Extended Reality, Pedagogy, and Career Readiness: A Review of Literature

Patrick Guilbaud[1](✉), T. Christa Guilbaud[2], and Dane Jennings[3]

[1] Graduate School and Learning Technology, Winthrop University, Rock Hill, USA
`guilbaudp@winthrop.edu`
[2] Learning Design and Technology, UNC at Charlotte, Charlotte, USA
`tguilbau@uncc.edu`
[3] Catapult Games, Schenectady, USA
`DaneJ@CatapultGamesVR.com`

Abstract. Recently, there has been a significant spike in the level of ideation with, and deployment of, extended reality (XR) tools and applications in many aspects of the digital workplace. It is also projected that acceptance and use of XR technology to improve work performance will continue to grow in the coming decade. However, there has not been a robust level of adoption and implementation of XR technology, to include augmented reality (AR), mixed-reality (MR), and virtual reality (VR) within academic institutions, training organizations, government agencies, business entities, and community or professional associations. This paper examines the current literature to determine how XR and related technologies have been explored, evaluated, or used in educational and training activities. As part of the literature review, we paid special attention on how XR tools, applications are being deployed to increase work and career readiness, performance, and resiliency of students, adult learners, and working professionals. Results from the study showed that XR applications are being used, often at pilot-testing levels, in disciplines such as medicine, nursing, and engineering. The data also show that many academic institutions and training organizations have yet to develop concrete plans for wholesale use and adoption of XR technologies to support teaching and learning activities.

Keywords: Extended reality · XR · Technology-enhanced learning · Affordance · Pedagogy · Skills development · Career readiness

1 Introduction

Considerable focus has been placed in the last few years on the importance and benefits of introducing new and advanced technology to support active and experiential learning activities within and outside the classroom environment [1–3]. As offered, by Ertmer [4] and many other authors [5–7] proper integration, use, and administration of education technology along with appropriate pedagogy such as active and experiential learning could facilitate greater student engagement, participation, and involvement in learning. Other researchers [8–10] have also offered that the use of technology along with hands-on

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learning activities offer greater likelihood of knowledge retention, transfer and sharing. With the prevailing global knowledge economy, academic institutions from high school to colleges and universities continue to face the challenge of ensuring that their students will have the right combination of technical, professional, and socio-cultural skills to be ready for the workplace and for active citizenship upon graduation [11, 12]. As a result, it is critical for learning or training efforts, irrespective of the complexity level or delivery mode, to be designed and taught in a manner that allows the mastery of hard and soft skills and competencies. These include technical knowledge, numeracy, computer programming, critical thinking, decision-making, collaboration, and teamwork, all of which are in high demand by employers [13, 14].

Faculty and instructors strive to use the educational technology tools and applications that are available at their institutions to develop and offer stimulating and engaging learning opportunities for students. However, due to lack of time, resources, or other challenges, they often are unable to create and implement “hands-on” and “minds-on” activities that are designed to promote or reinforce the mastery of career readiness skills [15, 16]. Yet, given the acknowledged list of skills that are required for career and professional success in the 21st century workplace, learner-centered instruction -- whether delivered by face-to-face, distance education, or hybrid delivery modes -- must be organized to meet the educational needs and interests of students and be in sync with future employment opportunities [17]. Further, domain-general skills (i.e., time management, teamwork, or leadership) must be emphasized in all learning activities and assignments to assure knowledge transfer and utilization in postsecondary school environments and the workplace [18].

This paper examines how Extended Reality (XR) technology including Virtual Reality (VR), Augmented Reality (AR), and to a lesser extent Mixed Reality (MR), are being used or investigated for the purpose of career readiness and mobility. As part of that work, we conducted a systematic literature review (SLR) to: (a) Identify and interpret linkages and connections that exist between deployment of XR technologies and career training and readiness; and (b) Highlight and assess ground-breaking implementations, approaches, and practices of XR technologies that support the development or strengthening employment-related skills. In the next sections of the paper, we present an overview and a more recent perspective on the use of advanced technology to support learning inside and outside the classroom. We also highlight the aspects of learning and pedagogy that fit well with both the modern digital environments and skills development. We then note the results, findings, and conclusion from peer-reviewed articles, with a focus on the integration, implementation, or use of XR technologies to support career readiness and mobility.

2 Related Work

2.1 XR Technologies

XR is a catchall term for technologies such as VR, MR, and AR, all of which blend the real and virtual world to some degree [19, 20]. Further, XR-related tools and applications make use of devices such as desktop computers, tablet PCs, smart-phones, headsets with visual capabilities, or other multi-media devices to allow users to interact with virtual objects [20–28].

While VR is widely used to indicate the blending of realities, AR has recently gained greater acceptance and recognition by the general public with the successful introduction of the game Pokémon GO in 2016 [26]. The game, which is a location and AR-enhanced application, allows players to use their smartphones or other mobile computer devices equipped with Global-Positioning System (GPS) to search and capture pocket monsters (i.e. Pokémon).

There has been considerable debate regarding the nomenclature and taxonomy to be used for the different "realities" in the broader XR field. As part of that debate, Milgram et al. [28] offered a model called the reality–virtuality continuum to denote the different variations and compositions of real and virtual environments and objects. As shown in Fig. 1 below, that nomenclature or model starts with the real environment where people live and interact. Then it offers terminology where technology is used to blend that reality and virtual objects or create a fully immersive virtual environment.

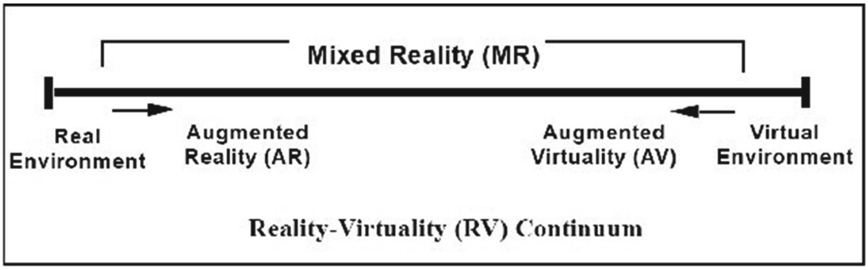

Fig. 1. Reality–virtuality continuum [23].

More recently, the term XR has been used as an umbrella term for all real and virtual environments [24–26]. AR, MR, and VR are now used to denote succeeding degrees of realities, generated by digital devices and wearables (body-borne portable personal computers) where interactions between people and virtual objects can take place. Although AR, MR, and VR are sometimes used interchangeably, they differ in the types and level of interactions they afford the user with virtual objects. VR, for example offers the user the possibility to have full immersion (i.e. 360°) in virtual worlds with the use of head-mounted displays (HMD) or CAVE (for Cave Automatic Virtual Environment) [27, 28]. In contrast, AR and MR are used in situations or contexts that blend the real and virtual worlds. Therefore, each technology affords a unique and targeted learning experience. Given the opportunity for engagement or interaction with the real and/or virtual world, both VR and AR technology can be leveraged in education and training situations that involve problem-solving, collaboration, and decision-making [21, 29, 30].

2.2 Evolution of XR Related Tools

Interest in VR tools and applications has been on the meteoric rise in the past 10 years with the introduction of Oculus VR headset and similar technologies that allow users to enter into a virtual world [31]. Yet, as shown in Table 1, the technology known today as XR really began in 1957 with the introduction of Sensorama, a simulator console created by Morton Heilig that offered users an interactive experience with virtual objects in an extended-reality space [32, 33].

Table 1. Key VR/AR related tools [34]

Year	Product	Display	Major achievement
1957	Sensorama	Kiosk	Interactive experience
1961	Headsight	Camera	Motion tracking system
1966	AForce Sim	Computer	VR for training purposes
1987	Project VIEW	Computer	Virtual objects
1995	Virtual Boy	HMD	Display of 3D graphics
1997	Virtual Vietnam	Computer	Medical treatment
2014	Oculus Rift	HMD	Mass product
2014	Cardboard	Smart Phone	Uses cell phones
2016	Playstation VR	HMD	Gaming console
2018	Oculus Go	HMD	Wireless and standalone
2019	Oculus Quest	HMD	Positional tracking

Other key advancements in the field include the use of motion tracking capabilities, and the use of the VR technology in training starting with the Air Force Simulation Project and other military-related endeavors [35, 36]. Thus, XR technologies are being used in a wide variety of fields and learning contexts for skills development, career improvement, and military/operational readiness [25, 36–38].

2.3 Current and Affordable XR Tools

Table 2 lists some of the VR and AR tools currently available on the market along with their prices. As shown, standalone VR/AR tools i.e. those that do not require a computer, can be purchased for as little as $299. High end systems either standalone or those that require a computer or a smartphone can run anywhere from $1,000 to $3,000 and higher.

Table 2. Affordable XR Tools and Systems (2021)

XR tool	TYPE	Cost	Set-up
Oculus Quest 2	VR	$299	Standalone
Oculus Rift S	VR	$299	Requires a PC
Valve Index	VR	$999	Requires a PC
HP Reverb G2	VR	$599	Requires a PC
HTC Vive Pro Eye	VR	$1,599	Requires a PC
MS Hololens 2	AR	$3,500	Standalone
Magic Leap One	AR	$2,295	Standalone
Vuzix M4000	AR	$2,499	Standalone
Vuzix Blade	AR	$899	Standalone/Right lens Display
Google Glass	AR	$1000	Standalone
Bose Frames	AR	$250	Standalone - Audio only

2.4 Career Readiness

Soft skills, including critical thinking and teamwork, are in high demand by employers [39, 40]. In fact, many employers now indicate that soft skills are more important than hard or technical skills as the latter can be taught in the workplace [41]. Google, for example, found that the top seven skills related to success in the company were "soft" or people-related ones [42]. Moreover, global and collaborative work teams are now the norm in business today as multinational businesses use technology to create and use virtual teams, international collaboration, and multi-national partnerships and other strategic global business arrangements to stay ahead of their competitors [43–46].

As a result, students and other learners must be provided the opportunity to strengthen their critical thinking, problem solving, and teamwork skills to be competitive in the global economy. As Barrows [47] and Hmelo-Silver [48] noted, students and working professionals need decision and work-related skills to find and maintain suitable employment and advance in their careers. Consequently, we argue that XR technologies can be used as a heuristic tool to help students and working professionals develop or strengthen their academic and career-oriented skills. More specifically, we note that XR tools and applications supported by sound pedagogy offer a means for enhancing the hard and soft skills that are critical for success in the 21st century workplace [11, 48].

2.5 Technology-Enhanced Learning

Technology has long been used to support a wide variety of teaching, learning and education activities [49–51]. Whereas in the past, technology was used mainly for vertical interaction or content delivery, e.g., from teacher to learner. The affordances that are available in current instructional tools and applications, offer faculty and instructional designers the means to implement horizontal interactions or learner-learner and learner-content activities [8, 9, 52].

Kennedy and Dunn [53] argue that one of the key strengths of using technology-enhanced learning (TEL) is the opportunity that it provides to keep students cognitively engaged. Other researchers have found that technology can be used to strengthen connection to educational content by both individual learners as well as collaborative learning teams [53, 54, 55]. Moreover, recent studies have placed focus on exploring how to best leverage the affordances and unique features of modern technology such as VR to improve skills and learning outcomes.

Starr [56], for example, found that TEL tools and applications such as gaming and simulation software allow the creation and implementation of hands-on and minds-on learning activities within the classroom. Thus, TEL allows students to have increased levels of interaction with their instructors and their classmates, leading to a greater level of retention and disposition to apply learning materials in a real-world setting.

2.6 Affordance and Pedagogy

Considerable debate exists regarding what is meant by the term affordance [56–59]. Some authors and researchers restrict the meaning to the original perspective offered by Gibson [59], who argues that the environment and animals have co-evolved and not necessarily people-constructed. Therefore, according to Gibson, objects in the environment afford or support certain capabilities, activities, interpretations that are totally independent of people. Other scholars such as Norman [60] have expanded upon the original definition of the term affordance to incorporate an aspect of utility or functionality to it.

More recently, there has been increased awareness that the affordances, which are imbedded in XR technologies, and sound pedagogy can help students gain both domain specific knowledge and interpersonal skills [see 25, 62–65]. Shin [64] notes that using technology such as VR in education and training helps keep students cognitively engaged. Other researchers are actively looking at how applications such as gaming, VR, and artificial intelligence can strengthen human learning [67, 68]. Therefore, educators and designers can use modern technology tools such as XR along with appropriate pedagogy to offer innovative learning experiences to students that are meaningful and relevant to their post-graduation lives [48, 69].

2.7 XR for Education and Skills Development

For the purpose of this paper, we look specifically at the impact of XR technologies (including VR and AR) on learning, since they are the tools that are most often used in education, and training environments [see 29, 70, 71, 72]. Below, we outline how both of these technologies are being leveraged to elicit the types of learner-focused activities that can help to strengthen skills that are relevant for academic and career readiness.

As previously noted, learning is most effective when people have the chance to engage in a meaningful way with the course or training content (e.g., through investigations, social interaction, problem-solving, and other active or experiential learning tasks) [73–75]. Moreover, we note that the integration of XR in education affords learners opportunities for open-ended and non-linear activities. Use of pedagogical approaches that are learner centered (e.g., active and experiential learning, which are highlighted in some of the previous sections of the paper) offer a greater likelihood for knowledge acquisition, retention, transfer, and sharing due to their strong focus and emphases on hands-on and practice-oriented activities [8, 76]. Therefore, by combining XR technology with sound pedagogy learners will gain the opportunity to test out the knowledge they have gained in new and unique situations and then receive immediate feedback with guidance for improvement or words of praise and encouragement [see 25, 36, 77, 78].

3 Methodology

3.1 Context

This research sought to explore how XR technology, and most specifically VR and AR, along with appropriate pedagogy are being used to facilitate the acquisition of skills that are in high demand in education programs and careers. We also wanted to gauge, from the current literature, the level and degree to which those technologies are being implemented for the purpose of facilitating or strengthening career readiness and mobility.

3.2 Research Approach

According to Dewey & Drahota [77] a SLR, identifies, selects, and then critically appraises research in order to answer a clearly formulated question. Moreover, the SLR needs to follow a clearly defined protocol or plan where the criteria is clearly stated before the review is conducted [78]. For this paper, we conducted a SLR on XR technologies, which included VR, AR, and MR, that are currently being used in the context of academic education, professional training, and research.

3.3 Research Questions

Our SLR study was guided by the following two key questions:

1. How have XR technologies been used or integrated in learning environments?
2. How can the XR interventions that been identified can best be classified in relation to their impact to academic and career readiness?

3.4 Data Collection

The literature search was conducted in November/December 2020 and in early January 2021 from two popular databases, JSTOR and ERIC through EBSCO host. We started the initial literature search through JSTOR focusing on 2010–2020 timeframe. The search keywords used were "Virtual, Augmented, Mixed, and Extended Reality plus Education and Career", which yielded 8,084 search results as shown in Fig. 2. The search result helped the researchers gain a preliminary idea of the scope and types of the research conducted in the field that are related to our research questions. We then excluded 6,089 articles from the data collected. These involved studies and research that were deemed too old e.g., no mention of AR, MR, and HMD. Grey literature (e.g., reports, theses, projects, conference papers, fact sheets, and similar documents that are not available through traditional bibliographic sources such as databases or indexes) was also excluded during this step.

We then removed 2,445 articles, which did not directly place focus on career-related issues. Exclusion criteria were studies involving K-8 that specifically did not involve pre-service or certified teacher training or professional development. High school-oriented papers were included in the data selected if it involved teacher preparation for career. The remaining 270 articles were closely examined by 2 reviewers to ascertain whether their titles, abstracts, and research questions were in congruence with the focus of the study. We then skimmed through the full-text articles to further evaluate the quality and eligibility of the studies. We deemed 60 journal articles to be relevant for further scrutiny. Discrepancies between the reviewers' findings were discussed and resolved. This resulted in 25 articles to include in our review. These were put in a spreadsheet along with the full reference, author, year, title, and abstract for detailed examination and evaluation.

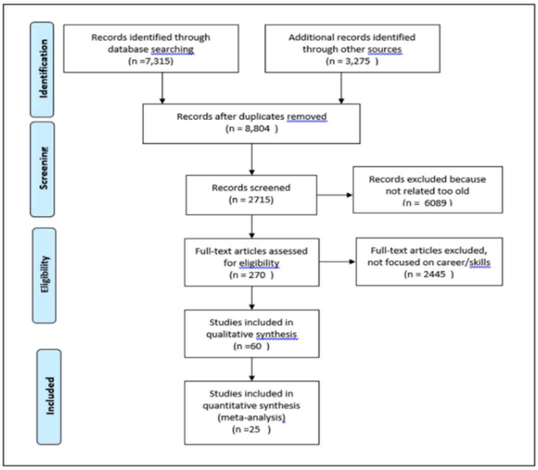

Fig. 2. From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. https://doi.org/10.1371/journal.pmed1000097. For more information, visit www.prisma-statement.org.

4 Results and Discussion

4.1 Dataset Categorization

The selected articles were analyzed, coded, and then categorized by the researchers according to their learning development aspect and field of focus. The first learning category developed for the data is Knowledge, Skills, and Abilities (KSA) development. Learning Domain was the second category that was determined for the study. Six sub-domain categories were identified. Further, we used two learning clusters for the articles to gauge whether the studies focused on school (A) or work related training (B). Table 3 below presents the Learning Domains and related clusters A, B, or A and B.

Table 3. Sub-domain Categories

Learning domain	Description	Cluster
Gen Ed	General Support and Readiness	A
LWD	Support for Learners With Disabilities	A
CPE	Continuing Professional Education (Non-Medical)	B
STEM	Science, Technology, Engineering, and Math (incl. Comp Science) Support and Readiness	A and B
Medical	Training of Physicians, Nurses, and other Healthcare Professionals	A and B
P/S/B Change	Personal, Social, and Behavioral Change	A and B

4.2 Literature Selected

Table 4 below presents the complete list of articles reviewed for the study along with the learning domains and KSA category for each of them. As shown, articles that met the selection criteria for the study range from 2017 to 2020. Further, the overwhelming majority of the selected articles (88%) were published in 2019 and 2020.

Table 4. Selected XR Articles

REF	LEARNING			XR	DATE
	DOMAIN	KSA	STUDY GOAL		
[81]	P/S/B Change	3	Enhance Behavior Intention	VR	2018
[82]	CPE	1, 3	Simulate marine battlefield	VR	2019
[83]	Sup of LWD	3, 5	VR and individuals with autism	VR	2017

(*continued*)

4.3 Question 1

Question 1 sought to gauge how XR technologies have been used or integrated in learning environments. To answer that question, we first identified sub-categories for KSA. This

Table 4. (*continued*)

REF	LEARNING			XR	DATE
	DOMAIN	KSA	STUDY GOAL		
[84]	STEM	4	Support problem-solving	VR	2020
[85]	STEM	2, 4, 5	Outdoor ecology	AR	2018
[86]	CPE	1–3	Enhance surgical education	XR	2020
[87]	P/S/B Change	2–4	Initial training of future teachers	AM	2020
[88]	CPE	2, 3	Computer animation affects	AR	2020
[89]	P/S/B Change	2, 3	Reduce sedentary behavior	AV	2020
[90]	Medical	1, 3	Telemedicine/COVID-19	AR	2020
[91]	CPE	2–4	Professional skill development	XR	2020
[92]	Medical	3, 4	Anatomical structure of heart	AR	2020
[93]	Gen Edu	3,4	Presentation and speaking skills	AR	2019
[94]	STEM	3	Learning Biochemistry concept	VR	2019
[95]	Gen Ed	3, 4	Improve critical thinking skills	AR	2019
[96]	STEM	3, 5	STEM efficacy for women	VR	2019
[97]	Sup of LWD	2, 4, 5	Accessibility/Design thinking	VR	2019
[98]	P/S/B Change	2–5	Preservice teacher self-efficacy	VR	2019
[99]	Gen Ed	3–5	Students' learning experiences	VR	2020
[100]	P/S/B Change	1–5	Classroom management	MR	2020
[101]	Sup of LWD	1,3,5	Supporting children with autism	MR	2019
[102]	Sup of LWD	1, 3, 5	Daily living skills disabilities	AR	2020
[103]	P/S/B Change	1, 3, 4	Nursing student motivation	MR	2020
[104]	CPE	1, 3, 4	Performance in welding practice	VR	2020
[105]	STEM	2–4	Complex chemistry concepts	VR	2019

was done via a careful review and examination by two authors of the paper of the research problems, background literature, and research objectives noted in the articles. Initial classifications were re-examined in case of divergence between the two authors. Final classification of determined upon agreement between the two authors. Figure 3 below presents the number of occurrences in the data for the KSA sub-category. As depicted, Self-Empowerment/Self-Efficacy (S EM/EF) had the highest level of focus. This was followed by Critical Thinking and Decision Making (CT/DM). The sub-categories of Technical Knowledge and Problem Solving (TK/PS) and Inclusive Excellence and Community of Practice (IE/CoP) both had 10 occurrences. Safety and Risk Reduction (S/R) had a total of 9 occurrences.

The studies reveal that XR technologies have strong potential to improve problem-solving and critical thinking skills [84]. For example, Syawaludin et al. [93] found that

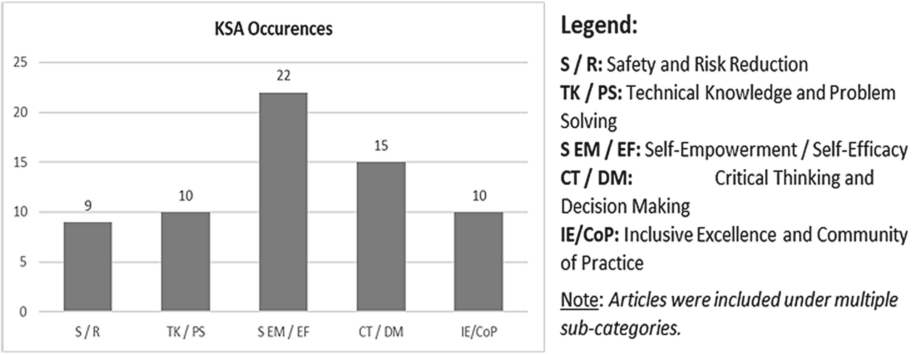

Fig. 3. Learning category

augmented reality media in learning about earth and rock structures helped pre-service elementary school teachers develop their critical thinking skills as they actively engaged in learning activities (e.g. information gathering, analyzing, and solving problems). Further, Wu et al. [82] found that students studying electrical circuit design perceived a higher level of self-efficacy and increased sense of presence when using head-mounted displays (HMD) Netland et al. [97] posited that VR facilitates active learning and assists students in learning and remembering challenging concepts in operations management.

Several studies also showed that XR technologies are instrumental in supporting pre-professional training and professional skill development [99, 100, 103]. Wells and Miller [102], for example, discovered in a study about welding skill performance that VR can be beneficial for psychomotor skill development. Thus, XR can help facilitate skills development in situations where hand and body motions are necessary to operate power machinery or perform medical surgeries as well as in contexts in which repeated practice and skill refinement is imperative.

In summary, XR technologies are being used in a variety of education and training contexts. Moreover, VR and AR tools and applications are being used to help learners across education settings (i.e., K-12, college, workplace, continuing and professional education) develop both technical skill (e.g., decision-making, information management, problem solving and critical thinking) and soft skills (e.g., teamwork, collaboration, diversity, and intercultural). Additionally, XR allow users/students to perform repeated trials in a low-risk environment for mastery of academic and career related skills and competencies.

4.4 Question 2

Question 2 sought to understand ways in which the XR interventions that have been identified can best be classified in relation to their impact on academic and career readiness. Figure 4 below presents the distribution of XR and Learning Domains found and the percentage of their occurrence. STEM Support and Readiness (STEM) and Training of Physicians, Nursing, and Healthcare Professionals (Medical) were the two highest sub-categories represented in the literature. Continuing Professional Education (CPE) came in last at 8%.

Given that many science-oriented fields are widely considered to be early adopters of various advanced technology tools, life-like patient simulators, three-dimensional imaging, digital holography, and telehealth [see 92, 103, 106], it is not too surprising that both of STEM and Medical sub-categories are well represented in current XR-related training, implementation, and research.

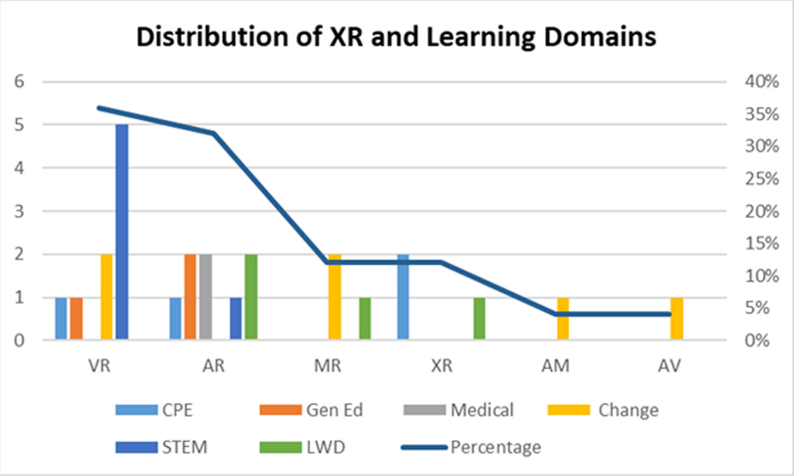

Fig. 4. Learning category

As shown in Table 5, 28% of the documents fell under the Academic cluster, 8% under Work-related and 64% under both clusters.

Table 5. Learning domains and focus

Domain	Focus*	%
General Support and Readiness	A	16%
Support for Learners With Disabilities	A	12%
Continuing Professional Education (Non-Medical)	B	8%
STEM Support and Readiness	A / B	24%
Training of Physician, Nursing, and Healthcare Professionals	A / B	24%
Personal, Social, and Behavioral Change	A / B	16%
**A = Academic; B: Work-related*		

While most of the articles focused on both academic and work-related related endeavors, a few studies, particularly those in the exploratory or pilot-stage, targeted a specific learning domain cluster. For example, Wu et al. [82] explored the link between HMD and planning strategies for problem solving as part of an undergraduate engineering course.

In another study focused on preservice teacher preparation, Cooper, Park, Nasr, Thong & Johnson [96] found that VR showed promising results with regards to supporting classroom activities.

Research studies with a dual focus were mostly in the areas of medicine and health. For example, Liu et al. [88] explored how XR could be used in a telemedicine capacity to support COVID-19 interventions. Likewise, Abbas et al. [84] and Hauze & Marshall [103] investigated how XR could be used to improve physician training. In the work-related category, Netland et al. [97] explored how XR could be leveraged to strengthen operational improvements while Gallup & Serianni [81] looked at how XR could be used to support learners with disabilities, most specifically those with Autism Spectrum Disorder (ASD).

Researchers are exploring the use of XR in a broad range of learning domains and foci. The data suggest that perhaps STEM and health-related fields show promising uses of XR as an instructional method to avoid injuries and reduce risks. In regards to providing support to learners with disabilities, VR tools allow both pre-service and in-service teachers to practice communication scenarios and test out ideas prior to working with real children. Nevertheless, given recent developments in the STEM and medical fields to reduce equipment and training costs while gaining greater consumer interest, we also anticipate that fields such arts, ecology, engineering, history, travel and tourism, will be a stronger part of the XR literature in the future.

5 Conclusion

Widespread availability modern technology and significant decrease in the cost XR technologies have opened the door for designers to imbed increased user interaction in all types of learning, education, and training contexts [25, 31, 107, 108]. With changing perceptions regarding the use and integration of virtual objects in instruction, more focus will need to be placed on learner-centric pedagogy to help enhance the academic and career readiness of students and working professionals [109]. Moreover, as the market economy demands for a workforce that is prepared to think creatively, problem solve, and be adept with the most up to date technologies, educational institutions will need to adapt their methods and instructional delivery. Learning environments that leverage relevant aspects of XR technologies help facilitate multifaceted engagement and interactions (e.g., learner-learner, learner-contents, and learner-agent/avatar) as part of educational activities [110, 111, 112]. These interactions and exchanges will stand to surpass those that are encountered in traditional classroom settings and learning contexts. Faculty, teachers, instructors and related professionals across the education spectrum (K-12 schools, colleges/universities, private training organizations and other learning entities) will therefore need to rethink their approaches so they can allow students and leaners to become owners, collaborators, and constructors of their own knowledge. Through the advances in technology, XR will allow education to be offered and delivered for optimal engagement and interaction with learning contents. The new paradigm being led by XR in the education field will thus allow educators to present course and training to maximize knowledge acquisition, retention, and application by all learners.

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