A Review on XR in Home-based Nursing Education

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***Abstract*—Recent developments using extended reality (XR) technologies have allowed for increased use in healthcare in the last few years. This review paper explores how XR applications are utilized in home-based nursing education, in particular, to identify future challenges and opportunities. The systematic literature review evaluates relevant extracted papers based on publication information, XR technology used for education purposes, target users, and study design and evaluation, including sample size. The results show potential for using XR technologies in home-based nursing education. In particular, Virtual Reality (VR) has become quite popular and the most used to date. However, Augmented Reality (AR) has also emerged as an alternative for the future.**

***Index Terms*—Extended Reality; Review; Home-based; Nursing**

I. Introduction

Information and Communication Technology (ICT) has consistently supported higher education with a wide range of applications for decades. ICT has been proven to increase motivation and engagement in studying and enhance the collaboration between educators and students [1]. Due to the Covid-19 pandemic, many universities have shifted (at least partially) their education from campus-based to distance education. Because of this shift, researchers and educators are exploring new ways of applying ICT to support distance education. However, programs such as nursing education which require extensive on-site clinical training, may struggle to adopt ICT into this shift in their curriculum. It requires an appropriate design and application of the technologies. Otherwise, the benefits can be limited.

Home-based healthcare is one such area in which ICT may be adopted into nursing education and practice. According to the World Health Organization (WHO), the percentage of people aged 60 and over will double from 12% in 2015 to 22% in 2025 [2]. In addition, 71% of global deaths are caused by chronic diseases. The increasing aging population has already heavily affected the healthcare systems worldwide. As a result, there is a trend to shift traditional hospital-based healthcare to home-based healthcare [3]. This trend also leads to changes in nursing education, as more home-based nursing education solutions are needed in the future. At the same time, the rapid development of ICT also brings several new opportunities to deliver a better education, even remotely.

Recently, as one of the most impactful ICT, Extended Reality (XR) has been applied in higher education. XR is an umbrella term for all the technologies that add virtual elements to the real-world environment to any extent. It includes Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), and anything in between [4]. VR is a 3-dimensional, computer-simulated virtual environment that can be explored and interacted with people in 360-degree [4]. AR is a real-time use of digital elements in a real-world environment [5]. MR is an interactive environment that combines a computer-simulated environment and a real-world environment [6]. The relationship among AR, MR, VR, and XR is shown in Fig 1. On the one hand, XR has been applied to education in different ways, with the benefits of improving students' problem-solving skills [7]. On the other hand, XR has also been widely used in healthcare, including disease prevention, treatment, medical training, and education [8]. XR devices are quickly becoming less expensive with the rapid development of technology. Hence nursing education with the help of these devices could play an essential role in increasing engagement, reducing the stress of learning, and creating an immersive experience with cutting cost and time efficiency [9]. This paper aims to explore the current state-of-the-art on applying XR in home-based nursing education and discover its future trends. To achieve the research goal, a systematic literature review will be performed. The research questions of this review are:

- **RQ 1**: How have XR applications been used in home-based nursing education?
- **RQ 2**: What are the future challenges and opportunities to apply XR technologies in home-based nursing education?

Applying XR technology in nursing and medical education is a relatively new concept and has recently gained popularity. Even though fewer works have explored the potential, the technology holds tremendous possibilities in the cross-domain linking XR and remote or onsite medical education. This has been demonstrated successfully with the growing application of VR, AR, and MR in pedagogy [7] [10] in several educational disciplines. This paper can help identify the initial advantages and challenges of leveraging XR technology in home-based nursing education.

II. Related Work

VR has been applied in medical education since early this century. Gallagher et al. proposed that VR could be introduced as a tool for surgical training to improve surgical technical skills in 2005 [11]. Since then, more VR-based

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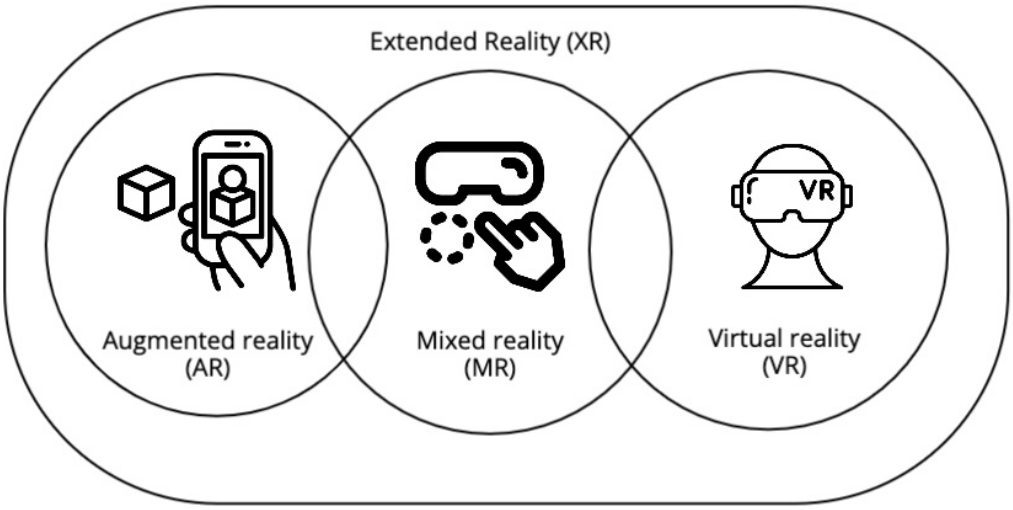

Fig. 1. XR technologies, including augmented reality (AR), mixed reality (MR) and virtual reality (VR).

surgical simulation programs have been implemented and used in different countries. A review of the use of VR in surgery training revealed that four commercially available simulators (dVSS, dV-Trainer, RoSS, SEP) had been demonstrated in doctor and nursing education programs. Most medical students who have used those four simulators have agreed that VR training is an effective way to improve skills and is comparable with the skills training in a lab [12].

Another review of XR game applications in healthcare noted that medical education and training are one of the main aims of applying XR into healthcare [8]. The training or education includes clinical training, basic life support training, nursing skills training, stress inoculation training, etc. [8]. Recently, immersive VR has been reviewed in nursing education [9]. This study indicated that immersive VR improved learning, cognitive, and psychomotor performance. However, the challenges of motion sickness and lack of visual comfort were also reported [9]. Existing review papers already clearly show how XR applications could contribute to nursing education in hospital-based healthcare. Considering the different requirements of home-based healthcare, unlike other reviews listed above, this review focuses on the XR applications in home-based nursing education.

III. Method

In order to answer the research questions, a systematic literature review is conducted. A systematic literature review provides a comprehensive and unbiased summary of current literature relevant to research questions. To maximize the coverage of our searched literature, we identified some of the most used words/concepts and synonyms in the research questions. We first conducted a manual search in computer science, healthcare and education. The selected databases were PubMed, Web of Science, ACM Digital Library, IEEE Xplore and Scopus. The publication year was not limited since XR is a recent emerging technology. In addition, the language of the papers was limited to English. The search string listed below was used to search in the selected databases:

- (“virtual reality” OR “VR”) AND (nurs*) AND (“educat*” OR ”teach*”) AND (home)
- (“augmented reality” OR ”AR”) AND (nurs*) AND (”educat*” OR ”teach*”) AND (home)
- (“mixed reality” OR “MR”) AND (nurs*) AND (“educat*” OR ”teach*”) AND (home)

The search string is sometimes modified slightly to copy the rules for search strings in different databases. The first search by the search string in all the mentioned databases produced 107 articles. The review processes are mainly based on the guidelines for performing systematic literature reviews in software engineering [13]. First, a primary evaluation was conducted by reading the abstracts and conclusions of all selected articles to explore the most relevant literature to our research questions. Then the second round of full-text review was conducted for the rest of the papers. The criteria applied for the evaluation are described in Table I.

TABLE I
INCLUSION AND EXCLUSION CRITERIA.

Inclusion criteria	Exclusion criteria
Written in English Studies that apply XR in home-based nursing education Have available full-text version Journal articles, conference papers and book chapters	Not written in English Less than 5 pages Review papers

Due to the small number after the two rounds of review, the only quality assessment criteria we applied in this study

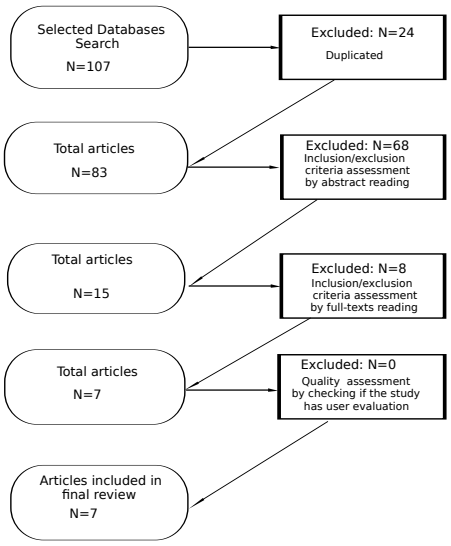

Fig. 2. Flowchart showing processes and results of systematic review

was to check if the paper has a user evaluation. The reason was the user evaluation results could be important inputs to answer our RQ2 compared with the only conceptual designs. After the inclusion/exclusion criteria assessment and quality assessment, data extraction was performed to avoid the bias of subjective preference. A method was applied in which one researcher extracted the papers, and another checked the extraction by reading the abstract of the selected documents. In the end, seven articles were selected for our thorough study, all included in the reference list. The flow chart of the stages and results of the systematic review is shown in Figure 2.

IV. Results

The following sections present the main results found in the review.

A. Publication Information

The selected seven papers were published in the last five years, starting from 2018 to 2022. Prior to 2018, few studies specially applied XR technologies in home-based nursing education. Figure 3 shows the number of papers for each year. The first three years have one paper for each year, but in 2021 and 2022, there were two publications. Among the seven papers, the countries and regions that carried out the studies are the USA (N=2), Spain (N=1), United Kingdom (UK) (N=1), Japan (N=1), Taiwan (N=1), and Brazil (N=1). It is a sign that applying XR in home-based nursing education is considered for broader use worldwide. Six papers applied VR, while one applied AR technology (See Table II). Other detailed information on the selected papers is listed in Table III.

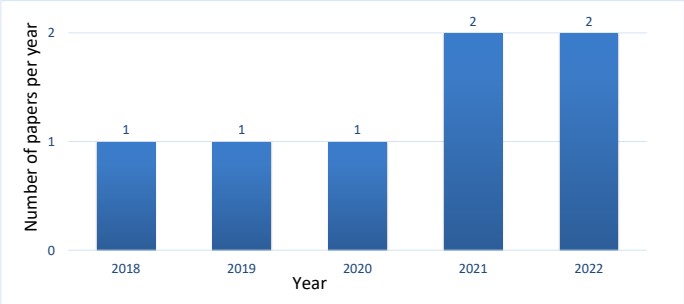

Fig. 3. Number of papers published each year as identified in the review.

TABLE II
XR technologies applied in the studies.

Technology	Number of papers
VR	6
AR	1

B. Education Purposes

All the studies aimed to transfer medical knowledge to the targeted nursing students in their specific areas. Three out of seven studies worked on care-skills training, such as endotracheal suctioning [14], Nasogastric tube care-skill training [15] and Neuroanatomy and Neurorehabilitation [16]. These skills training are not only for home-based healthcare but also apply to hospital-based care. The remaining four studies are more related to home-based healthcare scenarios, with one on general home-based healthcare [17] [18], elderly home-based care [18] and Parkinson's disease and associated disorders care [19].

C. Study Design and Evaluation

The study that applied AR technology [17] designed a mobile AR-based game for nursing students to learn how to deal with different situations when they visit the homes of different groups of people. The combination of mobile and game makes it easier to deliver distance education because of the flexibility and low cost. The designed game could improve the engagement of the students [17]. Most VR applications employ immersive VR, which uses Head-Mounted Devices (HMDs) to run the applications. Some were even assisted with motion capture sensors for interaction with the VR systems [14], [16]. One of the applications, namely Nursing XR, is an integrated platform mainly based on immersive VR technology [20]. The emphasis of the identified seven studies is varied. Some of them highlight the design and implementation of the XR-based education platform [14], [20]. Some others emphasize how the whole XR-based education or training program is designed [16], [18], [19]. In contrast, others are more focused on user evaluation [15], [17].

All seven studies include some user evaluation. Four of them use surveys as the primary evaluation method [16]–[19]. The questions contain standard questionnaires, researchers-self-defined questionnaires, and open-ended questions. The

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standard questionnaires include the System Usability Scale (SUS) [21], Gameful Experience (GAMEX) [22], QualCare Scale [23], etc. Those questions cover the XR systems' usability and user experience, the system's satisfaction, and the quality of home care. Two studies choose face-to-face communication methods like interviews [15] and workshops [20] to get direct feedback from the users. The study by Komizunai et al. [14] conducted a user experiment as the objective evaluation method. The data collected from the experiment is eye tracking data and motion of the whole body without fingers [14]. All seven studies received positive results on usability and user experiences from the evaluation results. The improvement in learning outcomes is also reported. Notably, the users from some studies pointed out the XR-based applications are fast to learn, free of learning stress, and enchanting the interdisciplinary collaboration [15], [16], [19]. However, the study by Chang and Lai [15] also mentioned that the convenience of the practice needs adaptation.

V. Discussion

Besides the traditional medical skills training, home-based healthcare also needs education on the different case studies in the home environment. It could help the home nurses to be well prepared before they visit different kinds of care recipients. Building up different home environments is unrealistic due to potentially high costs and access limitations. In this case, ICT-based simulations could play a significant role in it.

Previous studies [24], [25] indicated that case-simulation education could improve nursing students' empathy, confidence, and attitudes to dealing with healthcare recipients at home and cooperation in teamwork. The results of this review have similar findings with previous reviews only focused on XR applications in education [26] or healthcare [8], which shows that VR is the most applied technology in home-based nursing education. With its immersive feature, we believe that VR could significantly contribute to the home environment/case simulations for home-based nursing education. 3D virtual anatomical models and 360-degree videos are appropriate options for such simulations.

From our results, we also find the potential for applying AR technology in the future. Unlike VR, AR has its own feature of easy assessment and is not so dependent on auxiliary or other devices. In many cases, a smartphone is enough to run the applications. AR could provide widespread solutions at a low cost for home-based nursing education, which could benefit developing countries. Gamified XR applications for nursing education are another future trend to engage the students' involvement and improve the quality of education. Furthermore, some applications could also be introduced to other people who are involved in home-based care, in addition to the nurses. For instance, to the family members of chronic disease patients or elderly people who live at home, to develop a friendly and supportive community for those care recipients [27].

As with all new applications of ICT, the acceptance of technology in the home-nursing field also needs to be under consideration. Our previous study showed that home-based healthcare professionals could not easily adapt to the new ICT [3]. In addition, VR applications using HMDs can potentially induce motion sickness. This could be a challenge when applying XR technologies in home-based nursing education in the future. The time period of education, the level of integration of the XR technology, and the way of interaction with the systems are all aspects that need to be considered and further discussed with users when applying XR technologies in home-based nursing education.

Since this review only focuses on the XR applications in home-based nursing education, which is quite a narrow scope. The number of the included paper is only seven. It could affect the generalizability of the results of this review.

VI. Conclusions

This study conducted a systematic literature review to discover the current state-of-art XR applications applied in home-based nursing education and their potential and challenges. Seven papers are selected and analyzed based on the country or region, applied technology, education purposes, target users, study design, and evaluation. The results show that VR is the most used technology in this area for an immersive home-environment simulation. It could meet the empathy, confidence, and attitude education requirements for home-based nurses. Additionally, with other sensors, medical skills training could be performed outside the medical labs through VR applications.

AR was also applied in one study, but there is a general trend to develop more applications because of their low cost, flexibility, and accessibility. How to effectively integrate the XR technology smoothly in home-based nursing education and increase the target users' acceptance will be the challenge in the future. It is also essential to evaluate such systems with different target groups, such as patients, relatives, and medical professionals, before use.

Acknowledgment

This research was funded partly by the Knowledge Foundation, Sweden, through the Human-Centered Intelligent Realities (HINTS) Profile Project (contract 20220068).

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TABLE III
DETAILED INFORMATION OF THE IDENTIFIED PAPERS.

Study	Region	Technology	Educational purpose	Users	Sample size	Evaluation method
Pickering et al. [18]	USA	VR	Elder abuse and neglect	Nurses/social workers	36	Survey
Borges et al. [17]	Brazil	AR	Home visiting	Nursing students	135	Survey
Komizunai et al. [14]	Japan	VR	Endotracheal suctioning	Experienced nurses	12	Experiment
Chang and Lai [15]	Taiwan	VR	Nasogastric tube care skill	Nursing students	60	Interview
Obrero-Gaitan et al. [16]	Spain	VR	Neuroanatomy and Neurorehabilitation	Nursing students	30	Survey
Gilardi et al. [20]	UK	VR	Decision Making	Nursing students/ lecturers	12	Workshop
Hess et al. [19]	USA	VR	Parkinson's disease and related disorders care	Home healthcare professionals	52	Survey

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