Virtual Reality and Augmented Reality in Education

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Virtual reality (VR) and augmented reality (AR) are emerging technologies with a variety of potential benefits for sustainability education. Here, learning processes such as flow and presence seem to determine the learning experience. VR is understood as a computer-generated simulation that is three-dimensional (3D), multisensory, and interactive. The user can inhabit and act within a virtual environment. VR enables unique learning scenarios, as simulations allow students to act as if they were in a real environment while interacting with otherwise intangible or inaccessible objects. VR provides users with the experience of a different world that may otherwise be too dangerous, expensive, or impossible in the real world. AR, in contrast, is used to enhance and enrich the real-world learning experience. It involves overlaying digital information, such as images, videos, 3D models, or text, onto the real-world environment to provide users with additional context, interactivity, and engagement.

Keywords: virtual reality ; augmented reality ; xReality ; flow ; presence

1. Introduction

Virtual and augmented reality (VR/AR) technologies have increasingly gained attention in educational settings over the recent years. They are expected to be widely used in classrooms, but investigation of their educational potential has only just begun [1][2][3]. However, the nomenclature surrounding VR and AR technologies is somewhat disputed. On one hand, VR and AR could be viewed as end points on the same spectrum, where the distinguishing feature is the degree of immersion [4]. On the other hand, AR and VR could be construed as two different qualities of experience, where AR applications address a form of physical presence augmented by virtual features while VR aims at a form of telepresence, or feeling present within the virtual space [5]. Hence, Rauschnabel et al. [5] use the umbrella term xReality or XR to describe both AR and VR technologies, where the X denotes a placeholder. Here, it is not appropriate to equate XR with extended reality [6]

2. Virtual Reality and Augmented Reality in Education

2.1. Classification of VR/AR Technology

VR is understood as a computer-generated simulation that is three-dimensional (3D), multisensory, and interactive. The user can inhabit and act within an external environment [7][8]. VR enables unique learning scenarios, as simulations allow students to act as if they were in a real environment while interacting with otherwise intangible or inaccessible objects [9][10]. VR provides users with the experience of a different world that may otherwise be too dangerous, expensive, or impossible in the real world [11][12]. AR, in contrast, is used to enhance and enrich the real-world learning experience. It involves overlaying digital information, such as images, videos, 3D models, or text, onto the real-world environment to provide users with additional context, interactivity, and engagement [13].

In everyday language, the terms VR and AR are often used as umbrella-terms including a variety of heterogenous technologies [14][15]. Thus, VR and AR are presented to users through different technological approaches and devices, each offering distinct experiences. Whereas head-mounted displays (HMDs) completely immerse users in a computer-generated virtual world by covering their field of vision with screens [16], mobile devices' cameras are commonly used for AR learning scenarios by embedding digital content into the real world [17]. Further technologies are also utilized, for example HoloLens for AR, and various mobile devices (e.g., tablets) for VR. It has been demonstrated that many researchers face challenges when categorizing the technology they utilize. In many cases, a distinction is also made between immersive technologies (e.g., HMDs) and non-immersive technologies (e.g., tablets). However, often, a single technology combines features of both AR and VR [1], as is the case for the application investigated in the present study. Rauschnabel et al. provide a suitable alternative by introducing the term XR, with the X serving as a placeholder [5].

2.2. Learning with VR/AR

VR and AR technologies are considered to have great potential for designing teaching and learning scenarios. They open a range of multifaceted applications for schools, universities, and other educational institutions [1][2][3][18]. The Cognitive Affective Model of Immersive Learning (CAMIL) addresses two facets of immersion that improve learning through XR technology: agency and presence [19]. A higher degree of interactivity as well as the feeling of actually being in the virtual environment and interacting with seemingly real social agents are beneficial for the learning process, especially for procedural learning [19][20].

In recent years, there has been increasing effort to make use of the multiple possibilities of VR and AR to enhance and diversify learning processes in educational settings. In this context, the unique characteristics of VR and AR have been associated with several learning affordances such as improved spatial knowledge representation, enhanced empathy, increased motivation and student engagement, higher contextualization of learning, and experiential learning scenarios [11][21]. Thus, VR and AR are particularly relevant for learning content that cannot easily be studied in a traditional classroom setting [22][23], such as exploring the universe and planetary constellations or visiting the Amazon rainforest.

Recently, VR and AR technologies are increasingly being used for environmental subjects, i.e., climate change or biodiversity loss, as a tool to inform and engage the public with current and future environmental issues [24][25]. The potential to influence the affective experience through VR or AR appears promising. According to Mayer and Frantz [26], a feeling of connectedness to nature leads to a stronger concern for nature and can invoke tangible actions such as pro-environmental behavior. VR and AR technologies can indeed evoke such feelings of connectedness. They offer increasing engagement and provide interactive, action-oriented, affective, and empathetic experiences [13]. Individuals can take on someone else's perspective, get interactively involved, see consequences, foresee future climate change scenarios, and experience sensory stimulations that can have a strong impact on affections [27]. However, there are still only limited numbers of VR and AR learning applications dealing with sustainability topics. Valid research results for the use of these applications in the various fields of the Sustainable Development Goals (SDGs) are still in early stages [28].

2.3. Determinants of VR/AR Learning

With VR and AR technologies becoming increasingly prevalent and popular in classroom use—outside of sustainability education—several determinants of successful learning in VR and AR have already been examined. Ease of use seems to be one relevant factor, since many students find VR and AR technologies difficult to use [29][30]. Prior experiences with the technology and amount of practice also influence learning outcomes [31]. With these determining factors set, finding more relevant correlating variables could enhance our understanding of VR and AR learning even further. Specifically, exploring moderating factors could help explain how the affording mechanisms of technology, agency, and presence [19] influence learning.

Multiple previous studies present possible moderators. Johnson–Glenberg et al. [32] outline embodiment, collaboration, presence, and possibly novelty as key contributing factors. In addition, the experience of flow seems to be correlated with the success of a VR learning activity [33][34]. According to Zhang et al. [31], discipline plays an additional role, with overall large effect sizes for science, language, and health and medicine, and insignificant effect sizes for engineering. In that study, grade level, input as well as output devices, and pedagogy and instructional function did not play a role as moderators. In contrast, usability seems to be another relevant factor for feeling present in VR and AR applications [35]. In addition, it should be noted that contextual variables (e.g., the prior knowledge, prior interest, and prior attitude of users) may also have an influence on the learning outcomes [36].

2.4. Experiencing Presence and Flow in VR/AR

Presence has frequently been named as one of the underlying affordances of VR and AR technologies [19][36][37][38]. It is often understood as the feeling of being there, captured in three dimensions: Social presence describes the feeling of interacting with actual people, or with digital agents seeming real [39][40]. Physical presence refers to the sensation of being spatially inside the virtual environment, whereas self-presence refers to the feeling of being represented or the avatar feeling representative of oneself inside the virtual landscape [39][40]. Typically, 3D applications are associated with higher physical and social presence than 2D environments, while physical presence is frequently perceived stronger than social presence [41][42].

Generally, some research results suggest that presence influences learning in virtual environments. However, opposite research findings are detectable. Whereas some results indicate that the experience of presence has a positive effect on the learning outcomes to the extent that a higher level of presence experience requires a stronger focus of attention on learning-relevant stimuli [43][44], Makransky et al. [45] found a negative correlation between learning and presence experience. The authors concluded that higher presence could lead to distraction by many irrelevant details or high arousal.

Flow experience has also been associated with VR and AR learning technologies [46]. Flow is often characterized by perceiving an activity as highly satisfying, with a minimal or even complete absence of a sense of separation between the individual and the activity itself [47]. During such experiences, the actions become almost automated, leading to more efficient and faster performance. Another notable aspect of the flow state is the subjective loss of awareness of time passing [46]. Rheinberg and colleagues have conceptualized flow as a multidimensional construct, consisting of two key facets: absorbedness and smooth automated progression. The former represents complete engagement in an activity, while the latter refers to the seamless flow of consecutive actions [48].

In general, there remains a limited body of empirical research on the relationship between flow experiences in VR and AR and various learning parameters.

In game-based learning, engagement was linked to presence and flow, and had a positive effect on learning [49]. Kye and Kim [50] also found that presence and flow positively impact student satisfaction and learning outcomes. Likewise, in a game-based study, Janssen et al. [51] assumed that greater feelings of presence in VR leads to better user experiences and affords student interaction with the virtual environment. In their exploratory experiment, flow correlated positively with presence.

Overall, presence and flow seem to be related to a positive game experience, and by extension, to better task performance [51].

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