Online-Journals.org

iJET International Journal of Emerging Technologies in Learning

iJET | eISSN: 1863-0383 | Vol. 18 No. 14 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijet.v18i14.39871

PAPER

Challenges of Extended Reality Technology in Higher Education: A Review

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ABSTRACT

Extended reality is proposed as a means to deliver qualitative material to students in higher education institutions. The usage of this technology has increased due to Covid-19 lock down. This paper aims to categorize the challenges encountered by literature that deployed extended reality (XR) in higher education during and after the lockdown. However, the number of available articles addressing these challenges is limited, with a total number of 40 articles obtained from dimensions' dataset. In this study, bibliometric analysis is used to highlight the number of publications, citations, and authors in this field. Thematic analysis with inductive reasoning is applied to extract the primary challenge themes mentioned in 23 articles. After reviewing the eligible articles; we categorized the challenges into three main themes: Teacher, Student, and Technology.

KEYWORDS

Extended Reality (XR), Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), Education, Covid-19, bibliometric analysis, thematic analysis, themes, challenges, higher education, Teacher, Student, Technology

1 INTRODUCTION

Extended reality (XR) technology enables interactive experience and visualization of 3D dynamic objects in an immersive environment. It encompasses various emerging technologies and applications such as augmented reality (AR), virtual reality (VR), and mixed reality (MR). These technologies have found extensive use in computer gaming, socializing, psychological relaxation, and more recently in the field of education [32].

The importance of XR in education was highlighted during the "Educators in VR International Summit 2020." The summit offered training programs, packages, workshops, and digital communities aimed at integrating VR/AR/XR/MR into education through various virtual social platforms [https://educatorsinvr.com/]. This advanced technology plays a crucial role in enriching the educational development process by facilitating delivery of complex and abstract concepts to learners. It also

Obeidallah, R., Ahmad, A.A., Qutishat, D. (2023). Challenges of Extended Reality Technology in Higher Education: A Review. *International Journal of Emerging Technologies in Learning (iJET)*, 18(14), pp. 39–50. https://doi.org/10.3991/ijet.v18i14.39871

Article submitted 2023-03-25. Resubmitted 2023-05-05. Final acceptance 2023-05-05. Final version published as submitted by the authors.

provide an active learning experience within new types of environments, working in conjunction with the traditional class room and online classes [9]. This collaborative approach to learning fosters the "learning-by-doing effect" [5]. In the design of XR tools for education, various approaches are utilized including storytelling, game-based learning, problem-based learning, and participatory simulations [25].

New innovations in learning environments are being introduced to foster student engagement in the learning process. While students have experience in exploring the digital world, they often become passive and disengaged during traditional classroom settings [23]. This is because students are looking for practical experiences rather than simply receiving information. They also value opportunities to develop critical thinking that can be applied to real-time scenarios [31]. AR enables knowledge acquisition and interaction, which has a positive impact on cognitive and emotional learning [11]. Research has shown that experiencing positive emotions and high level of immersion in AR environment significantly enhances knowledge acquisition [6].

During the Covid-19 lockdown, educational institutions have embraced XR technologies in combination with traditional and online approaches. Case studies and practical strategies of how institutions have implemented AR/VR in education are beginning to emerge in the published literature [2]. However, there is a lack of sufficient studies that especially addresses the challenges associated with the application of XR in higher education.

To address the gap, this paper, utilizes the Dimensions database [https://app.dimensions.ai/discover/publication] to identify relevant publications on the topic. Dimensions, launched by Digital Science in January 2018, is currently a preferred choice among researchers as it provide broader coverage compared to other databases like Scopus and Web of Science and also, it is partially free [30].

Figure 1 illustrates the upward trend in the number of publications that contain the keywords: "virtual reality," "challenges," and "higher education." The search was performed in abstract and titles of articles using the Dimensions database. A total of 180 publications were identified during the period of 2014 to 2022. The upsurge started from 2019 and continued during the Covid-19 lock down and beyond. These publications include: article, chapter, proceeding, preprint, and edited book. In this paper, the focus is placed on publications published between 2019 and 2022. This time frame was chosen because it aligns with the period when the surge in publication began and when educators started actively implementing XR technologies in their teaching practices.

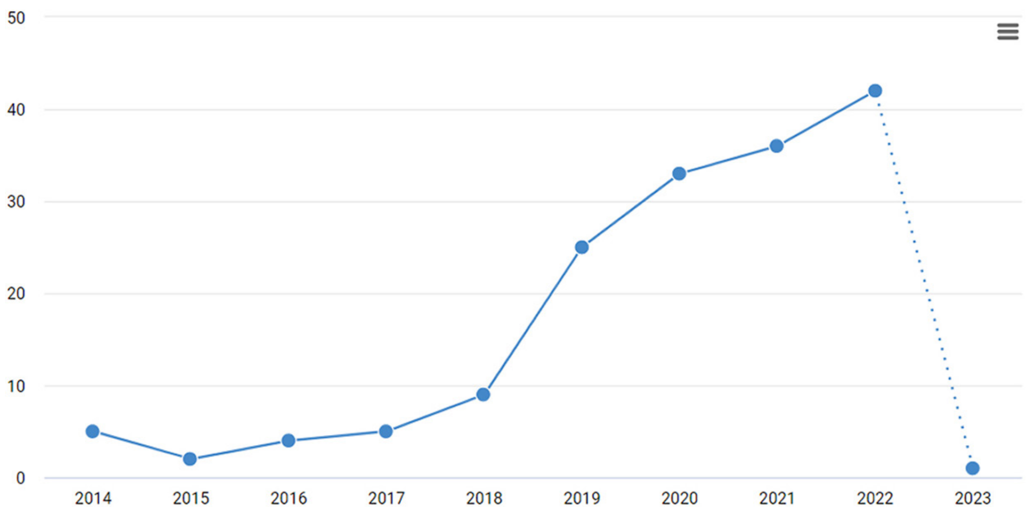

Fig. 1. Number of publications during the period 2014 to 2021 in dimensions dataset

In this study, we employed a combination of bibliometric analysis using VOSviewer within the Dimensions dataset and thematic analysis to identify the challenges of applying XR in higher education. The dataset used for analysis includes publications from Dimensions, which encompasses Scopus, Web of Science, and other datasets.

This study to address the following research questions:

Q1. What are the publications and citations trends related to challenges of XR in higher education?
Q2. Who are the leading authors, institutions, and countries with the most publications of this topic?
Q3. What are the challenges encountered in deploying XR in higher education?

This paper is structured as follows: Section 2 provides an overview and definition of XR, Section 3 explores the use of XR in education. Section 4 explains the research methodology employed. Section 5 presents the results of the analysis. Finally, Section 6 concludes the paper and discusses future work.

2 OVERVIEW OF EXTENDED REALITY

The emerging technologies and applications of XR include: AR, VR, and MR. The definition of each type is explained as follows:

- Augmented reality is considered the first generation of newer and more interactive MR experiences. It originated in 1990 when Tom Caudell, a researcher at Boeing, developed a head-mounted device that displayed specific drawings of an aircraft [24]. AR is defined as a computer generated images onto the real world, providing users with a composite vision [8]. Through the use of specialized devices, AR enables a real-time experiences where visual objects superimposed onto user's view of the physical environment. This enhances the user's sensory perception by adding virtual objects to the real world, creating a blended reality experience [12].
- Virtual reality refers to the creation of a simulated 3D environment in which the users can immerse themselves and interact with virtual objects using specialized equipment. This environment can either be a replica of the real world or an entirely imaginary setting. VR was introduced by Ivan Sutherland in 1965 who wanted to create a 3D virtual world that felt realistic and responded logically to user's actions [28]. VR is characterized by three key features: immersion, presence, and interactivity [17]. In VR; the 3D virtual environment is presented through a head-mounted display, a computer screen, or a large projection screen. Hand sensors systems are often used to navigate and interact with objects within the virtual environment [17].
- Mixed reality refers to the integration of VR and AR technologies to create an immersive experience that combines both physical and digital elements including human, computer, and environmental interactions [14]. MR introduces a new technique of human computer interaction called Tangible User Interface (TUI) that allows users to manipulate digital information through physical objects [20]. MR is a combination of five aspects of reality that can be simulated within a virtual environment, including audio, motion, haptic, taste/flavor, and smell [27]. However, not all of these aspects are necessary or applicable in every MR application; their inclusion depends on the concept being simulated. For example, a simple MR application could involve a 360-degree image that combines visual and audio elements to create an immersive experience for the user.

3 EXTENDED REALITY IN EDUCATION

The outbreak of Covid-19 has had a profound impact on the delivery of educational contents to students. With the implementation of lockdown measures, there was a need to find alternative ways to deliver high-quality education to the students in their homes. XR technology emerged as a solution to bridge the gap created by distance learning and the need to understand both practical and abstract subjects within various courses. One of the key advantages of XR technology is its versatility, as it can be applied to wide range of contexts. However, it is essential to ensure that XR applications aligns with the course curricula and are implemented accordingly [25].

Many researchers have conducted studies on the importance of incorporating different types of XR applications in education as a collaborative learning method has a profound impact on student learning.

One study [19] showed that the interaction and manipulating of 3D content during classes enhances the understanding and retention of abstract concepts compared to passive learning environment.

The usage of VR has proved to be beneficial in various fields, including surgical operations, chemical/biological laboratory, psychotherapy, and Science, Technology, Engineering, and Mathematics (STEM) education [9]. For example; VR-based classes provide learners with the ability to minimize risks associated with chemical, radiation, or biological experiences, allowing them to replicate the processes multiple times without the need for expensive laboratory equipment [10].

Many studies have shown the positive impact of XR in learning. These studies have demonstrated that the outcomes of virtual labs are comparable to those of in-person labs [10] [1]. A quantitative analysis conducted by [14] has confirmed the assumption that XR is an excellent technology that facilitates teaching processes, enables students to manage their learning strategies, and supports interactivity and connectivity. Research conducted by [29] investigated the effectiveness of MR in enhancing university student's performance in learning design subjects. The authors compared the MR experience with the traditional learning methods, and the results indicated positive progress in terms of learning collaboration and various measured effects.

The authors of [16] utilized VR technology, specifically Facebook's Oculus Rift hardware and software, as an interactive educational simulation tool to enhance interactive education for future engineers (IE). Their work was implemented in engineering courses at Tecnologico de Monterrey in Mexico, aligning with the university's educational model called "TEC21." The results demonstrated improved teaching methods, enhanced creativity skills, and increase student motivation in their daily learning.

A promising positive outcome was observed through the creation of a MR environment for a virtual science laboratory class utilizing Microsoft HoloLens [20]. The authors also acknowledged the high cost associated with purchasing such technology for educational purposes and emphasized the need for preparation and training of both students and teachers prior to using the equipment. From a learning perspective, [3] examined the student perspective on the use of VR in higher education. The findings revealed that most students considered VR to have useful pedagogical implications. However, students suggested that the use of XR should be optional rather than mandatory due to cost limitations, hardware complexity, and potential health concerns.

Furthermore, apart from to classroom settings, the practical application of 3D and VR for visualization and analysis is also relevant in academic libraries. A qualitative study conducted by [7] identified challenges related to the visualization and analysis of 3D data in the context of developing a national library strategy. The authors highlighted the importance of establishing standards and best practices to support the growing 3D/VR community.

4 RESEARCH METHODOLOGY

In this research, two analytical approaches were utilized: bibliometric analysis and thematic analysis. Bibliometric analysis was performed using the Dimensions dataset to gather relevant publications related to the question "What are the challenges of deploying XR in higher education?" Bibliometric analysis employs mathematical and statistical techniques to examine and analyze scientific production from various authors [22][18]. On the other hand, thematic analysis is the process of analyzing qualitative data, such as transcripts and articles, to identify themes and categories. It involves six-steps: familiarization, coding, generating themes, reviewing themes, defining and naming themes, and writing up. For this study; an inductive semantic approach was adopted, which involves analyzing the data to determine the themes.

The process involved in data collection for each analytical approach is elaborated below.

- ***Data Collection for bibliometric analysis***

This paper explores research articles on the challenges of XR in higher education, collected via Dimensions database. In this study; articles from the period 2019–2022, which encompasses the time during and after COVID-19, when XR technology was deployed, will be reviewed. The data were retrieved on January 18, 2023. Only 40 eligible articles were collected after performing the following tasks:

1. **Searching and identification of articles**

The search process was conducted on Dimensions database website (https://app.dimensions.ai/discover/publication) using the following keywords: (challenges and (("virtual reality" AND "higher education") OR ("augmented reality" AND "higher education") OR ("mixed reality" AND "higher education") OR ("extended reality" AND "higher education"))). Figure 2 displays the keywords in search along with additional variables criteria.

Fig. 2. Keyword search and criteria used in dimensions website search engine

2. **Criteria Add-on to the search**

The search was conducted in the titles and abstracts of the articles. Several criteria were applied in the search process such as limiting the publication type to articles only and selecting publications within the year 2019 to 2022. This step yielded a total of 71 publications. Next, we further narrowed down the field of research to education, resulting in a reduced total of 40 articles. Figure 3 illustrates the distribution of these 40 articles according to publication year.

PUBLICATION YEAR	Number of Articles
2022	18
2021	9
2020	9
2019	4

Fig. 3. Number of article publications between 2019 and 2022

- ***Data Collection for Thematic Analysis***

To collect articles for thematic analysis, a screening process was conducted on the 40 articles obtained previously. During this step, each of the 40 articles were screened by reading full text to determine the eligibility of the article for further thematic analysis. The articles had to meet the following criteria:

1. The article's full text is available and written in English.
2. The article is about challenges of using XR, including AR/VR/MR, in higher education or related fields.
3. The article provides qualitative analysis, review, or a case study.

During this process, 17 articles were excluded and considered ineligible for this study. Four articles' did not have their full text written in English. Five articles were not qualitative analysis review articles or case study. Five articles were systematic review that did not focus on challenges related to the research topic being explored in this paper. The remaining three articles that were excluded, were not available. As a result, the total number of eligible articles for thematic analysis is 23 articles.

5 RESULTS AND DISCUSSION

It is noticeable that there is a limited number of studies highlighting the challenges of applying XR in higher education, which is reflected in the bibliometric analysis results. Only 40 articles were obtained and met the criteria applied to the dimensions' dataset. With the aim of addressing these limitations and gaining insights, the bibliometric analysis aims to answer the following questions:

Q1. What is the publication and citation count of articles on challenges of XR in higher education?
Q2. Who are the leading authors and which university has the most publications and citations in this field?

The results indicates a growing interest in the utilization of XR in higher education, focusing on both the advantages and challenges associated with this technology. The circumstances of the Covid-19 lockdown have played a significant role in encouraging the adoption of XR in education. The analysis demonstrates an increasing count of articles and citations, reflecting the expanding research in this area. Among the 40 articles, a total of 56 authors contributed to the research. The cumulative number of citations for these articles is 285 citations. It is worth noting that

22 out of the 40 articles received at least 1 citation. Figure 4 illustrates the upward trajectory of citation counts within the period of 2019 to 2022. Figure 5 highlights the top five authors with most number of articles and citations.

	2019	2020	2021	2022
Citations (total)	2	29	96	145
Publications with citations	4	7	6	5

Fig. 4. Number of article citation within the period of 2019 to 2022

Name Organization, Country	↓Publications	Citations
Thomas D Cochrane University of Melbourne, Australia	3	4
Mariana-Daniela González-Zamar University of Almería, Spain	2	66
Emilio Abad-Segura University of Almería, Spain	2	66
Thomas Hainey University of the West of Scotland, United Kingdom	1	26
John Yin Gwee Yap National University of Singapore, Singapore	1	25

Fig. 5. Name of top five authors, publication, and citations

According to "THE IEEE GLOBAL INITIATIVE ON ETHICS OF EXTENDED REALITY (XR) REPORT 2021," the challenges of adopting XR in education are multiplied and increased compared to the use of e-learning. Further reading and analysis of 23 articles was conducted to finalize and summarize the challenges that encounter the growth of XR in higher education. A thematic analysis approach was applied to synthesis the findings from the literature transcripts. This involved grouping the codes identified in the studies and identifying main themes that encapsulates the challenges of XR in higher education. The study followed a six-phase thematic analysis framework proposed by [4].

The analysis process was performed manually by the authors and agreed upon categorizing the challenges into three themes: teacher, student, and technology. Each theme was further divided into subthemes as illustrated in Figure 6. The figure provides an overview of themes, subthemes and number of publications that referenced each subtheme.

The first theme focuses on challenges related to Teachers, and a total of 19 articles mentioned these challenges. Several subthemes were extracted from the literatures. One of the subtheme extracted from the literature is Motivation. A significant hurdle in the adoption of XR in education is the willingness of teachers to adopt this new technology.

The acceptance of new innovations and technologies depends upon teachers perceiving the values embedded in such technologies as explicit, clear, and relevant to their teaching practices [13]. Many teachers may be hesitant to change their teaching approaches and may prefer a more conservative approach instead.

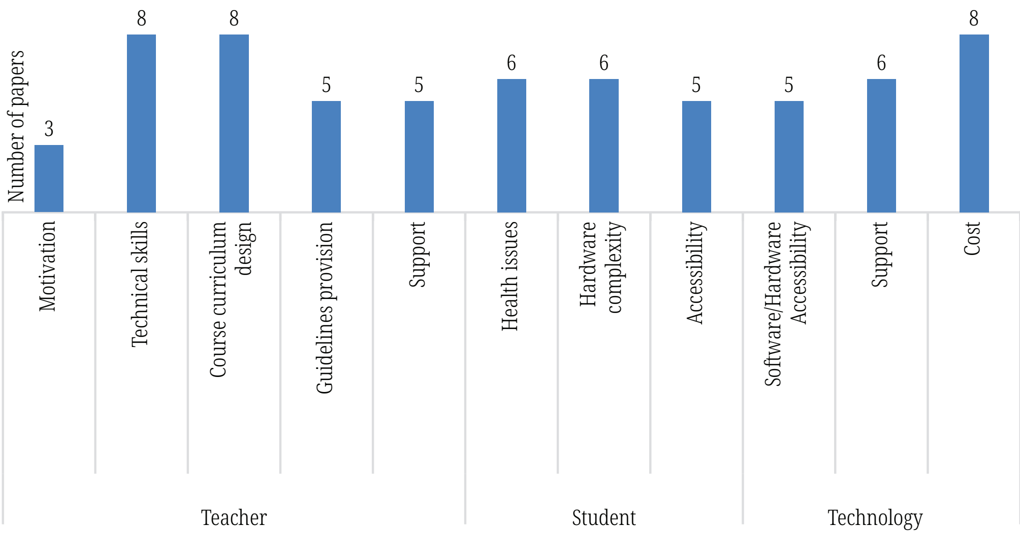

Fig. 6. Number of papers that mention each subtheme

Regarding technical skills, the literatures showed that many faculty members lack familiarity with up-to-date technology and require technical skills training before they can effectively utilize XR devices and applications [21]. The process of designing a professional XR course require outsourcing VR skills such as: working with software companies, as creating such courses can be challenging teachers who may not have experience of creating such courses. Currently, to minimize costs, university administrators often support the use of inadequate XR content creation outcomes by students, faculty, and staff. However, it is crucial to develop a carefully designed curriculum integrated with XR to deliver a high-quality and professional AR/VR course to students. The VR tools implemented must align with the curriculum and serve the intended purpose effectively [9]. While there are free, high quality open-source available from various institutions, this content is typically not specifically tailored to a specific course curriculum or educational process [26].

An important obstacle of applying XR is that there is no clear framework on how to implement XR within the course curriculum in terms of course-design, practice, and programming skills [3]. Universities are obligated to prepare long-term plans for VR adoption and conduct pilot cost-benefits studies across different disciplines to determine the applicability of VR [21]. It is important to develop a clear framework that includes guidelines for XR course deployment. The framework should provide regulations, data protection, and accessibility in addition to technology standards.

Finally, the support of adopting XR is important. A sustainable investment from university's administrators for XR content creation is essential for the successful deployment of XR [7]. Because the staff is not trained or does not have fundamental training, it is important to connect the staff with outsourcing technical support [21].

Regarding challenges related to students, 16 articles considered challenges from student's perspectives. Six studies in the literature stated several health issues that may emerge from VR usage. This must be considered when designing VR content for educational purposes. According to medical scientists, the use of VR devices may cause for certain people a cyber-sickness. Cyber-sickness is similar to motion sickness that cause blurry vision, nausea, vomiting, cold sweats, dizziness, and headache.

The authors of [3] examined the student perspective of VR used in higher education. In their study, students suggested that the use of XR be optional and not forced due to several reasons, including the cost of VR equipment, the complexity of the hardware, and potential health issues. Others have shown that the learning process can slow down because students can easily get distracted by the enjoyment of using VR technology. Additionally, the cost of VR equipment prevents students from accessing VR content outside the class room, making the technology inaccessible at anytime and anywhere.

A further issue highlighted is how to access XR content, where to store 3D contents, and who will utilize VR systems [7].

Challenges related to technology arise from the fact that XR platforms require 360-degree movement. It has been stated in 20 articles of the literatures that VR devices are associated with sensory richness and interaction. This can be achieved by using certain hardware devices, such as VR, VR on a tablet, or Head Mounted Display-Augmented Reality (HMD-AR) [25].

Current products of AR/VR devices are primarily used for gaming and entertainment purpose and typically designed for a single-user experience. Some examples of current AR/VR devices include Microsoft HoloLens, Google Glass, Oculus Rift, Samsung VR with Oculus, Lenovo Phab 2 Pro with Tango by Google, Asus Zenfone AR with Tango by Google.

The range cost of such items is between 400$ to 750$. Moreover, all participants of XR technology require accurate, reliable and specific training before using either equipment, or application [20]. For educational purposes, administrators need to provide devices for a class session with at least 20 students. The cost of procurement such tools is approximately high [20] [15].

6 CONCLUSION AND FUTURE WORK

The future of education holds promising prospects for the use of XR in higher education. The global adoption of XR in education demands the overcoming of several challenges that have been mentioned in this paper. In this paper; three themes of challenges were identified using thematic analysis applied to 23 eligible articles. The themes are: Teacher, Student, and technology. The teacher theme is further divided into Motivation, Technical skills, Course curriculum design, Guidelines provision, and Support. The Student theme focuses on Health issues, Hardware complexity, and Accessibility. While the technology theme is divided into Software/Hardware accessibility, support, and cost. The challenges discussed in this article are considered the first step towards overcoming and finding solutions to improve and enhance the use of XR in higher education. For future work, each subtheme will be studied individually to propose solutions that addresses the specific challenges.

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