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Review

You Can Handle, You Can Teach It: Systematic Review on the Use of Extended Reality and Artificial Intelligence Technologies for Online Higher Education

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Abstract: Over the past year, defined by the COVID-19 pandemic, we have witnessed a boom in applying key emerging technologies in education. In such challenging situations, technology and education expanded their work together to strengthen and interactively impact the learning process in the online higher education context. From a pedagogical perspective, extended reality (XR) and artificial intelligence (AI) were accessible toolboxes to amplify an active and learner-centered teaching method. Whether and how such activities will continue in a post-COVID-19 situation remains unclear. In this systematic literature review, we document the application of XR and AI in online higher education settings and build up an accurate depiction of their influence after the COVID-19 pandemic outbreak. A significant contribution of the thorough analysis conducted was the corroboration of the growing interest of these fast-emerging technologies and their impact on learner agency and outcomes, making online education more accessible, effective, engaging, collaborative, self-paced, and adapted to the diverse academic trajectories. The momentum brought about by the pandemic has served as an impulse for educators and universities to expand the use of these technologies progressively, meet new challenges, and shape the future of online higher education.

Keywords: immersive learning; emerging technologies; online higher education; adaptive learning technologies

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1. Introduction

In recent years, a series of changes and innovations have introduced new access routes to higher education, providing more flexible and innovative educational options and widening the possibilities of many learners through online teaching [1–3]. Technology and education are changing, strengthening, and interactively expanding the teaching and learning process, resulting in an accessible toolbox with which to amplify experiences for students in higher education [4,5].

Digital resources could be as effective as non-digital ones if embedded within a solid pedagogical approach with well-defined training goals and guidelines [6–8]. However, there is still pending research to assess whether digital tools are applied to support new learning methods or imitate old-style teaching and learning forms [9]. In terms of pedagogical applications, digital tools are not intended to replace traditional techniques; rather, they should be considered for the genuine profit they can bring.

Open and online universities have a long track record of using digital technologies to teach and gain insights into learning trends. These universities have broadened the possibilities for many students who had difficulties attending a traditional university because of schedule, geographical location, and responsibility (like work, family, or both) [10,11].

Over the past two years, defined by the COVID-19 pandemic, we have witnessed a boom in the application of emerging technologies to education [12–14]. This has impacted traditional educational operations, creating drivers of diversity in teaching and learning, and reshaping the path of future higher education. Whether and how such activities will continue in the post-COVID-19 situation remains unclear.

The educational application of extended reality (XR; e.g., augmented reality (AR) and virtual reality (VR)) and artificial intelligence (AI) constitute a critical step toward constructivist and activity-based education. Embedded with other resources such as mobile devices for learning, are still active and adapting to student needs and educational trajectories. These tools produce novel forms of pedagogical approaches that include ingenious combinations of teaching and learning modes.

1.1. Extended Reality Technologies

Progressively, XR tools have become a source of attraction to scholars. They offer the possibility of integrating environments that could (1) combine a physical scenario with a virtual one or (2) offer entirely immersive virtual experiences. Although still in the early stages, AR and VR are progressively used in education [15].

AR layers physical elements and scenarios with virtual content, and the user often accesses it with a smartphone [16]. VR comprises a highly immersive experience using head-mounted displays, such as HTC Vive or Oculus Rift, facilitating manipulations and interactions with virtual objects [3]. Another form of XR is mixed reality, a hybrid method merging the digital and physical context to generate new virtual simulations and environments [17]. Moreover, as a consequence of using digital resources, 3D printing is frequently used to replicate physical objects in three dimensions using various techniques and materials to improve haptic learning experiences [18].

1.2. Artificial Intelligence

Artificial intelligence relies on computer systems to execute tasks and activities that functionally and traditionally rely on human cognition, especially in terms of learning and problem-solving [19,20]. AI comprises a wide range of technologies, including algorithms, machine learning, and neural networks [21,22]. AI leverages algorithmic machine learning principles by channeling big data, allowing human-like task completion, predictions, and decision-making through repetitive processes of learning and process adjustments [23]. AI debuted in the Horizon Report in 2017, and its repercussions have substantially increased over the years [15,19,24–26]. Currently, we are seeing a significant expansion of AI-related resources in higher education in elements embedded into learning management systems, student information systems, test generators, plagiarism-detection systems, and accessibility products [27,28]. The application of these intelligent resources allows for detecting at-risk students, analyzing their metrics, and designing tailored learning adjusted to their needs and academic trajectories [29–33].

Here, we propose a systematic review focused on documenting the fast-emerging technologies and building up an accurate depiction of their influence on online higher education after the COVID-19 pandemic outbreak. Indeed, all of these depend on enhanced technology enabling the practice.

The systematic mapping of the existing publications will allow us to answer the following questions:

RQ1. How are publications implementing XR and AI bibliometrically distributed since the COVID-19 outbreak: which journals and languages are they published in, and which are the most frequent and cited authors in the literature?

RQ2. Which data collection and research design methods were set out to support XR and AI technologies-based learning and teaching?

RQ3. How are XR and AI technologies applied in higher education, and within which disciplines are they integrated?

2. Materials and Methods

We present a clear, systematic, reproducible search strategy, considering both inclusion and exclusion criteria, filtering and screening records, and standardizing reporting details following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [34] (Figure 1).

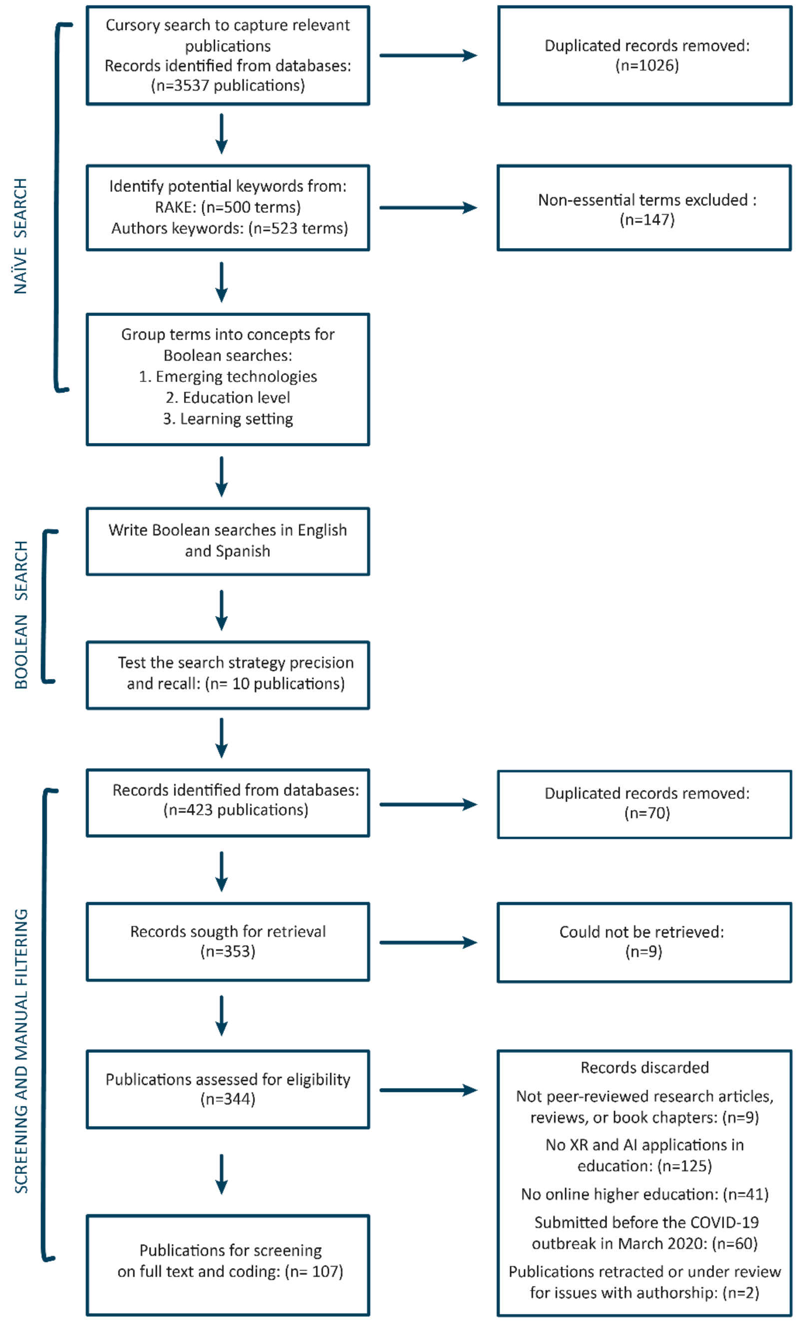

Figure 1. Preferred reporting items for systematic reviews and meta-analyses diagram (adapted after [34]).

Furthermore, for outlining and selecting our search terms rigorously and systematically, we used the R package *litsearchr* [35]. This package uses the Rapid Automatic Keyword Extraction algorithm [36] to detect potential keywords from a compilation of titles and abstracts and merges them with the author- and database-tagged keywords to find keywords relevant to our review.

2.1. Pipeline

First, on 6 June 2022, we ran a "naive search" in Scopus, Web of Science, and EBSCO Education sources with no date restrictions to capture a set of relevant articles (Figure 1).

Naive search terms included: ((“higher education” OR “college” OR “undergrad” OR “graduate” OR “postgrad”) AND (“virtual reality” OR “augmented reality” OR “mixed reality” OR “haptic technology” OR “mobile application” OR “artificial intelligence”) AND (“e-learning” OR “online learning” OR “virtual learning” “distance learning” OR “remote learning”)).

A total of 3537 initial records was retrieved from Scopus (n = 1984), Web of Science (n = 1529), and EBSCO Education (n = 24). Afterward, 1026 duplicated imported results were removed. Two methods extracted all potential keywords from the article titles, abstracts, and keywords. Firstly, the Rapid Automatic Keyword Extraction (RAKE) algorithm [36] and n-grams detection were implemented for extracting 500 terms from the titles and the abstracts. Secondly, 523 keywords used by authors were retrieved from the records using the tagged method [35].

After appending all the terms extracted, the potential keywords were identified by their predominance in a keyword co-occurrence network. Afterward, this network is quantitatively evaluated to determine cutoff point changes and the importance of a particular keyword to a concept. A total of 147 non-essential terms were excluded for building up an efficient and exhaustive search for our systematic review. Once the keywords have been isolated, we grouped them into three blocks: Emerging technologies, Education level, and Learning setting, to set up the search strategy for the Boolean searches in English and Spanish (Table 1).

To test the search strategy precision and recall, we compiled a set of ten papers of known relevance to the review. These publications served as a benchmark list. Again, we conducted a new search on the Web of Science, Scopus, and EBSCO Education. All ten papers were indexed and captured by the terms used, meaning we could run the final search for the systematic review.

Table 1. Search string in English after the naive search.

Topic	Search Terms
Education level	“higher* educ*” OR “colleg* student*” OR “univers* student*
AND	
Emerging technologies	“artifici* intellig*” OR “360 video*” OR “immers* learn*” OR “machin* learn*” OR “mixed realit*” OR “virtual* realit*” OR “augment* realit*” OR “intellig* tutor*” OR “mobil* applic*” OR “mobil* devic*” OR “XR* technolog*”
AND	
Learning setting	“distanc* educ*” OR “distanc* learn*” OR “onlin* educ*” OR “onlin* learn*” OR “onlin* teach*” OR “remote* learn*” OR “e-learn*” OR “onlin* cours*”

2.2. Final Search, Screening, Coding, and Data Extraction

Once the Boolean terms were defined (Table 1), we ran the final search string in the Web of Science, Scopus, and EBSCO Education, including titles, abstracts, and keywords. Considering the inclusion and exclusion criteria defined for this systematic review (Table 2). A total of 423 observations were identified (Figure 1). Afterwards, 70 duplicates were removed. Furthermore, we excluded nine articles because we could not access them through the journal publication or by contacting authors.

Table 2. Inclusion and Exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Indexed in Web of Science, Scopus, or EBSCO Education.	Not indexed publication in these three platforms.
Peer-reviewed research articles, reviews, and book chapters.	Not peer-reviewed research articles, reviews, or book chapters
Publications including updated information on the application of XR and AI in education	Publications not including updated information on the application of XR and AI in education
Online higher education	No online higher education
Submitted after the COVID-19 outbreak in March 2020	Submitted before the COVID-19 outbreak in March 2020

Afterward, publications were filtered, only including peer-reviewed research articles, reviews, and book chapters (nine papers removed). Any other format of publication was not considered for this review. The articles included provided updated information on the use of XR and AI for educational purposes (n = 125 papers discarded) for online learning in higher education (n = 41 publications removed). We conducted further exclusion criteria by only including articles submitted after the COVID-19 outbreak in March 2020 (n = 60 publications withdrawn). One retracted paper and another under review for issues regarding their authorship were not considered either.

After carefully evaluating the publications excluded, 107 publications remained for screening on full text and coding (Figure 1). We coded articles based on a hierarchical ontology of relationships between entities to extract all relevant data for the systematic analysis. Codes included: authors, year of publication, source name, times cited, type of publication (research article, review, and book chapter), language used (English and Spanish), research design, data collection method, the technology used (XR and AI), scope and application in higher education (Tables 3 and 4). Further data processing was conducted with the R packages tidyverse [37], dplyr [38], and graphics with ggplot2 [39] and fmsb [40].

Table 3. Scope of application of XR and AI in higher education.

Group	Field
Arts	Fine arts; Performing arts; Graphic and audio-visual arts; Design
Behavioral sciences	Psychology; Psychobiology; Anthropology; Cognitive science
Business, Economics, and Administration	Accounting; Economics; Management; Public administration
Computer sciences	System design; Computer programming; Data processing; Networks; Computer information technology; Information systems; Software development
Education sciences	Teacher training programs; Curriculum development; Educational assessment; Educational research
Engineering	Chemical engineering; Mechanical engineering; Thermal engineering; Informatics; Computer engineering; Robotics; Electric engineering; Architecture; Design and Technical Drawing; Aviation engineering; Civil engineering
Health sciences	Medicine; Nursing; Medical services
Humanities	Foreign and native languages; Cultural studies; History; Archaeology; Philosophy; Ethics
Journalism and Communication	Journalism and Social communication

Table 3. *Cont.*

Group	Field
Sciences	Biology; Zoology; Astronomy; Physics; Chemistry; Mathematics
Social sciences	Political science; Sociology
Sports and Tourism	Physical education; Sports; Tourism
No particular domain	Included multidisciplinary research articles and those where the field of application was not specified.

Table 4. XR and AI technology application in higher education.

Categories	Definition
Adaptive learning systems and personalization	A study where XR and AI have been used to either design or implement learning content dynamically adjusted to the pace and progress of students, helping improve their performance with automated and instructor interventions. Integrating personalized learning models facilitates student guidance, knowledge, and skill-sharing between learning teams.
Analytical, problem-solving, and practical knowledge	A publication where emerging technologies helped students improve analytical skills, such as collecting and analyzing data, programming, or making complex decisions such as designing a manufacturing system. It also includes research articles reporting the use of XR and AI to instruct learners on performing hands-on and field-specific practical training.
Assessment and evaluation	When XR and AI implement evaluation methods such as remotely proctored exams, measure knowledge acquisition and engagement, provide automated grading and feedback, ensuring integrity and academic honesty.
Behavioral and psychological impact	When XR and AI aim to assess the behavior of learners or the psychological impact and awareness of the Covid-19 pandemic on learning habits, academic performance, and mental health issues. These tools are also be used to change perceptions, improve peer interest, and enhance engagement and learning motivation.
Best practices	When XR and AI are implemented at the universities as a factor of change to favor teaching practices' quality and improve learners' involvement, motivation, and development of skills.
Intelligent tutoring and mentoring systems	It was assigned to articles introducing an intelligent tutoring system to reproduce the behavior and guidance of a human tutor. This resource can learn as it performs and interprets complex learner responses. In addition, it can discern where and why the learner has deviated in their understanding and offer assistance in addressing the issue.
Profiling and prediction	When XR and AI are applied to assess how students progress throughout the learning process, to provide feedback and recommendations in learning-related matters. It also considers the development of early warning systems detection of students at risk of failing, dropping out, or struggling with mental health issues due to the pandemic.

2.3. Research Design

Considering the scope of this systematic review and the research questions stated, we have followed a combination of the Creswell and Creswell [41] and Wendler [42] research design frameworks. Therefore, the publications screened have been coded as qualitative, quantitative, mixed methods, and design-oriented research.

2.4. Data Collection Method

Moreover, as we screened the publications, we identified different types of data collection methods used by the authors, including survey, case study, literature review, focus group and interview, experimental design, records and documents, and development. Moreover, we noticed some authors combined methods such as focus group and interview with surveys on one side and literature review with case study on the other. Each article screened was assigned to either of the abovementioned categories following the definitions provided by Cohen et al. [43], Creswell and Creswell [41], Wendler [42], and Paré [44].

2.5. Scope of Application in Higher Education

Based on the information provided in the research articles analyzed, we distributed them across 12 groups of disciplines, including multiple fields of applications of XR and AI in higher education. The list of domains used to code the research articles reviewed was adapted from the UNESCO International Standard Classification of Education [45]. We also found articles that did not comprise a particular domain because their scope was multidisciplinary or because the authors provided no further specifications. A detailed explanation of each group and field can be found in Table 3.

2.6. Technology Application in Higher Education

We defined and retrieved from the literature the categories explaining the application of XR and AI in online higher education only from research articles. This classification was performed following and adapting schemes previously used by Crebert et al. [46], Zawacki-Richter et al. [27], and Radianti et al. [3]. A detailed explanation of each category can be found in Table 4.

2.7. Systematic Review Limitations

Although this systematic review was rigorously performed, it is worth noting that each study is limited by the search strategy developed. In this case, only peer-reviewed publications in English or Spanish were retrieved from the three extensive and international databases selected, leaving out papers allocated on other platforms and published in other languages. When we included in this review papers submitted right after March 2020, we acknowledged that, in many cases, the data provided would have been collected before this date. After a careful review, we considered that the process of producing the articles selected was affected, directly or indirectly, by the outbreak of the pandemic and the impact it had on students, faculty, staff, and educational institutions in general.

3. Results

3.1. RQ1. How Are Publications Implementing XR and AI Bibliometrically Distributed since the COVID-19 Outbreak: Which Journals and Languages Are They Published in, and Which Are the Most Frequent and Cited Authors in the Literature?

3.1.1. Journals

Since March 2020, there has been a visible increase in publications addressing the use of XR and AI resources in higher education. Of all the peer-reviewed papers retrieved, 97 were published as research articles, seven as reviews, and three as book chapters. Most frequently, the studies analyzed came from the International Journal of Emerging Technologies in Learning (n = 6), seconded by Education and Information Technologies (n = 5) and Sustainability (n = 5). Figure 2 lists the ten journals that published the most significant number of articles applying XR and AI since the COVID-19 outbreak.

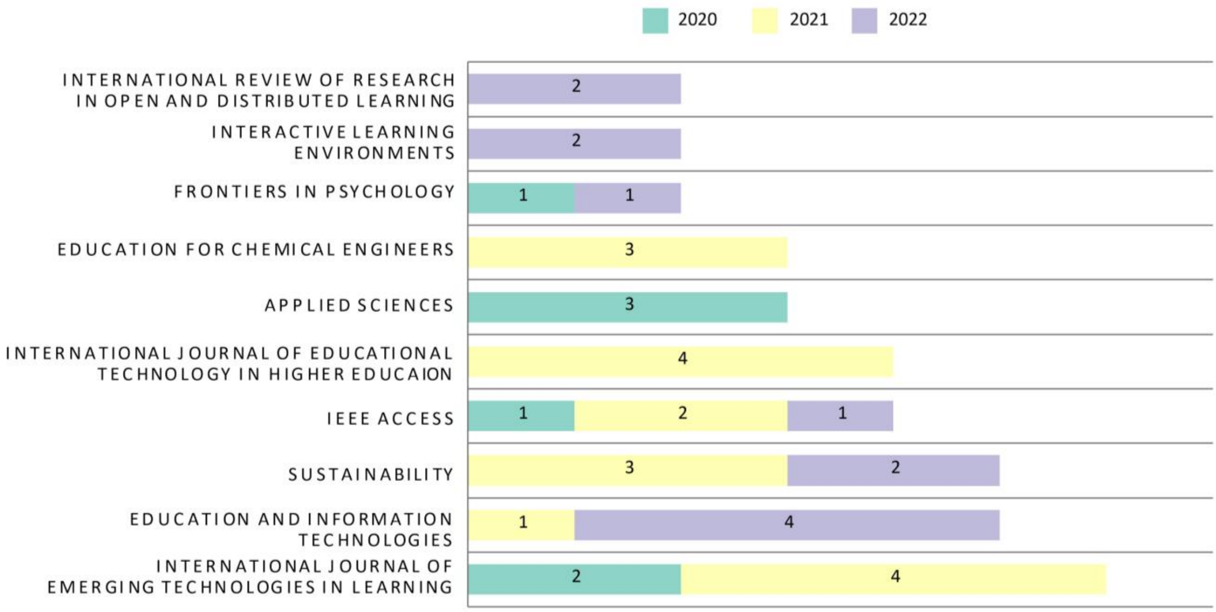

Figure 2. The top ten publishing journals on XR and AI in online higher educational contexts since the COVID-19 outbreak.

3.1.2. Languages

Figure 3 shows that most of the publications retrieved are in English. In the case of AI, we found that 66 papers were in English (e.g., [47,48]), whereas only three were in Spanish [49–51]. Moreover, we retrieved 35 papers in English applying XR in higher education (e.g., [52,53]). However, we could only find one publication on this topic written in Spanish since the COVID-19 outbreak [54]. Furthermore, two publications in English brought together XR and AI [55,56].

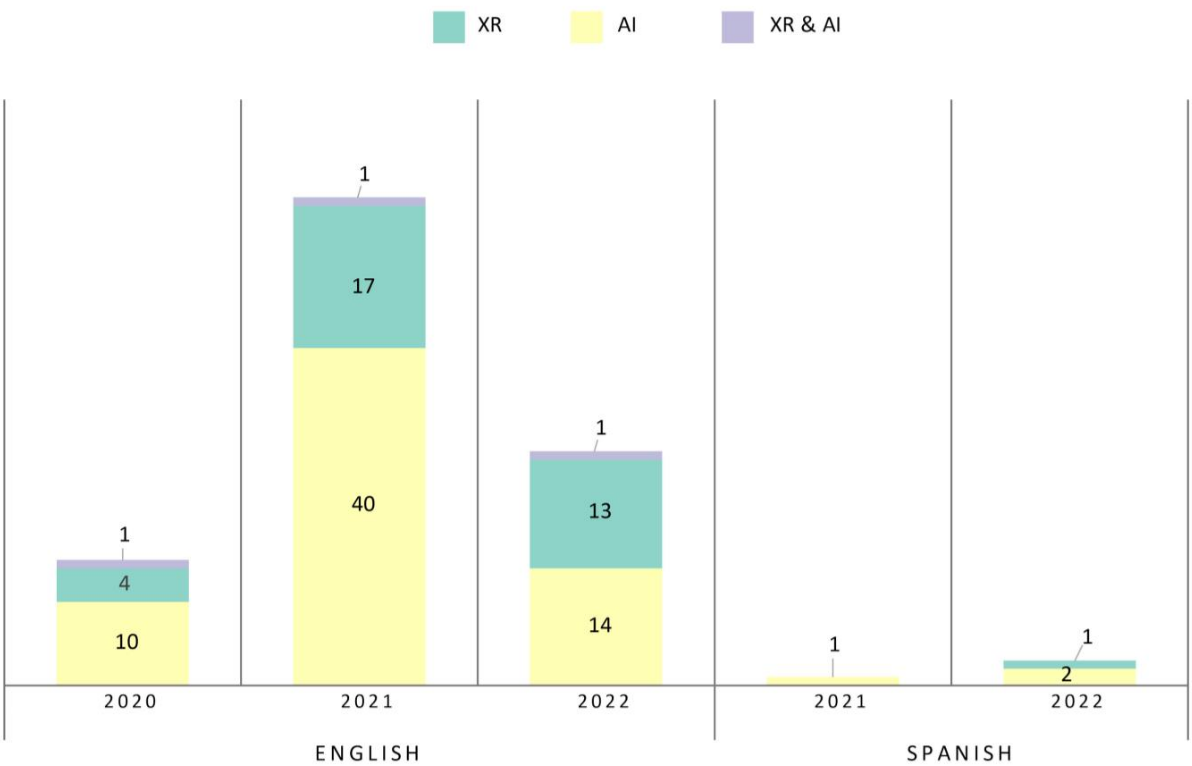

Figure 3. The number of publications retrieved in English and Spanish.

3.1.3. Authors

On 5 August 2022, we updated the number of citations that each of the publications in our database had. Eight research articles and two literature reviews were among the top ten most cited. Here, we will only reference the literature reviews, as more details of the other research articles will be given in the following sections. As displayed in the comprehensive list provided in Figure 4, Ratten's [56] literature review took the lead with 66 citations. The author focused on COVID-19 and entrepreneurship education, addressing AR and AI to simulate a real environment. In the sixth position with 23 cites, Luan and Tsai [57] presented a systematic analysis of empirical studies implementing machine learning to predict learning performance in online or blended settings in Computer science or STEM disciplines.

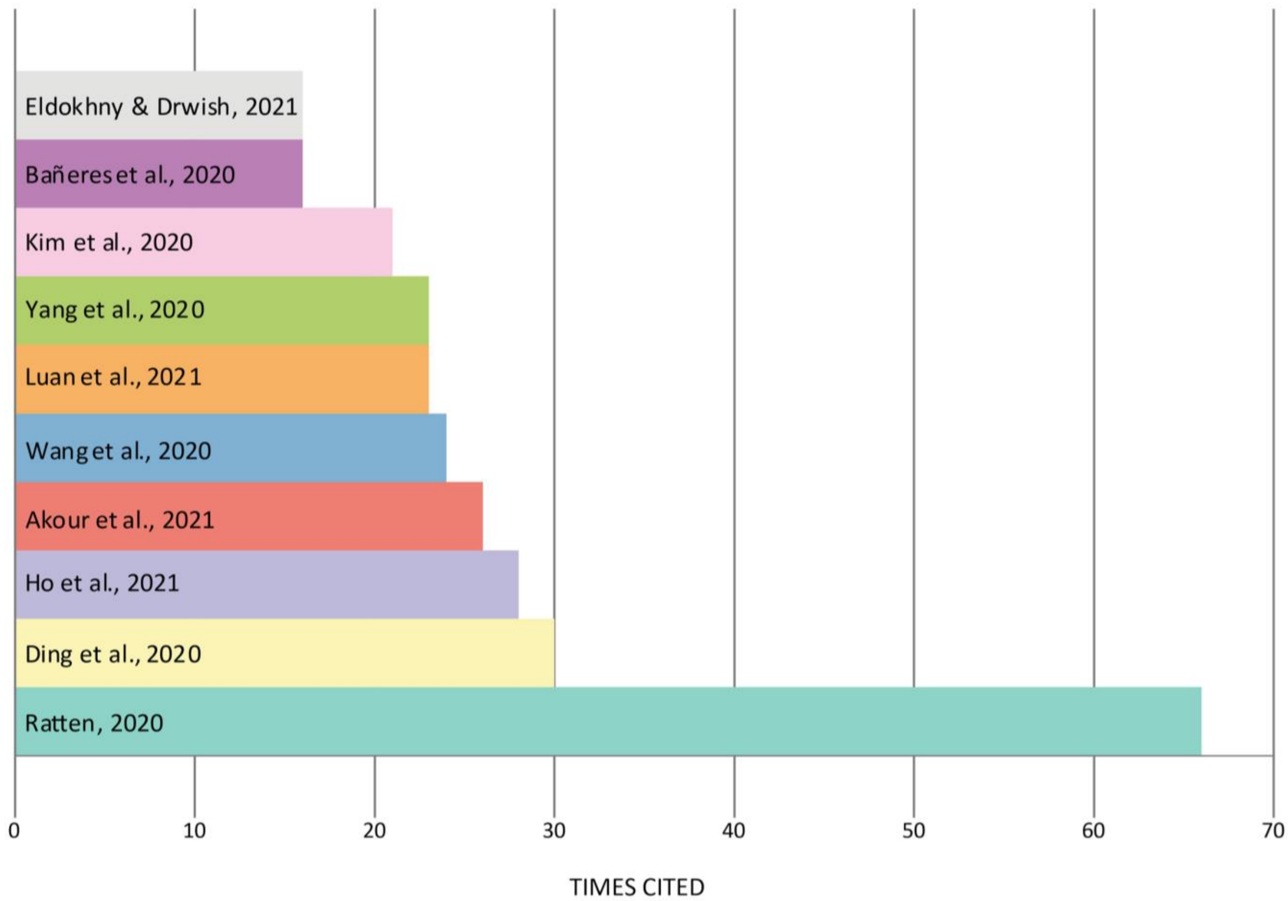

Figure 4. The top ten most cited authors [16,52,56–63].

3.2. RQ2. Which Data Collection and Research Design Methods Were Set Out to Support XR and AI Technologies-Based Learning and Teaching?

Figure 5 shows the relationship between data collection and research design methods. The bubble size is determined by the number of publications retrieved for each combination. Concerning XR, the authors preferred using a quantitative methodology in 15 publications, mainly relying on a survey (e.g., [64]) and experimental design (e.g., [16]) as collection methods. Nine papers followed a qualitative research approach using diverse data collection strategies such as surveys [18,65], focus group and interviews [66,67], and case studies [68,69]. Notably, only one paper measured student feedback on a VR tour reflecting on contemporary Hong Kong youth culture using a survey, interviews, and writing essays [70].

Mixed methods were implemented in six publications, mostly paired with focus group, interview, and survey techniques [54,71,72]. The design-oriented approach was popular in six articles combined with development [52,73–77].

Following a similar pattern, the publications addressing AI implemented a quantitative analysis in 45 articles combined mainly with experimental design (e.g., [78]) and survey (e.g., [48]). Meanwhile, when obtaining data for the literature review, the use of qualitative analysis [14,79,80] and mixed methods [57,81,82] was predominant. The bubble plot shows that design-oriented research was dominant when collecting data using development approaches (e.g., [58,83]). By looking deeper into the combination of XR and AI (Figure 5), we found a literature review following qualitative research [56] and a quantitative experimental design study [55].

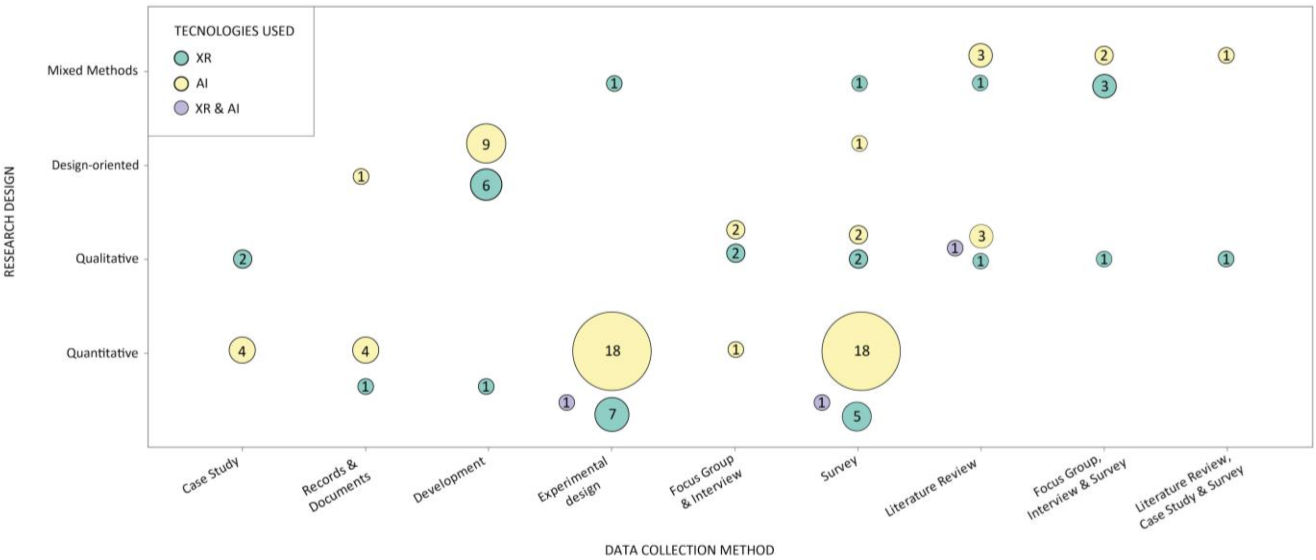

Figure 5. The relationship between data collection and research design methods (the number of publications retrieved determines the bubble size).

3.3. RQ3. How Are XR and AI Technologies Applied in Higher Education, and within Which Disciplines Are They Integrated?

Figure 6 displays the radar chart explaining the relationship between the technologies analyzed and their scope of application in higher education (Table 3) in the research articles coded (*n* = 98). Of all disciplines plotted in the coordinate system, Engineering (*n* = 29 publications) and Computer sciences (*n* = 16) were the most popular application areas, showing the large projection of AI (e.g., [59,84]) and XR technologies (e.g., [16]). We make a special note regarding the 14 research papers using AI where no particular domain was located, either because no specific discipline was mentioned in the publication [85] or because this technology was applied across multiple disciplines [86]. A combination of XR and AI was also implemented in one article addressing Behavioral Sciences-related fields [55].

Looking at the plot, we obtained much more information about how these variables are related. We found publications focused on Humanities (*n* = 6; e.g., [87]), Behavioral (*n* = 6; e.g., [88]), Education (*n* = 3; e.g., [89]), Health (*n* = 3; e.g., [90]), and Social sciences (*n* = 2; e.g., [67]). Likewise, we found research articles applied to Sciences education (*n* = 5; e.g., [74]), Arts ((*n* = 5; e.g., [91]), Business, Economics, and Administration (*n* = 4; e.g., [92]), Sports and Tourism (*n* = 4; e.g., [93]), and Journalism and Communication (*n* = 1; [60]).

Moreover, to address this question, we coded research articles following the seven categories explained in Table 4. The applications of XR and AI in the publications reviewed will be reported as follows.

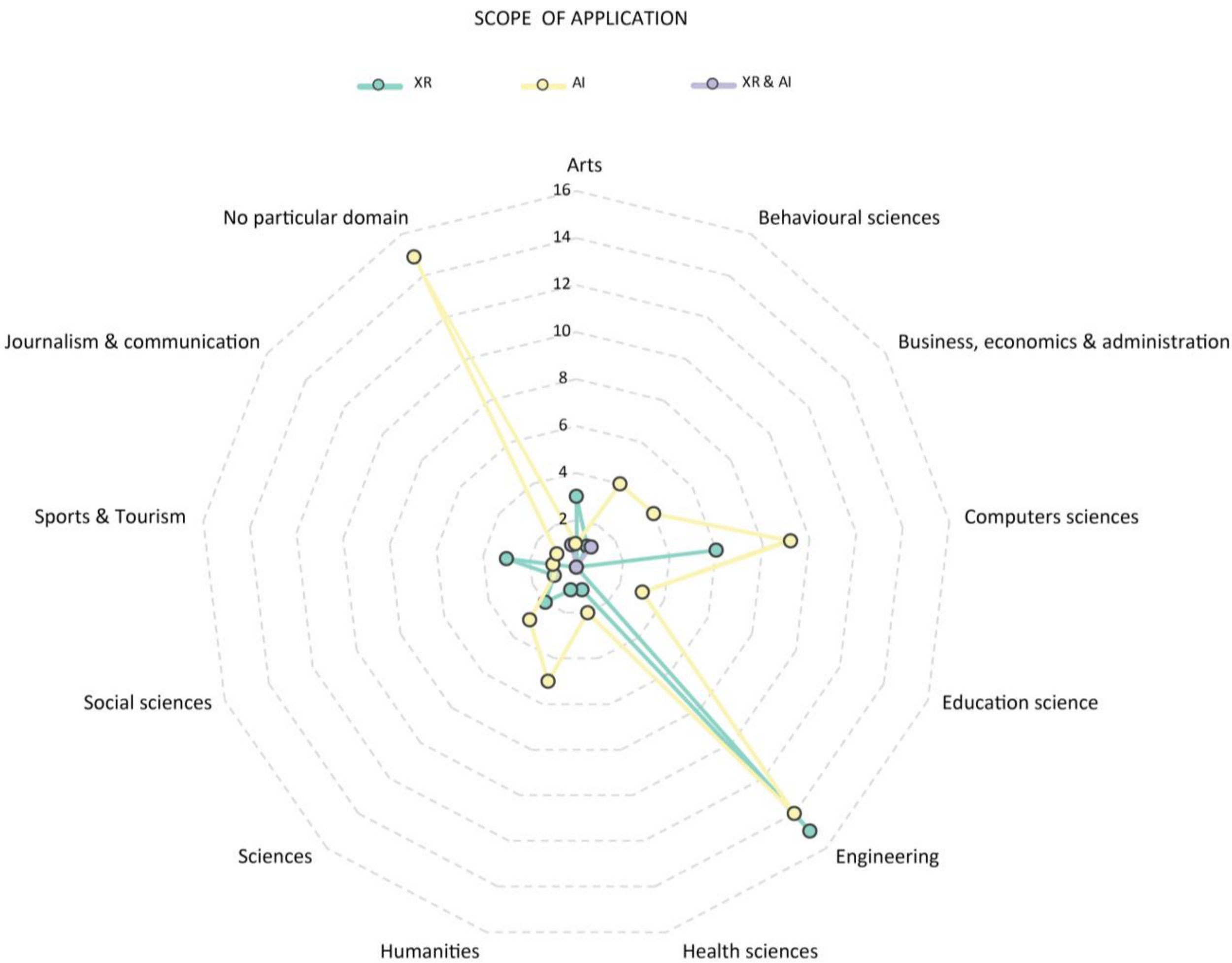

Figure 6. Scope of XR and AI application in higher education in the research articles coded (*n* = 98).

3.3.1. Adaptive Learning Systems and Personalization

A significant number of research articles analyzed (*n* = 27) are within this scope (Figure 7a), suggesting that it is becoming an effective tool for improving educational practice. Considering all the publications reviewed, XR (*n* = 19) was favored by the authors based on its significant educational benefits when integrated into the instructional and learning designs. Eight XR publications focused on teaching and learning Engineering [73] in subareas such as Architecture [54], Thermal [18], and Chemical engineering [76]. One of them reported the development of an AR platform for improving mobile e-learning in software engineering [94]. Meanwhile, another presented the design of VoRtex, an open-source metaverse system that enhanced collaborative learning and educational process during the pandemic by mimicking real-life experiences in a virtual world [75].

Another three articles relied on the effectiveness of VR and AR and on evaluating student experience in Computer sciences education [16,95,96]. Two Science-related publications focused on combining mobile learning with XR resources to theoretically corroborate the use of AR in physics education [69] and enhanced invertebrate zoology online teaching [74]. Two publications within the Arts deployed a pedagogical approach for interior and industrial design teaching conditioned by the COVID-19 pandemic and drew future applications of XR in this context [68,97]. Similarly, two research papers used XR for Sport-related education and highlighted the importance of a solid infrastructure and user feedback in physical education [52,98]. Coded in Social sciences, Ramírez-Montoya and González-Padrón [67] examined student perceptions of social skills integrating emerging technologies such as XR for creating entrepreneurship projects. Within the Humanities, Cheung and Wang [70] connected cultural studies education with VR. Nourishing this idea, the authors implemented a virtual tour to enhance the knowledge of Hong Kong popular culture, showing that VR embedded with real-life experiences provided effective education and engagement.

Eight studies deployed adaptive and personalized learning settings using AI across multiple disciplines. Two relied on the application of Computer sciences [99] and Engineering [100] to explore the implementation of AI and machine learning in online higher education. Two publications examined the impact and effectiveness of AI-enabled e-learning interaction in online learning during the pandemic in areas related to Education sciences [101], and also in no particular domain in higher education but rather a selection of students and instructors from different majors [102]. One paper focused on Business, Economics, and Administration in entrepreneurship education [103]. Coded within the Humanities, Yang et al. [58] integrated an intelligent cloud platform for practical personalized teaching on a cultural industry management major based on a massive online and self-paced open course. The system intelligently manages the teaching process and incorporates content into educational scenarios. Moreover, one paper proposed ideas to customize the distance teaching system for music dance courses to improve the current curriculum and learning outcomes based on machine learning and developing the Ologit model [91]. The last paper included in this category showed the positive impact of computer-assisted instruction in physical education [93].

3.3.2. Profile and Prediction

The 23 reviewed articles assigned to this category were distributed across 9 groups of disciplines. Detailed information about the contribution of each disciple can be found in Figure 7b. Most frequently, the 21 publications centered on the application of AI relied on machine learning and data mining algorithms. This trend of classification, modeling, prediction, determining satisfaction of students, and quality of learning experience was found in eight papers focused on no particular domain [47,61,86,104–107]. From this group, Ali et al. [108] developed a mechanism that intelligently predicted the appropriate preferences for virtual assistance and course selection for Agriculture, Mathematics, and Computer sciences students. Moreover, following a multidisciplinary approach, Kuadey et al. [104] used machine learning algorithms to calculate the continued use of e-learning management systems in developing countries such as Ghana.

In terms of predicting student behavior, performance, and learning status, five publications were based on Engineering education [84,109–112], one in Social Sciences [113], one in Humanities [114], and two in Sciences [115,116]. Notably, Raza et al. [115] designed a time-series predictive model through a long short-term memory network based on information obtained from previous online course interactions and outcomes to predict student progress in the future. The other two papers coded in Computer sciences proposed implementing early warning systems [59] and creating an intelligent nudging system [117]. Two publications were based on monitoring at risks-students in the Health sciences and Behavioral sciences groups [78,118].

To a lesser extent, only two publications retrieved within this category applied XR. In both cases, authors predicted technology acceptance and use in higher education among Psychology [53] and Tourism students [64].

3.3.3. Intelligent Tutoring and Mentoring Systems

Although still in the early stages, the introduction of intelligent tutoring and mentoring systems in online higher education has enabled teachers to reinvent courses effectively and improve student learning and progress. We found 15 studies within this scope (Figure 7c). From the literature reviewed, we coded only one study relying on XR and using an embodied agent tutor in an immersive virtual environment [119].

The five papers focused on Engineering education explored the student acceptance of intelligent tutoring systems [120], expansion and optimization of learner communication [121], adaptively supporting students in learning environments [122], and improving learning experiences by providing personalized educational resources and processes based on student needs [123,124]. Following a similar pattern, the application of AI in Computer sciences was present in three publications signed by Troussas et al. [83,125,126] and focused on Computer Sciences students. The first introduced a personalized tutoring system [83]. The second focused on developing intelligent educational software to expand learner–computer interaction in tutoring Java programming during the COVID-19 lockdown [126]. The third centered on providing intelligent tutoring application content for learning programming [125].

AI was applied in two papers coded as Humanities. The first explored the contribution of automated and teacher feedback to academic writing achievement in English learning [87]. The second implemented Arabic chatbots for educational use in Saudi universities [127].

Two papers coded within Business, Economics, and Administration education relied on an intelligent tutoring system to implement personalized feedback [49] and improve the performance of online learners [92]. Furlan et al. [90] developed a virtual patient simulator and intelligent tutoring system for clinical diagnosis in medical education. The last paper assigned to this category focused on understanding the perceptions, usefulness, and ease of communication of AI teaching assistants with students from disciplines within the scope of Journalism and Communication [60].

3.3.4. Behavioral and Psychological Impact

The articles coded within this category aimed to search for the means to improve academic performance, peer interest, and motivation. Still, they can be classified into those focusing on changing habits, perceptions, and behaviors in teaching-learning processes and those more centered on investigating the impact of the COVID-19 pandemic on mental health.

In the first group, we included five papers (Figure 7d). One did not focus on one particular domain and relied on machine learning algorithms to predict the benefits of using mobile learning platforms during the pandemic in the United Arab Emirates [62]. The authors looked into the adoption behavior and integration of students in their learning process and highlighted the importance of emotions in the training experience.

On the other hand, Chessa and Solari [128] explored the use of a web-conferencing system and a VR social platform in Computer sciences to understand if extended reality systems would enhance distance lectures and meetings by providing the psychological sense of being in a classroom. Meanwhile, Avsec [129] proposed improving transformative learning and innovation skills using AI in a remote sustainable architecture design course. Laurens-Arredondo [130] also presents a pilot study showing the positive impact of mobile learning and AR on motivation and meaningful learning in Engineering-related programs. One last publication reported using XR to find a nexus between an individual's positive experience and online engagement in avatar-mediated environments in students enrolled in a design course [131].

From the eight studies assigned to this second group, we can extract the effects of the COVID-19 outbreak on the mental health of online higher education students, faculty, and staff in critical and persistent ways. Research using AI resources reflected the challenges faced by the students and their level of satisfaction with online classes [132], the increased anxiety, stress, and depression, and its impact on academic performance in large datasets of Chinese college undergraduates [63], Egypt, Jordan and Saudi Arabia [133], and Spain, Colombia, Chile, and Nicaragua [88]. Interestingly, in the latter publication, authors reported that during the lockdown, these symptoms either increased or remained over the weeks where online learning experience and accessibility to services were impacted.

Research coded in this category also highlighted how the support provided by the university impacted the online learning experience via the development of an expert mental health education and daily consultation system [134] and the development of a reference framework that improved the quality of distance learning [135]. Using XR, Sood and

Rawat [136] developed a cyber–physical system that dealt with panic attacks during remote learning and computed effective well-being determination and prediction. Combining XR and AI, Nelekar et al. [55] adapted embodied conversational agents for managing academic stress by providing students with study tips and tailored explanations.

3.3.5. Analytical, Problem-Solving, and Practical Knowledge

As shown in Figure 7e, six papers coded within this category reported the application of XR in Engineering education focused on developing practical knowledge and problem-solving in subareas such as Chemical and Biochemical [137], Civil [72,138], Aviation [71], Architecture [139], Electrical [77], and Food [140]. VR simulations were implemented in health sciences education to improve analytical and hands-on skills [66]. Furthermore, we retrieved an article exploring the potential of using AR, AI, and mobile applications in learning how to play the piano, providing a novel opportunity to revolutionize Arts education [141].

3.3.6. Assessment and Evaluation

Online education has benefited from using AI for assessments and evaluations during the COVID-19 pandemic, as noticed in the seven articles assigned to this category (Figure 7f). Two studies focused on implementing remotely proctored exams [89] in Education sciences and integrating online oral assessment tools [142] in Computer sciences, guarantying academic honesty and integrity.

Two publications focused on the automated assessment of student understanding and corrective feedback in Computer sciences [143] and the Humanities [50]. Similarly, another study presented algorithms that automatically evaluate and classify learners by groups based on their assessment using a remote laboratory system for Electric engineering [144]. Two other studies implemented tools to evaluate learner progress and engagement. The first presented an intelligent assessment tool that explored both the implicit and explicit non-verbal behavior of Engineering students, providing data on the level of knowledge acquisition [145]. The second analyzed grading after the pandemic e-learning experiences in a large dataset of students in Sciences and Computer Sciences [146].

3.3.7. Best Practices

Most papers coded within this category demonstrated that institutions are developing programs to keep and improve instructional balance in online education after the challenges faced by the COVID-19 outbreak (Figure 7g). One article related to Computer sciences disciplines proposed a university e-learning framework comprising three interconnected layers: human resource management, technological and policy-making [147]. Another paper centered on how higher education institutions, learners, finance, and business management faculty can benefit from using AI and digitization if introduced into the academic curriculum [148]. Two papers retrieved did not focus on one particular domain. The first one examined the usage of chatbots for enhancing e-learning, aiming at impacting researchers, policymakers, educators, and learners [149]. Whilst the second investigated the quality of education and the image of a university using remote education and AI based on faculty and staff assessments [85]. Following this trend, [51] developed a virtual course for enhancing knowledge of AI tools and their application to future educators.

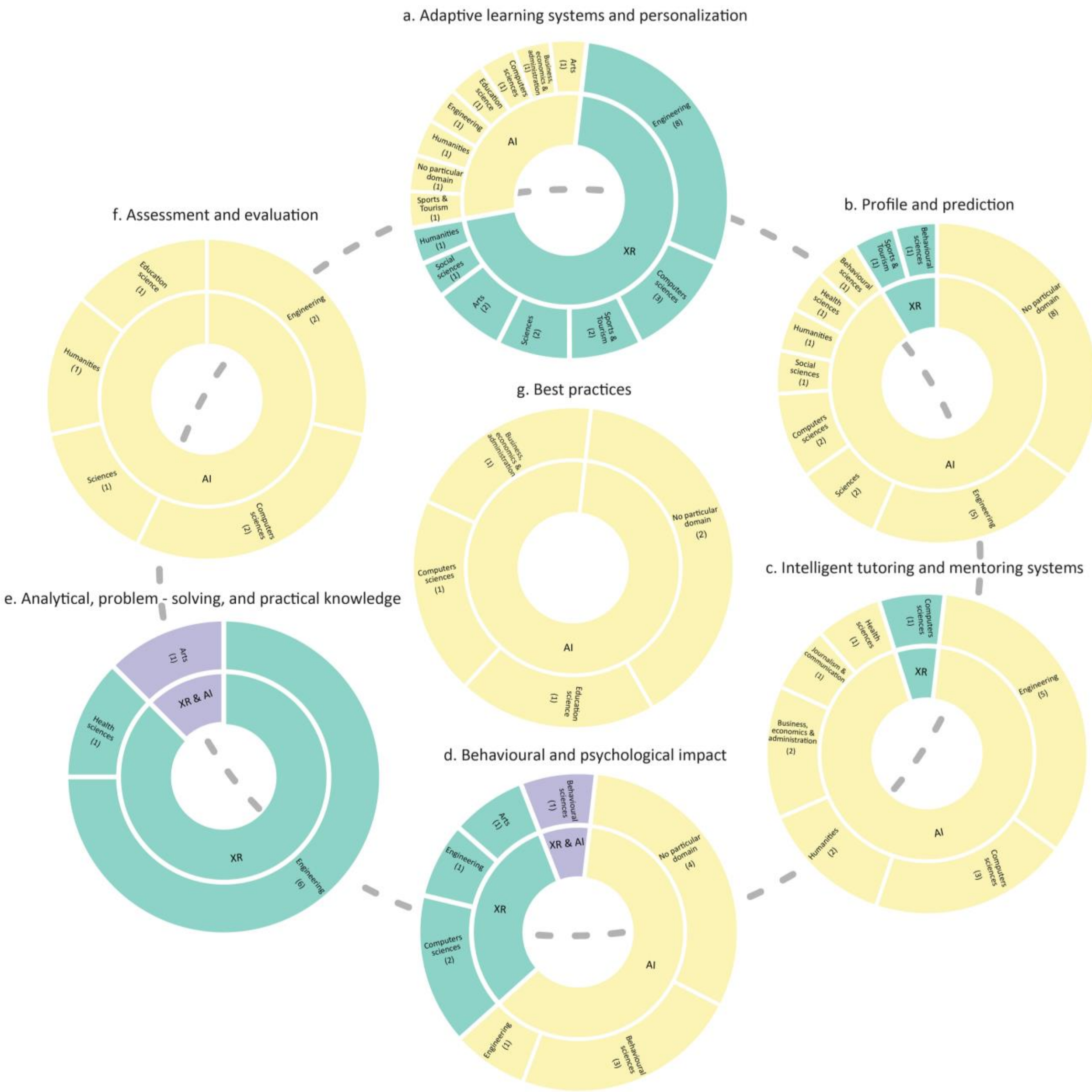

Figure 7. XR and AI technology applications in higher education are distributed into seven categories.

4. Discussion

The literature analyzed in this systematic review evidences an increasing number of educational projects using XR and AI actively integrated into online higher education, especially since March 2020. Significant technological advances are contributing to rethinking and elevating the instructional design so that educational materials that are more specifically applicable are provided to students at their appropriate level of learning. Moreover, the publications reviewed suggest that when using key technologies, learners feel inspired to learn, retain more knowledge, and are more interested in completing the assigned activities [65,66,70,143].

Amid the COVID-19 outbreak, many higher education institutions faced multiple challenges when mutating from face-to-face to virtual teaching. One of them was to provide materials accessible to all learners [72,139]. Another way to manage the teaching-learning process is by making it self-paced, simulating real-life experiences, and improving collaboration under such difficult circumstances [18,68,75,101].

Interestingly, a growing need exists to customize courses and curricula to fit student needs by impacting education. Although this does not replace actual educational experience, for example, in healthcare contexts [66] or marine and terrestrial biodiversity fieldwork [74], it enhances time on task, the expertise, and the engagement of online learners. Following this trend, XR has also been used to encourage academic achievement and gaining skills in virtual classrooms, as shown by Eldokhny and Drwish [16] and Chessa and Solari [128] during the pandemic.

From a pedagogical and technological perspective, a thread emerges that co-design processes using XR and AI with more conventional resources still benefit learning [70,84]. With the advent of AI, new forms of online learning and teaching support appear to expand student satisfaction, knowledge acquisition, personalized programs [126], and intelligent tutoring–mentoring tools [91].

Interestingly, contrary to other studies, after comparing technology acceptance of e-lectures, classroom response systems, classroom chat, and mobile VR [53], we noticed a decrease in the perceived usefulness and behavioral intention after three months of students using mobile VR. The main reasons for such poor technology acceptance feedback were mainly related to functional and technical issues of mobile VR. It is clear that the problems presented above are not new. However, it highlights the necessity for a re-evaluation of critical approaches for the appropriate implementation of emerging technologies in terms of curricula design, educational policies, technological resource implementation, and digital competencies and skills at all higher education levels.

Based on the revised literature, it is evident that online higher education efforts toward using emerging technologies are not happening naively. AI is applied to predict how students access, select, and use the information for online higher education processes [108]. In this scenario, automated student performance monitoring has been indispensable in qualifying and quantifying individual learning [115]. Based on profile and prediction analyses, educators and universities, in general, may deploy nudging intervention systems, control drop-out and retention rates, monitor student trajectories, and guide them to academic success [117]. Moreover, using machine learning algorithms, it is possible to predict the use of learning resources, adoption behavior, and integration in the educational process [62,104], and systematize the academic evaluation process [89,146].

Another aspect to consider is the psychological challenges that COVID-19 has posed to online higher education students, faculty, and staff. When addressing this matter, Atlam et al. [130]. Jojoa et al., [84] and Wang et al. [129] found that anxiety, stress, and depression were common denominators that could persist for a long time.

In this case, higher education institutions should play a critical role in raising awareness of mental health issues and deploying resources to assist when needed [55,134,136]. A lack of adequate support may impact students negatively by reducing their level of satisfaction, attention, and academic achievement, but also educators who set an example of endurance after dealing with their mental exhaustion while caring for learner needs. Implementing early warning systems localizing and attending to mental health challenges may improve academic success and help reduce psychological distress resulting from this pandemic [135]. Research on the mental health impact of the COVID-19 pandemic is still in its early stages, but there are vast opportunities that we will see more of in the future.

Special attention should be paid to the effects of the overuse of emerging technologies for keeping track of and enhancing communication and collaboration in online education during pandemic times, such as information overloading, distraction, and time-wasting. Additionally, there is a risk of discriminating against those who cannot fully access these services, which may end up alienated from the processes of collaboration and communication within the educational process due to factors such as the complexity of the interface, limited access to smart devices, or lack of a suitable network signal in remote areas. Although the pandemic has accelerated the pace for universities to explore longer-term digital transformations toward enhancing online education, attention should be paid to not widening the gap between those with technological advantages and those challenging to access essential resources.

We cannot rule out that applying XR and AI to educational settings takes an economic investment. However, as these technologies become more frequent, their deployment cost decreases, making them more sustainable in the long term than traditional analog learning. Looking ahead, it is plausible that this trend will continue to evolve worldwide, making access to remote learning more effective and adapted to current needs.

No technology is without drawbacks. The subtext that we can extract is that—such as was the case with pandora's box—the opening of AI in higher education remains controversial. Intelligent systems and automated nudge products that profile students and predict their performance-based outcomes are not free from scrutiny. Although these are compelling resources, care must be taken to ensure that they are carefully monitored to ensure that boundaries of privacy, ethics, and access to private data are not crossed [21,150]. Should this happen, it might end up negatively impacting the educational experience.

XR and AI have progressively evolved into strategic and accessible ways to create new paths in higher education. Nevertheless, humans and technological resources are needed to provide high-quality education. The success of this technology depends not only on solid infrastructure and facilities but also on educators and students [52,98].

Even though these are promising predictions, the long-term impact of AI and XR in teacher-learner interactions remains elusive. Unquestionably, with automated AI solutions taking the lead in education in the near future, concerns are raised about potential faculty replacements. From a pedagogical perspective, as emerging technologies evolve, they might provide the necessary resources for improving the educational process and grant teachers the time to focus on providing knowledge, support, and tutoring with tailored programs adjusted to the needs and different trajectories of the students.

5. Conclusions

Here we presented a systematic review mapping the implementation and influence of XR and AI on online higher education after the COVID-19 pandemic outbreak. Since then, face-to-face learning–teaching activities have had to migrate into virtual settings. Even universities accustomed to working in online environments had to adapt to the new circumstances. All this resulted in the need for a tailored and successful support scheme for educators and learners.

This systematic literature analysis corroborates the growing interest in using XR and AI to impact learner agency and outcomes, making online education more accessible, effective, engaging, collaborative, and self-paced. Nowadays, implementing key emerging technologies has a critical role in shaping the future of online higher education. Online university education is a pillar for most students with complex academic trajectories demanding a more flexible educational experience with synchronous and asynchronous resources. Although this has been latent in recent years, the COVID-19 pandemic has fast-paced the ways tertiary education transmits knowledge and builds expertise. Hence, more than before, teachers seem to rely on technology to meet the challenges of providing learning curricula in flexible and customized ways.

Notably, over the past two years, educators have applied XR and AI (either independently or combined with other technologies and systems), allowing them to enhance and even reinvent teaching processes. The momentum brought about by the pandemic is expected to make using these resources one of the online higher educational preferences in the future.

Upcoming research should aim at implementing the search string developed in more databases and languages, such as French, Portuguese, Chinese, Korean, and Russian, to expand the scope of this review for a broader analysis of the metadata. Including full papers from major topical conferences such as conferences on AI in higher education will also be considered. Moreover, as education evolves with the needs of the current times, we aim to produce future research on other critical emerging technologies such as Micro-credentials and Open Educational Resources.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15043507/s1, Table S1. Mobile learning applications to improve invertebrate zoology online teaching.

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