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A Review of Immersivity in Distance Higher Education STEM Subjects

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Abstract. Immersive augmented reality, in practical terms, is a real-time, immersive processing experience which bind together elements of real life with the images presented. The study is a systematic literature review that aims to analyze the main methods and projects for the development of virtual learning environments (VLEs), especially in STEM disciplines, with immersive scenarios in the field of distance higher education. The analyzed scientific productions underwent revision on the search strings, which presented a high growth in the application of Virtual Reality, Augmented Reality, Mixed Reality and Extended Reality in education. The studies revealed that the use of Immersive Augmented Reality in education is able to increase students' motivation and interest in studies, mainly due to the teaching and learning environment becoming more dynamic. Additionally, it enables students in the immersive environment to interact and achieve effective learning.

Keywords: Immersive learning, Virtual Reality, Augmented Reality, Virtual Learning Environments, STEM subjects.

1 Introduction

Currently, the new technologies in the field of education stand out for the diversity of applications and devices used, which contribute in an innovative and diversified way to the teaching and learning processes [1]. Virtual Reality (VR), for example, is one of the most well-known and widely used contemporary technologies in the videogame industry, although it is not restricted to this field alone, once its use is present in other areas of science, such as in education and/or in medicine [2], [3]. Higher Education Institutions (HEIs), by incorporating new technologies in education, provide learners with greater interest in their studies and demonstrate understanding on the relevance of immersive learning tools.

The study aimed to analyze the main methods and projects for the development of virtual learning environments (VLEs), especially in STEM disciplines with immersive scenarios, in the field of distance higher education. The study was carried out through the use of Systematic Literature Review (SLR), with scientific productions comprised

between the period of 2018 to 2022. The SLR is one of the types of literature review which synthesizes all existing information about a phenomenon in an impartial and complete way [4], [5]. Unlike the unsystematic process, the systematic review is done in the most detailed manner.

Hence, it establishes a careful and well-defined sequence of steps [4]. The methodological procedures follow aspects of quali-quantitative and basic research, inspired by the use and assumptions of Design Science Research (DSR). Solutions for the development (construction) of computer-altered reality environments, through immersive virtual reality devices (hardware), development tools (software) and connectivity, with application in teaching and learning scenarios, are presented by scientific productions [7]-[9].

The study is structured as follows: in section 2 the methodology used to carry out this work is presented, in section 3 the results of the research are described, in section 4 the conclusions are derived, and in the final section bibliographical references are made.

2 Methodology

The use of the Systematic Literature Review (SLR) is validated by the fact that it is done in a meticulous manner, that is, its process seeks to exhaust all information relevant to the objective outlined in a given study, and therefore it is possible to develop even further the scientific production.

According to the SLR process, the following steps were taken to prepare the study, considering the work methodology [4]-[6]:

2.1 The SLR Elements

The elements considered in the SLR for carrying out the research are presented in Table 1.

Table 1. SLR elements (adap. [4], [7]).

Elements	Task/Target
Analyze	Theses and scientific publications
with the purpose of	Characterizing and analyzing
in relation to	Conduct a survey of existing research on digital bibliographic databases on the elaborate search string
from the point of view of	Researchers
in context of	Academic and Scientific

Using SLR as a method, applied to identify, evaluate and analyze relevant works for this study, the following keyword search strings (main findings) were elaborated for Table 2.

Table 2. Keywords.

Keywords	Immersive Learning; Virtual Reality (VR); Augmented Reality (AR); Mixed Reality (MR); Extended Reality (XR); 3DVLE (Virtual Learning Environment); STEM Subjects

The search strings (key findings) are based on the keywords: Immersive Learning; Virtual Reality (VR); Augmented Reality (AR); Mixed Reality (MR); Extended Reality (XR); 3DVLE (Virtual Learning Environment), STEM Subjects, seeking scientific documents and productions published in the bibliographic databases. The keyword Immersive Learning is justified by having greater grasp to the area of concentration, Education and New Technologies.

2.2 Flow of the Search Strings Development Process.

Figure 1 illustrates the flow of the search strings development process. Truncation operators are used to insert "wildcard" characters and use only the stem of the word (without having to repeat singular/plural, amongst other). E.g. "robot". Boolean operators are the AND to link keywords, and the OR operator to enclose synonyms (using parentheses).

Figure 1 shows flow of the search strings elaboration process.

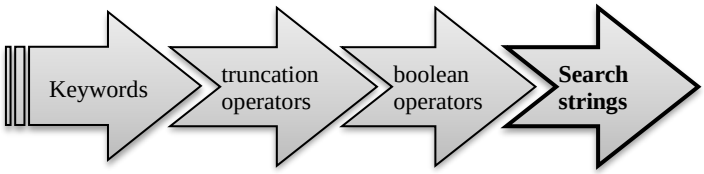

Fig. 1. Search strings elaboration process (adapt. from [4, 7]).

By using the aforementioned process, and considering the definitions of the Boolean operators, where AND is disjunctive and OR is connective, the following search string was elaborated: (“Education” OR “Immersive Learning”) AND (“Virtual Reality” OR “Augmented Reality” OR “Mixed Reality” OR “Extended Reality”) OR (“3DVLE” OR “Virtual Learning Environment”).

For the IEEE Xplore the following string was used: ((("Author Keywords":"virtual reality" OR "Author Keywords":"VR" OR "Author Keywords":"Augmented Reality"

OR "Author Keywords":"AR" OR "Author Keywords":"Mixed Reality" OR "Author Keywords":"MR" OR "Author Keywords":"Extended Reality" OR "Author Keywords":"XR") OR ("Author Keywords":3DVLE OR "Author Keywords":learning) AND ("Author Keywords":educat* OR "Author Keywords":learning) OR ("Index Terms":"virtual reality" OR "Index Terms":"VR" OR "Index Terms":"Augmented Reality" OR "Index Terms":"AR" OR "Index Terms":"Mixed Reality" OR "Index Terms":"MR" OR "Index Terms":"eXtended Reality" OR "Index Terms":"XR") OR ("Index Terms":learning OR "Index Terms":educat*) OR ("Index Terms":3DVLE OR Virtual Learning Environments)) AND ("Full Text Only":"distance education").

The chosen scientific digital libraries are listed in Table 3.

Table 3. Scientific digital libraries selected.

Digital library	Link
SciELO – Scientific Electronic Library Online	https://scielo.org/
Science Direct	https://www.sciencedirect.com/
Google Scholar	https://scholar.google.com
IEEE	http://ieeexplore.ieee.org/Xplore/home.jsp
CAPES Periodicals (Higher Education Personnel Improvement Coordination)	https://www-periodicos-capes-gov-br.ez485.periodicos.capes.gov.br/index.php

The selection of the scientific articles derived from the initial research, and, from the searches carried out in the aforementioned database, resulted in more than 5000 found and analyzed publications. After applying the selection filters, analysis of the inclusion/exclusion criteria which are described in 2.3 (below), articles published in the subareas were selected by the keywords Computer Science and Education, reducing significantly the number to only 42 results, all available for download, which, after reading and analyzing their abstracts, the last filter (extraction) was applied, when finally the doctorate theses were the only remaining selected.

The aforementioned theses were utilized as the current study is rather incipient, where references are scarce and quite recent.

Thus, only theses were considered, precisely because they are studies which relate to the theme proposed in this study, as well as because they are more robust references. It is worth mentioning that these are recent references, which are justified both by the fact that the respective topic is current and by the fact there is not a lot of published material on this subject.

2.3 Inclusion and Exclusion Criteria.

The relevance of the selected theses is justified because they present a great theoretical-practical contribution, which served as the basis for the present study. Scientific productions result in significant experiences that contribute to the continuity of other studies, as well as the qualification of new experiences related to virtual reality for learning.

The teaching of STEM subjects; augmented reality for educators; the effects of immersion on learning in educational virtual environments; immersive environments for teaching computer science and among others.

The inclusion and exclusion criteria applied are as follows:

1. **Empirical/Conceptual**: Empirical - theses that present empirical experiments on teaching/learning environments. Conceptual - theses that present theoretical discussions related to the teaching/learning of STEM disciplines in computer science courses in distance learning.
2. **Target audience**: identify the target audience of the studies, such as teachers, students and other education professionals, especially in STEM courses.
3. **Research tools**: identify which research instruments were utilized to produce data from the selected papers.
4. **Research approach**: identify whether it was qualitative, quantitative or mixed approach used.
5. **Origin of studies**: countries of origin of the studies analyzed.

After reading and analyzing the documents and applying all filters, 3 theses were selected for the full reading of the final sample. Table 4 shows a preliminary survey of the current surveys with the amount of results obtained in each of the databases before and after the application of the exclusion criteria.

Table 4. Results obtained from search strings in databases.

Source	Execution	Selection	Extraction
SciELO	75	2	0
Science Direct	73	8	1
Google Scholar	1643	18	1
IEEE	4886	0	0
CAPES Periodicals	735	5	1

3 Results and Theses Chosen

The analyzed productions showed that VR can promote new learning possibilities in distance higher education institutions. It also allows designing, delivering, and evaluating different forms and strategies for the teaching and learning process. The VR-based educational process is capable of filling gaps between practical applications and theoretical discussions about the value of using immersive VR for education in the context of distance higher education [3].

Augmented reality tools effectively promote students' development in STEM-based learning. Through the indication of a change in the ability of organizations to infuse technology integration with STEM-based learning, it is feasible to feed back on the action of teachers, as they demonstrate flexibility and refinement in their craft and, consequently, grow more and more as educators [1].

Researchers and/or educators which work with immersive technology is significant for feedback from the educational field, especially due the fact that learning is not a sterile future science to be kept away in hiding in laboratories. Therefore, immersive technology is an approach that can qualify teaching and learning processes in a truly immersive and engaging way [5].

Figure 2 is the Research Model for Investigating the Influence of VR Characteristics on Learning Outcomes (yellow: supplied media and media effects; blue: learner's traits and trait effects; green: learner's states and state effects; purple: learner's outcomes).

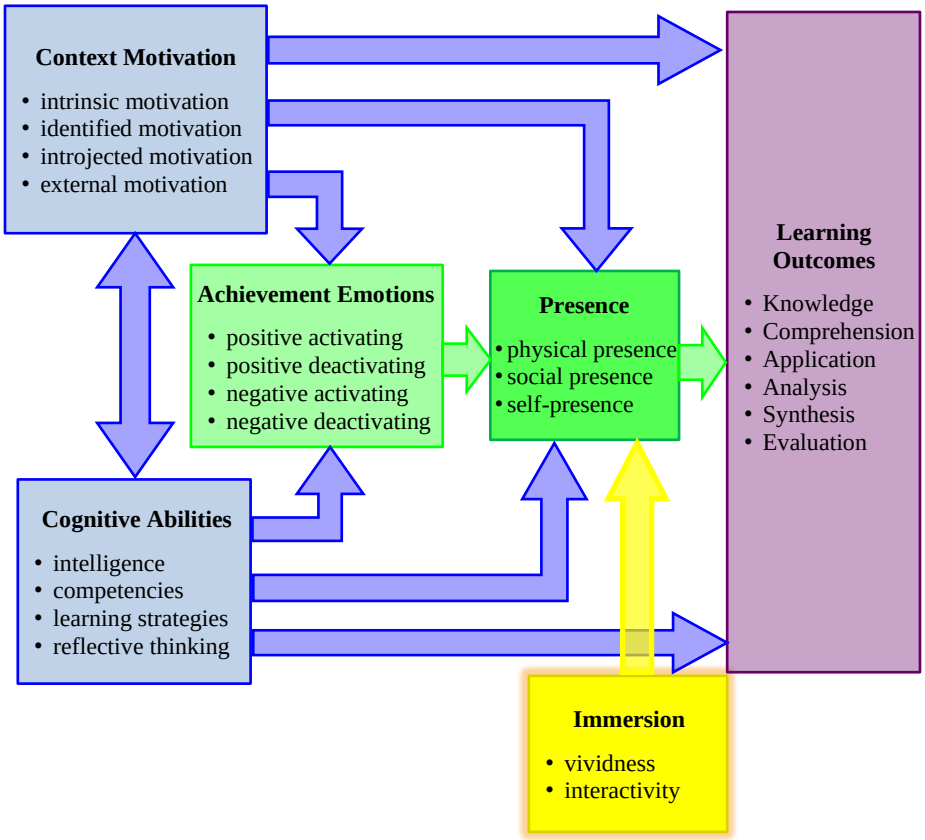

Fig. 2. Research Model for Investigating the Influence of VR Characteristics on Learning Outcomes (adapt. from [5]).

In summary, the teaching and learning processes in higher education combined with available technologies can provide capital knowledge and skills which then allow students and educators to create safe bases through the use of proven active learning methods [10], [11].

The next table 5 shows chosen theses.

Table 5. Chosen theses.

Author	Title	Problems addressed
S. BACEVICIUTE	Designing Virtual Reality for Learning [3]	How we can combine knowledge from human cognition, psychology and behavioral insights to understand the efficacy of learning in VR. Use this knowledge to guide the design of VR applications which improve learning and training.
R.S. BOOKHAMER	STEM in Elementary School Education: Evaluating a STEM and Augmented Reality Professional Development Workshop for Educators [1]	What are the educator's perspectives of STEM education? Based on the professional development workshops, what is the educators understanding of STEM principles and the 21st century skills after completing the workshops? Based on the professional development workshops, how are educators prepared and adapt to effectively integrating augmented reality tools into STEM-based instruction?
A. DENGEL	Effects of Immersion and Presence on Learning Outcomes in Immersive Educational Virtual Environments for Computer Science Education [5]	What are the effects of technological and person-specific factors on learning outcomes in Educational Virtual Environments for learning Computer Science?

4 Conclusions

The analyzes of scientific productions demonstrated the substantiality of the use of immersive virtual, augmented and extended reality in teaching and learning in STEM disciplines for distance learning of informatics. Innovation in the field of education is so vitally fundamental, as it enables students and educators to broaden their perspectives on the different processes and perspectives as to guarantee teaching and learning, considering the wide range of technological means available.

Virtual, augmented and extended immersive reality proves unpaired relevance in the context of teaching and learning STEM subjects for computer science in distance higher

education, impacting on educational, practical, and theoretical processes in a dynamic way, reassessing how technological means are fundamental in the field of education, adding great value to teaching and learning. Having thus in mind, an SLR was elaborated to dig deeper in the concepts as to obtain a clear overview of the research which undergoing in this area.

In the aftermath, the great benefits of the technology and resources in the context of education through augmented immersive reality, provide a real sense of "being there", also identified as presence, whereas the learners engage at real time, with objects and contextualized environment perceived as 'real', therefore they do not necessarily have to be real physically [5].

Furthermore, the use of these technologies has the potential to revolutionize the way we approach education, providing new opportunities for interactive and engaging learning experiences. By harnessing the power of immersive virtual, augmented, and extended reality, we can create dynamic and personalized learning environments that cater to the individual needs of each student. This not only enhances the learning experience but also helps to bridge the gap between theory and practice, providing students with a deeper understanding of the subject matter. As such, it is essential that we continue to explore and develop these technologies to ensure that we are providing the best possible education for future generations.

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