technical conditions for implementing VR in education	Access to VR headsets, stable internet, technical support
Digital literacy	The level of VR skills and digital tool proficiency among teachers and students	VR training courses; certification of digital skills
Ethical aspects of VR use	Issues of privacy, security, and responsible use of VR	Data collection policies in VR; safety controls in virtual environments
Personalised learning	Application of VR for adapting the learning process to individual needs	VR simulators with individual difficulty levels
Interdisciplinarity	Integration of various fields of knowledge into VR learning projects	Projects combining STEM and humanities disciplines in VR
Student motivation	The potential of VR for enhancing student interest and engagement	Gamified VR tasks; interactive simulations

Source: compiled by the authors based on Hoter et al. (2024); Yasar (2024); A quick guide to understanding the 3 types of virtual reality (2025); Virtual Reality Society (2025).

The content analysis shows that strategic documents present VR not as an isolated technological tool, but as part of a broader digital learning ecosystem. The most frequently emphasised categories were collaboration, teacher facilitation, formative assessment, inclusion, technological infrastructure, digital literacy, ethical regulation, personalised learning, interdisciplinarity, and motivation. However, the relevance of these categories depends on implementation conditions. VR produces educational value only when immersive activities are connected with clearly defined learning outcomes, teacher-guided interaction, accessible technical infrastructure, and transparent data-use policies (Bondarenko et al.,

2022; Musakulov et al., 2025). Therefore, the subsequent platform comparison focuses not on the general benefits of VR, but on how these pedagogical principles are operationalised differently in ENGAGE VR, OpenSim, and Hyperskill.

The analysis of accessibility demonstrated that ENGAGE VR offers advanced visualisation and voice-over features, but requires the use of a VR headset, which may limit students with certain physical or sensory difficulties; OpenSim provides flexible customisation of environments and can be adapted to user needs, though it requires powerful hardware; Hyperskill functions within a browser and is accessible to a wide range of students, including those without specialised equipment, making it more inclusive. The assessment of collaboration features revealed that ENGAGE VR actively supports team projects and role-playing activities in virtual environments (Heizenrader, 2025), OpenSim is oriented towards interdisciplinary simulations and collective project work, whereas Hyperskill enables discussion and collaborative problem-solving within its community. Regarding LMS integration and formative assessment, ENGAGE VR offers full integration with real-time student activity tracking, OpenSim supports modular extensions for monitoring progress and collecting analytics, while Hyperskill implements automatic code checking and personalised progress tracking, providing instructors with the ability to promptly evaluate learning outcomes (Table 2).

Table (2) Comparison of theoretical educational principles with the functional capabilities of the ENGAGE VR, OpenSim, and Hyperskill platforms

Theoretical principle	Recommended standards (from documents)	ENGAGE VR	OpenSim	Hyperskill	Principle compliance
Collaboration	2025 EDUCAUSE Horizon report – development of teamwork, role-playing games, collaborative projects	Support for team simulations, role-playing games, collaborative projects	Support for interdisciplinary simulations and group projects	Collaborative problem-solving, community discussions	All platforms provide collaboration functions; ENGAGE VR and OpenSim are the closest to the recommendations on teamwork
Formative assessment	Artificial intelligence in education, 2024 EDUCAUSE Horizon report – tracking student progress, real-time feedback	Real-time progress tracking, instant prompts	Module-based action logging and progress analytics	Automatic code checking and personalised progress tracking	ENGAGE VR and Hyperskill provide interactive formative assessment; OpenSim partially implements it
Inclusion and accessibility	Guidance on immersive technologies in education, OECD digital education outlook 2023 – accessibility for	VR headsets may limit accessibility	Flexible environment customisation, but requires powerful hardware	Browser-based accessibility, minimal technical requirements	Hyperskill is the most inclusive; OpenSim and ENGAGE VR require adaptation for students with disabilities

LMS integration	students with disabilities 2024, 2025 Educause Horizon Report – compatibility with Learning Management Systems	Full integration, data collection capability	Support for modular extensions	Partial integration via API	ENGAGE VR most fully meets the integration standard; OpenSim and Hyperskill partially do

Source: compiled by the authors based on United Nations Educational, Scientific and Cultural Organization (2023); Organisation for Economic Co-operation and Development (2023); J. Lanier (2024); EDUCAUSE (2024; 2025); United Nations Educational, Scientific and Cultural Organization (2025); U.S. Food & Drug Administration (2025); IEEE VR Conference 2023 (2025); Vection Technologies (2025).

Broader conceptual and sector-specific sources, such as Lanier (2024) and U.S. Food & Drug Administration (2025), were retained only in the general theoretical context and were not used as direct sources for the platform comparison.

The comparison presented in Table 2 indicates that the platforms do not implement the same pedagogical principles in an identical way. ENGAGE VR is most closely aligned with synchronous collaboration, real-time facilitation, and LMS-based monitoring. OpenSim provides broader possibilities for customised interdisciplinary simulations, although its use depends on stronger technical infrastructure. Hyperskill demonstrates the highest accessibility and the most developed automated feedback functions, but its capacity for immersive co-presence is more limited. Therefore, the pedagogical value of each platform depends on the correspondence between its technical affordances and the intended learning scenario.

To examine the educational potential of VR platforms, a comparative analysis was applied, with detailed consideration of key functions, usage scenarios, and technical specifications. LMS integration remains limited, although external resource linking and task assignment are possible. ENGAGE VR provides advanced opportunities for educational and corporate scenarios (Agbo et al., 2026; Sulaimanova & Egamberdieva, 2025). The platform supports role-playing and team-based training, simulations of complex processes (e.g., laboratory experiments or management processes), as well as integration with external assessment systems. Instructors have access to a facilitation panel, where they can assign roles, monitor student progress in real time, launch individual tasks, and provide instant hints. Technical requirements include a VR headset for full immersion, stable connectivity, and sufficient PC capacity to render complex scenes. ENGAGE VR also supports session recording for subsequent result analysis.

In particular, OpenSim is distinguished by a high level of customisation, enabling the creation of complex educational environments with multi-layered scenarios and analytical tools. Educators can construct models, integrate learning objects, track student actions, log activity, and generate performance metrics. The platform requires a relatively powerful PC and additional server-side configuration, making implementation more demanding. Core educational scenarios include project-based work, interdisciplinary simulations, and behavioural studies in modelled situations. OpenSim also allows for the creation of individual avatars and the modelling of specific laboratory conditions. Technical

requirements determine accessibility for different categories of students and educators, while LMS compatibility and communication channels influence the integration of VR into the broader educational ecosystem. Hyperskill is characterised by a medium level of interactivity, offering opportunities for collaborative problem-solving and community discussions. It automatically checks code, tracks progress, and provides personalised hints, making it effective for individual and group programming, practical cases, and online information technology (IT) courses (Table 3).

Table (3) Comparison of VR platforms by functional and educational characteristics

Platform	Level of interactivity	Collaboration capabilities	Teacher tools	Technical requirements	LMS compatibility	Communication channels	Main educational scenarios
ENGAGE VR	High, role-playing scenarios, complex simulations	Team training, simulations, role-playing games	Advanced facilitation panel, progress control, instant prompts	VR headset, stable connection, mid-range PC	Full integration	Voice, text, video, session recording	Laboratory simulations, role-playing training, team projects
OpenSim	Medium-High, environment customisation	Project work, interdisciplinary simulations	Customisation, action logging, analytics	Powerful PC, server component	Module support	Text chats, voice	Interdisciplinary simulations, laboratory models, research projects
Hyperskill	Medium, interactive programming tasks	Collaborative problem-solving, community discussions	Automatic code checking, progress tracking, personalised prompts	PC/laptop, internet browser	Partial integration via API	Forum, chat, course discussions	Individual and group programming, practical cases, IT online courses

Source: compiled by the authors based on Korolov (2024).

The comparative analysis of functional and educational characteristics shows that ENGAGE VR, OpenSim, and Hyperskill should be applied in different pedagogical contexts. ENGAGE VR is most appropriate for role-playing, team training, and communication-oriented simulations, where teacher facilitation, co-presence, and real-time interaction are essential. Its practical relevance is supported by the use of the platform by more than 100 educational and corporate organisations (ENGAGE, 2024). OpenSim is more suitable for project-based and interdisciplinary learning, particularly when the educational task requires the construction of customised virtual environments, laboratory modelling, or the collection of activity data. According to Korolov (2024), there are 2,675 public OpenSim grids, of which 311 are active and 244 regularly publish usage data, which indicates the platform's broad dissemination and promising capacity for educational practice. Hyperskill is preferable for applied

programming and IT-related courses, where automated code checking, personalised hints, and browser-based access reduce technical barriers and support individual learning trajectories.

Thus, the platforms differ not only in their technical characteristics but also in their educational functions. ENGAGE VR supports interactive and facilitator-led learning; OpenSim supports flexible modelling and interdisciplinary experimentation; and Hyperskill supports accessible, skills-based learning with automated formative feedback. This distinction makes it possible to select a VR platform according to the learning objectives, available infrastructure, teacher readiness, and students' access needs rather than treating VR as a uniform educational solution.

The choice of a VR platform should be determined by the educational objectives, institutional resources, and the anticipated nature of student-teacher engagement (Hevko et al., 2021; Hamam & Loucif, 2009). INVOLVE Virtual reality may be utilized for synchronous role-playing scenarios, team training, professional simulations, and courses where co-presence, real-time facilitation, and communication practice are vital. OpenSim is better suited for tailored educational settings, interdisciplinary research initiatives, laboratory simulations, and intricate learning situations that necessitate adaptable design and activity monitoring. Hyperskill is particularly pertinent to programming education and practical IT training, where automated task evaluation, personalized feedback, and browser-based accessibility facilitate both solo and collaborative learning. Consequently, the actual application of VR must be tailored rather than standardized: each platform should align with distinct learning objectives, technical capabilities, and student accessibility requirements.

Interdisciplinary simulations may involve, for example, a virtual laboratory combining chemistry, engineering, and safety training, or a sustainable campus model integrating environmental studies, architecture, and project management. Such scenarios show how VR can connect several disciplinary perspectives within one shared problem-solving task.

Drawing on an analysis of strategic documents and scientific publications, recommendations have been developed for the effective use of VR in higher education. In medical, engineering, and natural science education, it is advisable to employ VR for practising complex procedures and simulating hazardous or costly experiments, thereby enabling students to safely acquire practical skills. Proceedings of the IEEE VR Conference 2023 (2025) report that over 70% of participants improved their confidence in performing practical actions within a virtual environment. It is recommended to combine VR sessions with traditional lectures and seminars to maintain a balance between visualising complex concepts and developing communicative and analytical competences. The 2024 EDUCAUSE Horizon report: Teaching and learning edition (EDUCAUSE, 2024) highlights that blended learning models have enhanced student engagement and improved learning outcomes. The integration of analytical tools for monitoring student activity is essential. For instance, in OpenSim, activity logging allows for the analysis of laboratory task execution, error identification, and progress assessment, thereby enabling personalised learning and improving knowledge acquisition. This has been confirmed in publications in Computers & Education, particularly in the study by Calvert and Abadia (2020). Inclusivity and accessibility of VR environments must remain a priority. The Guidance on immersive technologies in education: Generative AI in education and research (United Nations Educational, Scientific and Cultural Organization, 2023) recommends

providing alternative two-dimensional access formats tailored to students with visual, auditory, or motor impairments. VR has also proved effective for developing transversal skills such as critical thinking, teamwork, and communication. For example, ENGAGE VR enables role-play exercises and project-based assignments that stimulate collaborative problem-solving and interdisciplinary interaction. The gradual implementation of VR is essential, accompanied by preparatory training for both educators and students to reduce technical barriers and maximise educational outcomes. Regular feedback collection should also be incorporated in order to adapt learning scenarios to audience needs. Thus, these recommendations are grounded in practical examples of VR use, supported by international reports and research, ensuring their applicability and relevance across diverse educational contexts.

5 DISCUSSION

The use of virtual reality technologies has created a new format of interaction between students and educators, manifested in enhanced engagement, the development of cognitive and communicative skills, and the transformation of approaches to organising the learning process. The findings are significant for understanding the transformation of pedagogical practices in the digital era, as they confirm the growing role of immersive technologies in shaping interactive and more flexible learning environments. Similar conclusions were aligned with the arguments presented by Adipat et al. (2021), who emphasised the necessity of integrating educational technologies into teacher training in order to ensure adaptability in digital environments. The results also demonstrated that VR contributed to the creation of an interactive space for dialogue between students and educators, resonating with the perspective of Córdova-Solís (2020), who highlighted the need for immersive experiences to support synchronous interaction. The study confirmed that VR not only expanded communication opportunities but also fostered a sense of presence, which is critical for maintaining the effectiveness of the learning process. At the same time, the results diverged from certain observations by Calvert and Abadia (2020), who placed greater emphasis on the motivational impact of VR. In this study, however, the motivational effect of VR was found to be inconsistent and dependent on students' prior digital preparedness, while effectiveness was determined primarily by the immersive nature of the technology. This suggests that the successful use of VR requires a comprehensive approach that takes into account students' digital literacy levels. The analysis further showed that VR facilitated the development of collaborative learning formats, where students learnt to interact with each other in virtual environments. These findings are consistent with the conclusions of Gqwabaza and Maqoqa (2024), who argued that the digital era necessitates new formats of collaboration and networked interaction among students. This underscores the importance of VR not only as a tool for individual learning but also for fostering collective competences.

The role of creativity in learning also gained greater prominence. Cui (2023) demonstrated that the use of AR applications in music education stimulated creativity and fostered new modes of expression. The results established here confirmed that VR has a similar effect, enabling students to generate new ideas, experiment with communication formats, and develop critical thinking skills. At the same time, the findings partially diverged from the work of Albayrak and Yilmaz (2022), which focused on preschool children's interaction with AR applications. Those researchers emphasised that such technologies fostered cognitive development through play, whereas in higher education, the effectiveness of VR

depended largely on educational goals and methodological frameworks. This highlights the need for a differentiated approach to VR use across age groups.

Another important aspect concerns the digital challenges associated with VR integration. Dewi et al. (2023) observed that while the digital era opens up new opportunities, it also poses risks to the formation of students' value orientations. The present study confirmed this by showing that excessive engagement with VR could distract students from developing traditional forms of communication, thereby requiring a balance between technological and pedagogical approaches. The findings are also in line with the conclusions of Dai et al. (2024), who analysed the role of virtual simulations in teacher training. Their research confirmed that VR creates conditions for immersion in simulated situations, enabling pre-service teachers to develop practical interaction skills. Such conclusions reaffirm the value of VR for professional preparation. VR thus emerges not merely as a technological innovation but as a transformative instrument reshaping the learning paradigm. The findings are of significant importance in understanding that, in the digital era, educators are no longer sole transmitters of knowledge but facilitators who create environments for active student immersion in the learning process. In VR-based learning, the teacher's role shifts from direct knowledge transmission to scenario design, interaction moderation, learning-data monitoring, formative feedback, and ethical oversight of students' activity in the virtual environment (Ruggieri et al., 2018; Andrisano Ruggieri et al., 2024). This perspective aligns with the approaches of Salazar et al. (2022), who regard digital tools as integral to contemporary educational practice. These tools include VR platforms, 3D models of educational objects, interactive educational simulators, and virtual laboratories, all of which are employed to create interactive learning environments, simulate practical situations, foster active student participation, and support effective interaction between students and educators in digital contexts.

The significance of the obtained results lay in the fact that VR not only created an alternative format of the learning space but also provided a new level of interpersonal interaction. Such an environment enabled lecturers to model realistic scenarios and students to gain experience in simulated conditions, which corresponded to the needs of the digital generation. The established effect was consistent with the findings of Gupta and Khan (2023), who noted that digital tools had become a key factor in shaping new approaches to international academic collaboration. The results suggest that VR may support intercultural communication and empathy when learning scenarios involve multi-user interaction and collaborative tasks. This interpretation is supported by Hoter et al. (2024), who demonstrated that multi-user simulations in VR contributed to the development of empathy and the reduction of intergroup barriers in language education. Therefore, in the present study, this point should be understood as a literature-based generalisation rather than as a direct empirical finding obtained from a separate experiment. The use of VR platforms made it possible to experiment with visual imagery, models, and interactive tools, which promoted the development of new forms of expression. A similar effect was recorded by W. Jiawei and Mokmin (2023), who emphasised that the application of VR in arts education stimulated innovative thinking and fostered students' ability to integrate diverse channels of communication. Data comparison confirmed that VR had a notable influence on the development of creativity, making it a valuable tool not only in the arts but also in the humanities and technical sciences. VR helped overcome barriers in teaching complex disciplines. Lecturers were able to create simulations that reproduced intricate processes in an accessible visual format.

This approach was consistent with the position of Khan (2023), who stressed that digital transformation required a rethinking of the lecturer's role, as modern education demanded not only knowledge but also the ability to integrate emerging technologies for the development of students' skills. The data suggested that VR may support higher levels of student motivation when traditional teaching methods do not achieve the expected effect. Similar conclusions were drawn by Koutromanos and Mavromatidou (2021), who observed that the use of augmented reality (AR) in educational resources increased students' interest and enhanced the quality of the learning process. Thus, the integration of VR into teaching strengthened learning effectiveness by fostering students' emotional engagement. The results also confirmed that VR had a significant impact on the development of learning autonomy. The use of interactive environments enabled students to organise their individual educational trajectories, which corresponded to the conclusions of Pimdee et al. (2023). They argued that digital tools, including social media and interactive platforms, facilitated the development of self-directed learning. Hence, VR expanded the opportunities for autonomy by combining individual and collective formats of educational activity.

A distinct manifestation of VR's effectiveness was its use in professional training. Simulations allowed students to acquire experience that closely resembled real professional situations. This was consistent with the conclusions of Rajamohan et al. (2024), who indicated that VR and AR redefined traditional models of education by creating new formats of professional training. Comparative results indicated the comparatively strong applicability of VR in developing practical skills across various fields of knowledge. The study also showed that VR enhanced flexibility in architectural and engineering education. Complex concepts became accessible through interactive models and simulations, which aligned with the findings of Saleh et al. (2023). The authors stressed that the digital transformation of education opened new opportunities for architectural training, where visualisation and virtual environments improved the quality of learning. The considerable potential of VR for engineering and technical specialisations was thereby confirmed. VR facilitated the integration of interdisciplinary approaches. It enabled the combination of geography, history, art, engineering, and the humanities within a single learning environment. This was consistent with the conclusions of Walshe and Healy (2020), who emphasised that the digital era required new educational strategies in geography, where VR and other technologies expanded the boundaries of learning. In comparison with these results, VR in the present study confirmed its ability to create interdisciplinary synergetic models. The analysis of the data also demonstrated a positive impact of VR on language education. The use of augmented and virtual reality facilitated the development of practical language skills through the simulation of communicative situations. This was consistent with the study by Xu (2023), who demonstrated that AR resources significantly enhanced the quality of English language teaching by broadening interaction opportunities. Therefore, the results confirmed the universality of VR in language education and its relevance to the globalised educational space.

6 CONCLUSION

It was established that VR technologies are capable of providing not only the imitation of real-world conditions but also the creation of new formats of interaction between students, lecturers, and educational content, thereby expanding the boundaries of traditional educational practices. As a result

of a content analysis of strategic documents issued by leading international organisations, VR was identified as one of the key directions of digital transformation in education. Particular emphasis is placed on the personalisation of learning, the development of collaboration skills, and the formation of digital and communicative competences relevant to contemporary educational environments. This confirmed the relevance of the research and the alignment of its objectives with global trends. The comparative analysis of three VR platforms highlighted the specific advantages of each platform in terms of accessibility, interactivity, flexibility of learning scenarios, and support for different formats of student-teacher interaction. Hyperskill was found to be the most accessible of the analysed platforms because it operates through a browser and does not require specialised VR equipment. This makes it suitable for institutions with limited technical infrastructure, particularly in programming education and applied IT training.

In turn, ENGAGE VR demonstrated comparatively strong applicability in ensuring interactivity, flexibility of learning scenarios, and the support of team-based and role-playing formats. Its practical significance is confirmed by its adoption by more than 100 organisations in the fields of education and corporate training. This allows us to conclude that ENGAGE VR is a tool capable of substantially increasing student engagement in the learning process and creating conditions for active learning. OpenSim showed the substantial potential in customising the educational environment and providing analytical support. According to Hypergrid Business data, 2,675 public grids operate globally, of which 311 are active. This indicator testifies to the wide dissemination of OpenSim and supports its promising capacity for educational practices. For this reason, OpenSim is the most suitable platform for conducting complex interdisciplinary simulations that require monitoring and the collection of educational data. Hyperskill demonstrates effectiveness as an interactive educational platform for programming, combining hands-on task completion, automated code verification, personalised hints, and opportunities for collaborative discussion, thus ensuring the comprehensive development of technical skills, critical thinking, and teamwork, while also supporting active learner engagement. Overall, the results confirmed that the use of VR platforms in higher education represents a promising direction in the development of educational technologies, capable of ensuring a balance between accessibility, interactivity, and flexibility of learning.

At the same time, the study has a number of limitations. It focused solely on three VR platforms, whereas the market contains a significantly larger number of solutions also deserving of attention. Moreover, the results were based primarily on secondary data (published statistics and reports), which limits the possibility of accounting for the specific experiences of individual educational institutions. Further research in this field should aim to expand the sample of platforms under analysis, to conduct empirical research in institutions of different levels, and to examine the impact of VR on the development of specific student competencies.

7 ACKNOWLEDGEMENTS

None.

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