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# EXPLORING VIRTUAL REALITY: A THEORETICAL REVIEW OF EDUCATIONAL GOALS, LEARNING DESIGN, AND EVALUATION

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**Abstract:** *The article provides a comprehensive overview of the basic principles for effectively integrating virtual reality (VR) into education. It is divided into separate sections, each focusing on a specific aspect of the integration process. The initial step in incorporating VR into education involves aligning the capabilities and applications of VR with the learning objectives of a particular subject or study program. The alignment includes defining the types of knowledge that VR use should support, emphasizing the critical need to synchronize these goals with a chosen VR application. The following section discusses the concept of educational design and explains the common strategies used for selecting or developing VR applications in an educational context. The third section delves into evaluating user experience design and learning outcomes, including a comprehensive typology of different learning outcomes. This can serve as a basic framework for evaluating the effectiveness of VR in educational settings. The article concludes by providing a set of basic guidelines to help educators and designers select or develop VR applications that align with educational goals.*

**Keywords:** virtual reality, education, immersion, learning, virtual environment

## INTRODUCTION

Virtual reality (VR) technology has been gaining attention in recent years, not only within the entertainment industry but also in formal and informal education. According to research (Kardong-Edgren, Farra, Alinier, & Young, 2019), VR has emerged from a period of disillusionment in recent years, and the initial interest has transformed into a realistic understanding of what can be achieved with immersive technologies. Currently, VR is positioned on the slope of enlightenment on the Gartner

Hype Curve, and a secondary wave of innovation is underway as new and effective ways of utilizing the technology are being validated.

Definitions of VR are generally based on the combination of a virtual 3D environment and several forms of user experience. VR is a computer-generated, three-dimensional graphical representation of a real or an imaginary environment in which users experience a strong sense of presence and immersion (Chen, Zhou, & Zhai, 2023). This is achieved using a special headset or a series of display walls.

Modern head-mounted displays (HMDs) represent a promising technology. These devices are becoming increasingly affordable, and their ability to isolate users from the external environment contributes to an enhanced sense of presence (Grassini & Laumann, 2020). Furthermore, contemporary HMDs offer users unrestricted movement, made possible through wireless communication with the computing system or through the intricate integration of the computing device directly into the HMD. An alternative to a simple and inexpensive HMD solution is the CAVE (Cave Automated Virtual Environment). A CAVE is usually a 10’ × 10’ × 10’ cubic room in a larger darkened space. Its side walls comprise canvases with rear projection, sometimes supplemented by floor projection. Advanced CAVE systems can also project scenes onto the ceiling to create a six-sided configuration (Muhanna, 2015). The scenes displayed on the screens adjust and rotate based on the user’s movement among the individual display elements. Users typically wear stereoscopic eyewear and interact using hands, data gloves, joysticks, or other input devices.

The immersive nature and sense of presence engage students in learning activities and help them acquire cognitive, emotional, and physical skills more effectively. In VR, communication allows users to interact with virtual objects through different senses, such as sight, touch, and manipulation (Huang, Rauch, & Liaw, 2010). This involvement of multiple sensory channels facilitates the complex acquisition of learning experiences and supports the continuous and permanent development of knowledge and skills (Ustun & Tracey, 2020).

Many studies highlight the educational benefits of VR, but some aspects are often sidelined or overlooked. Some research points to the tendency of researchers to be initially charmed by the novelty and excitement of using advanced technology, which often leads to over-refining the results or focusing on the wrong elements.

This article comprehensively explains the theoretical foundations for designing and implementing VR technology in education. The article is structured into several key sections, each dealing with a specific aspect of the integration process.

In the first part, the article focuses on the importance of defining educational goals and the types of knowledge that VR should seek to develop. It emphasizes aligning these goals with the specific VR application in question. The second section deals with the definition of educational design and provides insight into the various strategies commonly used to select or develop VR applications in the educational process. The third section explores the evaluation of user experience design and learning outcomes, including a typology of different learning outcomes. This section outlines the basic principles of evaluating the effectiveness of VR in education.

In conclusion, the article presents a set of basic guidelines to help educators and designers select or develop VR applications suitable for educational purposes.

## 1. EDUCATIONAL GOALS

Using VR in educational contexts should be a carefully considered step, avoiding spontaneity. Given the complex requirements of content creation and methodology development, the incorporation of VR should be guided by a thoughtful approach, carefully aligned with the overall learning objectives, to ensure that it enhances and complements the established curriculum without detracting from it (O'Connor, 2020). As a rule, the primary, measurable efficiency indicator is the results of education. In the process of integrating VR into educational paradigms, educators are tasked with effectively using its immersive appeal to strengthen and expand students' understanding of basic concepts, critical cognitive skills, and the ability to navigate complex problem-solving scenarios (Shi, Wang, & Ding, 2022), (Pottle, 2019), (Chang, Hsu, & Jong, 2020).

In line with Bloom's Taxonomy (Bloom, 1984), educational objectives typically fall into three categories: cognitive, affective and psychomotor objectives. By integrating insights from these sources and incorporating (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020), (Vukić, Martinčić-Ipšić, & Meštrović, 2020), (Diab & Sartawi, 2017), and (Makransky & Petersen, 2021), a more comprehensive understanding of educational goals in a VR environment can be obtained. This can be achieved by evaluating learning objectives through the lens of Bloom's taxonomy, which defines different levels of cognitive complexity. From this point of view, it is possible to determine specific categories of knowledge and skills based on a combination of several pedagogical theories (behaviourism, constructivism). The aim is to provide a more precise terminology for the types of knowledge and skills acquired when using VR resources.

- **Declarative knowledge** contains factual and conceptual knowledge. Factual knowledge is represented by basic (isolated) information related to intellectual abilities and knowledge acquisition, usually involving the understanding and retaining of specific information, details, and concrete facts. In science education, factual knowledge refers to the actual details of scientific facts rather than abstract ideas, concepts, or personal interpretations (Hew & Cheung, 2014). Conceptual knowledge is characterized by understanding complex, structured forms of knowledge that may include classifications, categories, principles, and generalizations. This category is sometimes expanded to include complete theories, models, and overarching structures (Makransky & Petersen, 2021).
- **Procedural knowledge** is understanding how to perform specific procedures, processes, or activities. It means understanding how to perform a task, follow prescribed procedures, master various techniques, or perform a specific function. Procedural knowledge includes the ability to perform tasks with fluency and accuracy. According to (Radianti et al., 2020), VR is most often used to build this type of skill. Acquiring procedural knowledge has been a typical element of VR since its introduction, especially when training for complex or dangerous real-world scenarios such as medical interventions (De Ponti et al., 2020), (Javaid & Haleem, 2020), safety operations (Morélot, Garrigou, Dedieu, & N'Kaoua, 2021), (Çakiroğlu & Gökoğlu, 2019), etc.

- Acquiring **analytical and problem-solving skills** is an integral part of most VR applications. By immersing students in interactive and dynamic scenarios, their active involvement, critical thinking, and creativity in solving challenges become intrinsic to activities in the virtual world (Araiza-Alba, Keane, Chen, & Kaufman, 2021). In VR, problem-solving is not solely about theoretical understanding, as students are placed in complex situations where they must analyse information, devise strategies, and make decisions. The overall functionality of the concept of building this type of skill is explained by (Vimal Krishnan & Onkar, 2019), while a significant result is that students with less favourable attitudes towards learning benefited more from the activity than students with more positive attitudes (Wu, Guo, Wang, & Zeng, 2021).
- **Communication and collaboration skills** are not originally included in Bloom's taxonomy but represent a necessary component of educational and work processes. VR environments offer a unique platform to enhance this skill by facilitating immersive and interactive experiences that simulate natural social dynamics. The utilization of these skills is frequently an integral aspect of problem-solving (Planey, Kim, Mercier, & Lindgren, 2023), engineering, or technical education (Tuttle, Savadatti, & Johnsen, 2019), (Hatzipanayioti et al., 2019). Some activities and research specifically focus on improving collaboration and communication skills while comparing them to their real-world counterparts (Dzardanova, Kasapakis, Gavalas, & Sylaiou, 2022).

Many authors who conducted VR experiments overlook or do not explicitly mention the connection to educational goals in their research. However, it is essential to emphasize that setting learning goals should be the first and most crucial step when considering the integration of VR into the learning process. Before integrating VR into education, it is essential to determine if and how VR can enhance the learning process and more effectively achieve educational goals compared to traditional methods. Only in the case of a positive answer and establishing sub-goals does the design phase begin, which includes determining learning strategies and activities. This approach ensures that the experiments are not narrowly focused and that the results remain unbiased.

## 2. LEARNING DESIGN DEFINITION

If the initial considerations of incorporating VR into specific topics demonstrate the potential to improve the learning process, it is possible to start designing specific elements for the VR environment. The primary goal is to create a strategy for seamless integration of VR into the curriculum. The essential design components are learning strategies and learning activities. Learning strategies consist of defining the inclusion of VR in the teaching process. Possibilities may include using VR as an introductory tool, a knowledge fixation method, or a tool to facilitate practical application. Learning activities are designed to be engaging, interactive, and follow the intended learning outcomes.

Implementing VR as a learning tool involves considering suitable strategies to maximize its benefits. Referring to the established classifications detailed in (Akdeniz,

2016) and the categorization used in a review examining the use of VR in educational contexts (Pellas, Mystakidis, & Kazanidis, 2021), the following instructional design strategies were the most frequently used in higher education:

- **Presentation**, in its original form, uses a teacher-centred approach in which students use predefined content with limited interactive functionality (such as adjusting the view or viewing position). Activities typically allow students to explore learning content in detail through 360° videos without haptic controls to interact with the virtual content.
- **Activity-based** represents strategy based on activities aimed at solving tasks in which the student progresses at his own pace under the teacher's guidance (Pellas et al., 2021). The teacher continuously monitors the student and provides him with the necessary feedback. The trend of recent years is that educators are increasingly reluctant to leave learning in this form completely under the student's control (Sharma & Kumar, 2018), and therefore, VR represents a suitable environment combining the student's freedom and the teacher's control.
- **Discovery** is an instructional strategy incorporating self-directed and constructivist learning (Bruner, 2020). It offers a student-centred design that encourages inductive reasoning and progression from the concrete to the abstract based on the realization of discovery activities (Akdeniz, 2016). Typical examples are virtual laboratory experiments, geographical concepts in discovering unknown locations or studying ecosystems, creative work, solving problems, etc.
- **Inquiry strategies** provide educational approaches and techniques that support the process of discovery, questioning and seeking answers as part of the learning process. Shamsudin et al. (Shamsudin, Abdullah, & Yaamat, 2013) defined decision-making, critical thinking, adaptability, tolerance and autonomy as the most important competencies. Typical examples based on this strategy include simulation of problem situations, various types of observations (astronomical, biological, historical, etc.) with extension to experimentation, etc.
- **Cooperative / Collaborative strategies** are aimed at the student, while one of the primary goals is social interaction in study groups, work sharing or joint problem-solving (Akdeniz, 2016). This instructional strategy requires system designers to enable multiple users to simultaneously communicate with others using the same VR application (Pellas et al., 2021). These activities can be the goal of education or just a tool to achieve the goal.
- **The experiential instruction strategy** as defined by Pellas (Pellas et al., 2021) allows students to learn through hands-on practice by engaging in various tasks tailored to their personal experiences. It is a strategy based on the intersection of the approaches mentioned above.

The choice of specific activities to achieve educational goals also varies depending on the age of the target audience. The studies mentioned in (Pellas et al., 2021) used project-based, game-based, and problem-based learning for the K-12 age group. In addition, studies have been based on a teacher-centred approach within specific instructional design, such as observing 360° videos in the classroom and virtual field trips in informal environments.

For older students, especially in higher education, the architecture of learning activities is shifting toward monitoring student interactions within instructor-led simulations. This often involves engaging in exploratory activities to discover solutions through research and interaction with the virtual environment. Another approach involves integrating experiential learning and presentation, allowing students to follow predefined educational content and apply it through practical activities (learning by doing). Problem-based collaborative learning allows multiple users to simultaneously interact with others to solve defined problems, either in the virtual or real world.

A key aspect of implementing VR applications into the educational process is the principle of student-centred learning, which makes the most of the immersive nature of VR to create an educational environment that puts students at the centre of their learning journey. This approach not only harnesses the potential of VR for engagement but also enables personalized and enriched learning experiences tailored to the needs and strengths of individual students.

## 3. EDUCATIONAL OUTCOMES EVALUATION

In AR/VR-based learning activities, typical learning outcomes include content knowledge, skills, and perceptions (Chen et al., 2023). Among them, perceptions are the most frequently evaluated outcomes due to the ease of administering questionnaires to participants. When introducing a new and unfamiliar technology or device using a learning environment, the emotions and attitudes of users play a crucial role in influencing their retention of information. As a result, many reviewed studies focused primarily on evaluating user perceptions.

However, evaluating the VR application in education includes two key aspects: the user experience (UX) design of the created objects and the educational impact of achieving learning goals.

**UX design evaluation**

There are two basic approaches used in VR to assess UX. One uses the derivations of the **TAM** model (Davis, Bagozzi, & Warshaw, 1989), while the other uses a large group of questionnaires created and edited by researchers.

The Technology Acceptance Model (TAM) is a widely used theoretical framework in information systems and technology management. TAM is designed to help understand and predict how individuals perceive and adopt new technologies, particularly in a workplace or organizational context. The model is based on the idea that perceived usefulness and perceived ease of use are the primary determinants of technology adoption and use. The key components of the technology acceptance model are perceived usefulness, which assesses whether an individual sees value in using the technology; perceived ease of use, which assesses the perceived simplicity and user-friendliness of the technology; behavioural intention to use expresses the level of perceived usefulness and ease of use - if an individual perceives technology as valuable and easy to use, they are more likely to use it; actual use of the system reflects whether people use technology in their work or daily activities.

One of the first models based on TAM and modified for use in VR is the model proposed by van Raaij (van Raaij & Schepers, 2008). This model builds on **TAM2** (Venkatesh & Davis, 2000) and includes moderating factors such as subjective norms, personal IT innovativeness, and computer anxiety.

Research (Ustun, Karaoglan-Yilmaz, & Yilmaz, 2023) builds on the **UTAUT** model (the Unified Theory of Acceptance and Use of Technology) defined in (Venkatesh, Morris, Davis, & Davis, 2003) and on the evaluation design uses the standard four factors (performance expectancy, social influence, effort expectancy, facilitating conditions), and modifies their items to reflect the acceptance of VR.

**CAMIL** (Cognitive Affective Model of Immersive Learning), defined in research (Makransky & Petersen, 2021), describes six affective and cognitive factors that can lead to VR-based learning outcomes: interest, motivation, self-efficacy, embodiment, cognitive load, and self-regulation. The model also describes how these factors lead to factual, conceptual, and procedural knowledge acquisition and transfer.

The summarization of UX evaluation models established over some standardized approaches provides valuable insight into simplifying and complicating UX evaluation based on questionnaires standardized for other technologies.

Currently, there is no direct and generally accepted model. Based on a critical analysis of the literature (Mütterlein & Hess, 2017), it is clear that in recently conducted research studies, there are significant differences in evaluating specific properties that describe virtual reality elements. The specific characteristics selected for evaluation were selected and used inconsistently and, in some cases, specified imprecisely. Presented research identifies standard features such as content quality, initial excitement, isolation, and distraction as potentially significant in VR.

The ideal user experience evaluation model may take some time to develop. While traditional UX evaluation models exist for other digital platforms, adapting them to the VR domain is challenging. Extensive research in this area shows that researchers are actively working to develop specialized VR-specific UX evaluation frameworks. Until these models are established and widely accepted, UX evaluation in VR remains an evolving and dynamic field.

**Learning outcomes evaluation**

Evaluation of learning outcomes in VR typically depends on the specific goals of the learning program and the content of the VR being used. There is no one-size-fits-all method or approach; evaluation should be tailored to the specific objectives, context, and content.

Research (Abich, Parker, Murphy, & Eudy, 2021) identified knowledge, skills and abilities that can be effectively trained or improved using VR and divided them into psychomotor performance, knowledge acquisition and spatial abilities. The items identified in the review (di Lanzo et al., 2020) encompass three broad and main categories: cognitive outcomes, skill-based outcomes, and affective outcomes, and each group can be described as follows:

- Cognitive outcomes aim to evaluate the dynamic processes of acquisition, organization and application of knowledge, which represents improving or enhancing students' knowledge retention and overall understanding. Assessment of cognitive skills includes tests and tasks that verify students' ability to correctly answer questions or solve problems related to the subject matter.
- Skill-based outcomes include performance assessment in simulated and training environments focusing on developing technical or motor skills that can lead to improved academic performance. Their assessment requires practical tests or simulation tasks that verify whether students can successfully perform a given activity.
- Affective outcomes assess aspects such as attitudes, motivations and goals related to learning objectives that facilitate the development of both professional and personal skills, often falling into the soft skills category. Assessment of affective skills involves measuring changes in attitudes, motivation, and emotions through surveys or student feedback assessments.

In the context of these categories, it is necessary to consider the specific type of knowledge or skills and choose the appropriate assessment methods and tools most relevant to them. Regarding cognitive skills (knowledge), the student's ability to understand, remember information or apply it in different contexts is verified. For practical skills, it is essential to determine whether the skills developed by pupils trained in different ways impact their subsequent practical application in a natural environment. Focusing on affective skills involves monitoring and evaluating changes in students' emotional and motivational spheres and verifying whether these changes positively affect their learning and performance.

Within each skill category, it is essential to define specific categories of outcomes that can be tracked and measured when evaluating the effectiveness of VR in education. Their choice depends on the goals of the research and the needs of individual characteristics to participate in the overall picture of the results. Based on the summarization of research, the following categories of measurable educational outcomes were identified (Christou, Tzanavari, Herakleous, & Poullis, 2016), (Safikhani, Holly, Kainz, & Pirker, 2021), (Abich et al., 2021), (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014), (Barbot, Kaufman, & Myszkowski, 2023), (Shaw et al., 2019):

- **Quantitative results**:
  - The **accuracy and success** of the tests reflect the degree of correctness in solving tasks, quizzes, knowledge retention tests, or problems in VR.
  - **Success in achieving goals** in VR can be expressed through various metrics, including the number of attempts required to achieve a successful outcome or using a success rate that represents the level of task completion in percentage.
  - The **speed of execution**, or the **time required to complete tasks** in VR, is essential in training scenarios where the success of the activity depends on completing it within a specified time interval.
- **Qualitative results**

  - **Deeper understanding** refers to the student's ability to apply the knowledge and concepts they have acquired at a deeper level.
  - **Creativity** represents the ability of students to generate new solutions or approach problems creatively. The ability to think outside the box, create innovative ways of solving problems and develop new ideas can contribute to a deeper understanding and development of critical thinking.
  - **Analytical and critical thinking** are closely related to creativity and deeper understanding. By singling out this category as a separate entity, the assessment of VR contribution primarily focuses on detecting changes in analytical, critical evaluation, and problem-solving skills.
  - The development of **communication and cooperation skills in** a virtual environment can be effectively facilitated through various means, such as role-playing, social networks, and collaborative activities.
- **Skill level:**
  - Developing **practical skills** is a fairly common goal in virtual applications. It focuses on activities that are key to preparing students for real work situations and increasing their practical skills (Aïm, Lonjon, Hannouche, & Nizard, 2016), (Gavish et al., 2015) developed within the scope of the SKILLS Integrated Project, for industrial maintenance and assembly (IMA.
  - **Spatial ability** is one of the first abilities developed in early VR models. It represents a specific skill and is related to improving spatial orientation for general use or developing skills for people with specific needs (Moreno, Posada, Segura, Arbelaiz, & García-Alonso, 2014).

Effective measurement of the various learning objectives in VR is key to understanding its effectiveness comprehensively. These are aligned with cognitive, practical, creative, spatial, and collaborative skills acquisition. Quantitative and qualitative data, including standardized tests, time spent on tasks, success rates, interactions, responses to open-ended questions, and project evaluations, are essential for a comprehensive assessment.

By integrated evaluation of all these types of data, it is possible to obtain a comprehensive view of student development within VR applications. In addition to quantitative results, it is also necessary to consider qualitative elements and skills, such as attitude, motivation, and application of acquired knowledge in real scenarios.

## 4. DISCUSSION AND CONCLUSION

Incorporating virtual reality into traditional educational methods brings positive results in the cognitive, skill and affective aspects of learning (di Lanzo et al., 2020). However, a comprehensive understanding of the real benefits of VR in education is currently limited due to the small number of study participants, the absence of a formal evaluation of the proposed tools, and problems related to standardization and transparency in evaluation processes and metrics. Another notable issue is the lack of realism in the virtual environment, which can distract students from their intended learning tasks and potentially compromise the immersive learning experience.

As educational technologies continue to evolve in the context of VR, it is crucial to explore and adapt effective theories and strategies from previous educational approaches. Many studies have produced inconclusive or inconsistent findings because researchers sometimes neglect educational design and do not fully exploit the possibilities of VR.

When designing and integrating VR applications into the educational process, aligning this process with fundamental educational principles, including educational goals, the definition of educational design, and the evaluation of educational objects in VR is essential.

The learning objectives provide clear direction and purpose for integrating immersive technologies and ensure that they contribute to the overall learning objectives of the subject or program of study. VR should be integrated into the curriculum through a well-defined plan that includes using VR objects to align with specific learning objectives, content delivery methods, and pedagogical strategies.

Part of the proposal for integrating VR into the educational process should also be an assessment of whether and how VR will effectively increase the quality of the educational process. Ongoing evaluation, which includes measuring the impact of VR experiences on student learning, understanding and skill development, is the first prerequisite for ensuring the effectiveness of VR in education. Final assessment methods should be designed to align with learning objectives, allowing educators to assess the actual success of VR integration. However, ongoing research suggests that integrating complex elements into VR training can significantly increase effectiveness.

Virtual reality is a powerful educational partner that transforming traditional teaching methods into immersive and engaging experiences. As technology continues to evolve, so does the potential of VR to enrich the learning process. It brings abstract concepts to life and equips students with practical skills in a safe and controlled environment. A gamified approach encourages curiosity, creativity, and a thirst for knowledge, making learning an exciting journey. The future holds endless possibilities to evolve and integrate seamlessly into the educational curriculum.

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