



Categorisation of the Benefits and Limitations of Immersive Technologies for Education

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Abstract

Virtual and augmented reality have become attractive technologies for application in educational setups. Hence, instructional designers are still struggling with the questions of whether immersive technologies can help to solve their current instructional problems and of how they should be incorporated into the educational program. This paper should bring us a step closer to the solution of this issue by proposing an extensive categorisation of the advantages and disadvantages of VR and AR technology for education. It was iteratively developed based on literature review, expert interviews and user reports. Each benefit category was assigned to the technological features such as multimodality, interactivity and visual-spatial representation that may bring forth the wished benefits. Additionally, some examples serve for a better understanding of how the benefits manifest themselves.

Keywords: Immersive technologies, virtual reality, education, virtual learning environments, benefits, limitations

1. Introduction

The human capital we possess is of essential importance for our life. Especially in times of crisis, we must entirely rely on our knowledge and skills. Hence, we search for further educational methods, practices and media that can improve and make the learning process more pleasurable.

Increasingly, due to the advantages they offer, virtual and augmented reality applications have established themselves over the past decades in the fields such as medicine, automotive, aerospace industries and entertainment. Furthermore, rapidly evolving and over time, more affordable immersive technologies motivate researchers and educators to explore further their application in the field of education. They aim to answer the questions, if and how those technologies are beneficial in enhancing the outcome of education, com-

pared to conventional teaching methods and media. However, the success of every learning environment based on new technology does not necessarily depend on the technology itself, but on its design and how it is integrated into the learning process (Mayer, 2009). It means that instruction designers and educators should not only understand what an immersive technology is, but also gain an insight into the particular features leading to the improvement of the learning outcome.

This paper proposes an exhaustive categorisation of the benefits and downsides of immersive learning environments. We have assigned each benefit category to the technological features such as multimodality, interactivity and visual representation that may bring forth the wished benefits. The examples serve for a better understanding of how the benefits manifest themselves.

The created categorisation has the objective to deliver a sound foundation for the creation of multifaceted



and standardised tools such as checklists or questionnaires. With their assistance, key stakeholder groups (such as instructional designers, educators or managers) can decide whether immersive virtual or augmented reality can help to solve the current instructional problems and meet the learners' needs. Furthermore, it can guide them in their decision making: which features should be implemented and how should the new media be incorporated into the educational program.

The paper follows a classical structure starting with an introduction and the related works. In the central part, we present the materials and methods used to achieve the resulted categorisation of the advantages and disadvantages (summarised in tables 1 and 2). The further development and utilisation of the results are discussed in the conclusion and outlook.

2. State of the art

There are different methods for evaluation of usability and benefits of immersive technologies. In the area of education, methods for determining the feasibility and profitability of using immersive technologies are presented by (Minocha, 2015) and (Pantelidis, 2010). Minocha uses a method from the strategic planning called SWOT analysis to study the strengths, weaknesses, opportunities and threats when applying VR in education. He concludes that the impact of virtual reality on learning outcomes is still limited and should, therefore, be used in addition to traditional classrooms and standard training (Minocha, 2015). Pantelidis made recommendations on when to use and when not to use virtual reality. She proposes a 10-step model that can be applied to determine when to use VR in an education or training course (Pantelidis, 2010).

Literature reviews and meta-analysis on learning with immersive technologies deliver categories of benefits and downsides (Lee and Wong, 2008; Radu, 2012; Merchant et al., 2014; Akpan and Shanker, 2017). The resulting categorisations help researchers to organise their results, but are often non-exhaustive, covering only specific aspects. It requires additional efforts and expertise to aggregate the results from many reviews and to use them for a general questionnaires, checklists or further research purposes.

The authors could not find so far a comprehensive or well-established categorisation of the advantages and disadvantages of VR and AR technologies for education. The first attempt on such categorisation resulted in seven main categories motivation (1), communication and evaluation (2), better understanding (3), adaptability and flexibility (4), safety and health (5), environmental aspects (6) as well as time and costs (7). This categorisation served as a base for the decision-making process (Häfner et al., 2018).

3. Materials and Methods

The categorisation was created based on a literature review as well as expert interviews and users' reports. The literature survey was conducted with a search in scientific searching engines and social networking sites for scientists and researchers such as ResearchGate, Academia.edu, Google Scholar and Mendeley. Furthermore, a search in the bibliographic databases Science Direct, IEEE Xplore Digital Library, Springer, Wiley and ACM Digital Library was also carried out.

The period of the literature survey encompasses the years 1995 to 2018. The main reason is that the concept of virtual reality and its potentials for learning were identified many decades ago, and the recent implementations vary only in quality due to the scientific and technological advances.

The main key terms used for the literature review were combinations of *immersive virtual reality in education*, *virtual or augmented reality learning applications* or *learning environments*. We distinct between non-immersive virtual worlds and immersive virtual reality worlds, and we have concentrated mainly on the latter. The benefits of computer games and simulation applications were still considered, but as features embedded in the immersive learning environment. The survey covers most domains and educational setups to identify all potential benefits.

Next to the literature review, interviews with technology experts, who have experience in authoring immersive learning environments have been conducted. Furthermore, reports of users operating VR trainings or using such applications for learning were from great benefit for the development of the proposed categories.

We considered all statements from the literature and interviews that tell about the benefits and downsides of VR and AR in education. On the one hand, the advantages and disadvantages that were evaluated through studies and proved in practice. On the other hand, those that were hypothesised, but not well assessed yet. The inclusion of potential benefits provided a better generalisation for the main categories and more exhaustive subcategories. Furthermore, it should ensure the sustainability of the proposed categorisation.

The used approach was an iterative process, which started with an initial set of categories and was further refined depending on the evidences found. We were able to identify more advantages than disadvantages, making the benefit categorisation more complex. An additional step was the organisation of the benefits in subcategories which provided a higher fidelity of the classification and allowed a better mapping of the technical characteristics and features.

The categorisation of the disadvantages is based mostly on the aspects connected to the technology limitations. Most of them can be avoided due to better design and development. Many of the limitations are linked to a particular key stakeholder group or applica-

tion area, which made the generalisation more difficult.

4. Results and Discussion

The main results of the method mentioned above are illustrated in two tables. Table 1 presents the categorisation of the benefits and table 2 the categorisation of the downsides.

4.1. Advantages of Immersive Technologies for Education

There are numerous advantages of immersive technologies in education, which are organised in seven main categories and eighteen subcategories. The main categories are: Enhancing learning outcomes (1), increasing motivation and concentration (2), fostering soft skills (3), safety and health protection (4), saving time and costs (5), adapting to individual and special needs (6) as well as facilitating teaching (7).

4.1.1. Enhancing Learning Outcomes

One of the most researched question in the area of virtual reality in education is how it improves the learning outcomes and process. There are different types of knowledge and skills, which leads to the split into two categories. The first category concentrates on the cognitive skills and in particular, the better remembering and understanding of concepts and processes. The improvement is connected to the main features of virtual reality such as the visual-spatial representation, the illustration of abstract concepts, non-visible, inaccessible or non-existent environments as well as the multimodality and interactivity of learning virtual environments (Dede et al., 2000; Pantelidis, 2010; Mantovani, 2001).

The second category is the enhancement of motor-coordination and physical skills, such as crafting or driving. Precision and procedural skills can be trained with the help of touch and force feedback and dynamic environments (Vander Poorten et al., 2014).

4.1.2. Increasing Motivation and Concentration

There is evidence that learners are more motivated and engaged and can better concentrate on the learning matter when using VR/AR learning applications. The cause for this lies in the interactive nature of immersive technology, which leads to the possibility for active participation, autonomous action and self-directed learning (Pantelidis, 2010; Bernert-Rehaber and Schlemminger, 2013). Furthermore, immersive environments lead to better management of complexity, and the incorporation of gamification elements allows intrinsic motivation and engagement through playful interaction and exploration of the virtual world (Minocha, 2015; Bernert-Rehaber and Schlemminger, 2013).

4.1.3. Fostering Soft Skills

The virtual simulation of situations like a job interview or talking in front of an audience using virtual agents or remote human-to-human interaction can foster communication skills. Many soft skills like problem-solving, decision making, teamwork, management and even leadership competencies can be trained in virtual learning environments. The multimodality of the immersive environments supports the learning of foreign language and can overcome language barriers (Pantelidis, 2010; Bernert-Rehaber and Schlemminger, 2013).

4.1.4. Safety and Health Protection

One essential benefit of virtual reality training is the protection of human health and the environment. It finds application in safety training to sensitise learners to dangerous situations, potential risks, accidents or injuries. Such training environments examples are surgeries, firefighting, mining evacuation, nuclear decommissioning and many other (Ausburn and Ausburn, 2004).

Many trainings have high power consumption, need many consumables or utilise toxic or contaminated materials (Iowa Waste Reduction Center, 2019). Next to the human health and safety, virtual reality can protect the environment, making the usage of the real resources obsolete (Stambolieva, 2017).

4.1.5. Saving Time and Costs

Immersive training has enormous potential to save time and resources, which leads to reducing costs. These savings are the reason why both time and costs share one benefit category. One example is the saving of operating resources, consumables or the reduction of machine downtime, which can be exacerbated by learners' mistakes. Some waiting times from real-world training can be skipped, such as preparation, follow-up activities or restarting a machine (Iowa Waste Reduction Center, 2019).

4.1.6. Adapting to Individual and Special Needs

Virtual reality supports the creation of customised learning environments that are suitable to various learning styles. Individualised training offers learning at own pace, where tasks can be optionally repeated, single step can be skipped, and there is no time pressure (Pantelidis, 1995). In an artificial environment, processes can be slowed down, and learning matters can be supplemented with additional information through multimodal representations (Mantovani, 2001).

Immersive technologies provide unique help for learners with special needs, who need assistance and specialised care because of sensory impairment, autism, learning disabilities or attention deficit disorder (Kim, 2013; Yuan and Ip, 2018; Parsons and Mitchell, 2002; Bowman and Liu, 2017).

Table 1. Categorisation of the benefits of Immersive Learning Systems (ILS)

| Main Benefit Category | Benefit Subcategory |
|--|---|
| Enhancing Learning Outcomes | Better remembering and understanding of concepts and processes |
| Increasing Motivation and Concentration | Enhancing motor-coordination and physical skills |
| | Increasing Motivation and Engagement |
| Fostering Soft Skills | Increasing Focus and Concentration |
| | Communication, discussion |
| Safety and Health Protection | Collaboration, peer-learning, improved group dynamics |
| | Problem-solving, decision making, teamwork, management, leadership competencies |
| | Fostering foreign language skills |
| | Human safety: Fewer to no accidents and injuries |
| Saving Time and Costs | Environmental safety: Less contamination and pollution |
| | Time savings: Skipping waiting and time-consuming processes |
| Adapting to Individual and Special Needs | Costs savings: Making changes or errors in a virtual world |
| | Personalised learning |
| Facilitating Teaching | Special educational needs |
| | Automated Learners Evaluation |
| | Easy changes of the training environment |
| | Saving time and efforts |
| | Usage of various pedagogical approaches |

4.1.7. Facilitating Teaching

Immersive learning applications can save educators time and efforts through the elimination of preparation and follow up activities or automated learners' evaluation. They can offer educators easy changes of training environments in order to customise the learning content because of new insights, technical change or learners' needs. Educators can choose various pedagogical approaches and design different virtual teaching scenarios. Parallel to the immersive media, they can focus on individual learners' needs or further teaching activities.

4.2. Disadvantages of Immersive Technologies for Education

Immersive learning environments are not beneficial in any case and have some limitations. The downsides categories include issues related to presence and immersion (1), acceptance (2) learning outcomes (3), time and costs (4), safety (5), security (6), communication (7), and miscellaneous (8).

4.2.1. Presence and Immersion

There exist technological (e.g. low immersion), or individual issues than can disrupt the presence, which can lead to weaker engagement, and which disturbs the knowledge or skill acquisition process.

4.2.2. Acceptance

Acceptance problems can arise because of technical issues such as low level of immersion (lags), low fidelity, low robustness (e.g. crashes), bad usability or discomfort (weight of the headset). For instance, low fidelity of a haptic simulation can lead users to prefer other training methods (Vander Poorten et al., 2014). Other acceptance issues may be that educators and students

actively reject the usage of the technology because of social pressure or anxiety. Further, unrealistic expectations or limited awareness may arise.

4.2.3. Learning Outcomes

Immersive technologies can lead to distractions interfering with the learning process, where instead of focussing on the educational experience, students get excited about the gadgets (Minocha, 2015). Furthermore, there can be no evidence for improvement of learning outcomes or process through the usage of VR technology.

4.2.4. Time and Costs

Higher level of fidelity and immersion of the immersive learning applications require higher costs and can lead to extensive development and maintenance efforts. There are cases where the cost of immersive technology cannot justify its use and benefits, such as a course with low attendance or which is conducted less frequently.

4.2.5. Safety

Using a virtual environment can be in some degree physically or emotionally damaging, like the occurrence of nausea, dizziness, headaches or some balance issues for some users (Runde, 2014). VR headsets, 3D glasses, controllers or earphones are potential fomites that can transmit infections between users. Some users report that they feel temporarily fuzzy, light-headed, or in a dream-like state after being immersed in a virtual reality. A study indicates that the exposure to VR can result in a lessened sense of presence in objective reality and can have dissociative effects such as depersonalisation or derealisation (Aardema et al., 2010).

Table 2. Categorisation of the downsides and limitations of immersive technologies

| Downsides Category | Description |
|------------------------|---|
| Presence and Immersion | Technological (e.g. low immersion) or individual issues that disrupt the presence |
| Acceptance | Technology issues such as low immersion (lags); low fidelity, low robustness (e.g. crashes), poor usability, discomfort (weight of headset); active rejection due to social pressure, fears and other user attributes or individual beliefs |
| Learning Outcomes | Distraction from the learning process; no evidence for improvement of learning outcome or process |
| Time and Costs | Too expensive to justify the usage and the benefits; Complex and time-consuming development process |
| Safety | Physically (motion sickness, hygienic issues) or emotionally damaging (fuzzy, light-headed, depersonalisation and derealisation) |
| Security | Risks of security breaches and misuse of personal information (profiles and avatars); no alignment with compliance regulations (e.g. because of embedded camera) |
| Communication | Social presence can be disturbed because of wearable; attention tunnelling |
| Miscellaneous | Occurrence of cultural, ethics, liability issues; training recognition issues |

4.2.6. Security

As any other technology connected to the internet, immersive technologies are exposed to cybersecurity risks such as security breaches or misuse of personal information such as profiles and avatars (McGee, 2020). There are concerns related to the usage of cameras on AR headsets, in organisations with strict compliance regulations.

4.2.7. Communication

VR and AR devices can be an obstacle to achieving a social presence in virtual spaces because they make facial expressions or eye contact difficult. Another problem that can hinder communication may arise from attention tunnelling due to the multimodal nature of immersive technologies.

4.2.8. Miscellaneous

Minocha lists some cultural challenges that can arise when using immersive technology for education. Examples are the occurrence of liability issues that can be caused by health problems, law enforcement or problems that may lead to an inventory loss of objects in virtual world (Minocha, 2015). Besides, there may be standards or laws that hinder the use of virtual reality training and do not allow its recognition.

5. Conclusion and Outlook

Not all advantages of immersive learning environments over traditional educational settings or their disadvantages have been explored in details thus far. Nevertheless, many researchers and users provide evidence for high potential and the existing limitations. The benefits and downsides of the virtual and augmented reality for education were summarised in two comprehensive categorisations.

These results should help key stakeholder groups to create multifaceted tools and to standardise the design process of immersive learning applications. Those tools can provide them with an in-depth analysis of the current educational needs. They can help to identify the potential of adapting the novel technology. During the

design and development process, the categorisations can facilitate educators and developers to define the requirements and the subsequent steps when designing and implementing an immersive learning environment. The downsides deliver a checklist to check for possible risks and to find solutions for the technical limitations as early as possible.

The results presented in this paper should support the process of enabling a holistic and objective decision-making on whether to integrate immersive technologies into an educational program. The standardisation of the design process should increase the quality of the application and ensure the feasibility and acceptance of the educational program.

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