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Teachers' prospective attitudes towards the adoption of extended reality technologies in the classroom: interests and concerns

Maram Meccawy[1*]

*Correspondence:
mmeccawy@kau.edu.sa

[1] Information Systems Department, Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract

Recent international empirical studies have demonstrated positive results when applying extended reality (XR) technologies such as augmented reality, virtual reality, or mixed reality in teaching and learning. Thus, the preconditions and challenges of use must be investigated from teachers' perspectives prior to implementing these technologies in Saudi schools and higher educational institutes. Therefore, this study examines the feasibility of applying XR tools and platforms in the classroom by understanding teachers' opinions, especially regarding creating or acquiring XR educational content. A qualitative study is conducted using semi-structured interviews with ten educators in Saudi Arabia. As a result, several themes are identified: (1) an XR level of awareness among teachers, (2) an XR-learning content-acquiring approach, (3) teachers' readiness for XR, (4) students' readiness for XR, and (5) XR challenges for schools, including social aspects that are often overlooked. These themes highlight teachers' interest in immersive technologies with their concerns about their possible use in the classroom. Hence, the study provides greater insights for exploration and application for future studies in this area. Moreover, it draws a realistic picture for policymakers and administrators, aiding them in creating an achievable adoption strategy for XR applications in the educational sector.

Keywords: XR, VR, AR, EdTech, Teachers, Immersive learning, Saudi Arabia

Introduction

The lockdown experience with online learning due to Covid-19 has led many educators and researchers to believe that future learning through the digital medium should be different; as many negative experiences have been reported by both teachers and learners during the pandemic. Hence, digital learning should be more than simply a case of replicating the physical experience in the classroom in the virtual space (Meccawy et al., 2021). Online learning experiences should be designed and delivered differently from traditional in-class education. In this new post-Covid-19 era, online education would be offered as a part of a blended learning experience, where personalised learning (Kem, 2022), AI tools using chatbots and virtual assistants (Chen et al., 2022), micro-learning via short videos on mobile devices (Shamir-Inbal & Blau, 2022), gamification and game-based learning (Al-Malki & Meccawy, 2022), MMOG (massively multiplayer online games) such as *Minecraft* (Alsaadi et al., 2022) and extended reality tools and platforms (Holly et al., 2021) would play major roles. Research in those areas should further investigate these technologies and suggest how they could be applied to create an individualised, effective, efficient, and flexible learning experience that motivates students to learn and improve their performance.

One of the aforementioned promising emerging technologies to bring innovation to education and online learning is extended reality (XR), also known as cross reality (CR), which includes augmented reality (AR), virtual reality (VR), mixed reality (MR), and any other reality that might emerge. AR provides an experience of the real environment with an overlay of computer-generated data, while VR encapsulates a user in a fully simulated virtual environment that replaces the real world. On the other hand**,** MR integrates real and virtual environments, so the user can interact with physical and digital objects in the real world. The pandemic and the lockdown that came with it highlighted the importance of remote learning and collaboration, and those XR technologies make it possible for learners and teachers to share a virtual online learning space while being physically in separate locations. This enables them to work on group projects or attend classes. The literature has reported many benefits of the use of these immersive technologies in education, such as increase learners' motivation, enhance engagement, improve knowledge retention, bridge the gap between theoretical and online learning and a risk-free simulation and training environment. Moreover, it can aid students with learning difficulties or special needs. XR technologies can be of great support to teachers as it helps them educate and motivate their students, regardless of their skills, abilities or learning styles, as well as increase the interaction and participation in the classroom.

Several degrees of immersion can be experienced with XR technologies (Alqahtani et al., 2017): 1) fully immersive, which requires special devices such as a VR headset to allow users to be part of the virtual environment by cutting out all outside information, 2) semi-immersive, which uses a real prepared environment or equipment that is compatible and connected to a desktop screen to increase the level of immersion without cutting all outside information and 3) non-immersive, which does not require any special devices to interact with the user, using mobile and desktops screens and is considered the lowest level of immersion.

VR and AR applications, tools, and platforms have already started to appear in classrooms, lecture halls, and science and medical labs before the remote learning promoted by the pandemic. However, they have yet to penetrate the mainstream of education. One of the major challenges of XR in education is related to creating and acquiring AR and VR educational content and learning platforms and aligning them with learning objectives and outcomes (Meccawy, 2022). Although authoring 3D content, which is a major component in all XR systems, might have become easier, it is still not easy enough for fast content production by faculty and teachers (Ziker et al., 2021).

In 2016, Saudi Arabia announced an ambitious strategic framework known as Saudi Vision 2030 in order to reduce its economy's dependence on oil, diversify the economy and improve public services. This national transformation program is built around three themes: a vibrant society, a thriving economy and an ambitious nation. As part of a thriving economy, learning becomes a cornerstone to drive and sustain this new economy. Hence, the vision advocates the concept of learning for working: “We will continue investing in education and training so that our young men and women are equipped for the jobs of the future. We want Saudi children, wherever they live, to enjoy higher quality, multi-faceted education. We will invest particularly in developing early childhood education, refining our national curriculum and training our teachers and educational leaders (..)We will also focus on innovation in advanced technologies and entrepreneurship” (Vision 2030, 2022).

In order to achieve those ambitious goals, there has been a growing interest in utilising educational technologies (EdTech), therefore many studies have been conducted in relation to the digital transformation and use of EdTech tools and systems in Saudi schools (Al Ohali et al., 2018; Al-Ohali et al., 2020) or the lack of such utilisation (Aljuhani et al., 2020). This interest has intensified as a result of the Covid-19 lockdown in the kingdom (Alghamdi, 2022), which forced education in all schools and higher educational institutes to be conducted online for nearly two years. In addition, the kingdom’s new educational strategy puts increased focus on STEM (Science, Technologies, Engineering and Mathematics) education, with several studies investigating their implementation in Saudi schools (Maashi et al., 2022; Madani, 2020), which are good candidates for VR, AR, and MR technologies. Another subject where the use of technology in general might have a positive impact in learning is English language learning (Al-Shehri, 2020; Bagunaid et al., 2022), where XR technologies such as VR can be also utilised (Alwafi et al., 2022). XR technologies can be used enhance the learning experience, therefore various studies have investigated the application of AR (Alqahtani & AlNajdi, 2023) or VR (Alhudaithy, 2019) for educational purposes in the Saudi context.

As mentioned earlier, the Saudi government intends to further invest in emerging technologies to advance its educational sector, hence a study that explores the teachers’ opinions as well as the educational settings in those schools is greatly needed.

XR technologies promises that it would allow students to learn in an exciting and unprecedented way. As teachers are the cornerstone of any learning experience, there is a need to assess their readiness for using XR technologies in the classroom either within a traditional face-to-face learning setting, or even as a part of a blended learning experience that involves both traditional and online learning settings. Currently, there are limited studies that engage teachers in this process early on and survey their opinions beforehand, especially with the Saudi Arabian context. Hence, it is important to investigate Saudi teachers’ perceptions and learn their level of interest and concerns about implementing these immersive technologies in the classroom before examining XR’s effects on students’ motivation or learning outcomes. Moreover, it is crucial to explore which of the available approaches to acquire learning content they are likely to follow if they start using or experimenting with XR. Therefore, a qualitative study using semi-structured interviews is conducted with ten teachers in Saudi Arabia as will explained in this paper.

Research objectives

The study aimed to address the following objectives:

1. Assess the level of awareness among teachers regarding XR technologies and their use in education.
2. Investigate the approach(es) that teachers are likely to follow to create XR learning content or acquire an immersive learning platform.
3. Explore teachers' main concerns, which they view as challenges that might hinder their application of XR technologies in the classroom shortly.

The paper proceeds as follows. First, the related work to teachers' opinions regarding XR in learning is presented in the next section, followed by the research methodology and results. After that, the discussion section is presented followed by practical implications. The paper ends with the conclusion, limitations, and future work.

Related work

XR benefits in education

The use of XR technologies in education has many benefits, as shown by various studies, with the focus being primarily on the use of AR and VR (Akçayır & Akçayır, 2017; Allcoat & von Mühlenen, 2018; Hussein & Nätterdal, 2015; Messner et al., 2003; Němec et al., 2017; Rodolico & Ding, 2021; Vasilevski & Birt, 2020). VR can excite, motivate and provide students with hands-on learning experiences, enabling an extreme close-up examination of an object they are learning about (Pantelidis, 2010). Moreover, it can offer a simulation to practice some procedures in a risk-free learning environment, like virtual scientific labs (Aljuhani et al., 2018). In addition, the immersive nature of virtual worlds offers learners a sense of exploration and involvement, resulting in an active learning experience (Hussein & Nätterdal, 2015). Thus, VR technologies were suggested for practicing foreign language speaking skills during the lockdown (Alwafi et al., 2022). In addition, VR can also be used for children with special needs to help them learn essential life skills (Alharbi et al., 2020). On the other hand, the most reported advantage of AR is that it promotes enhanced learning achievement (Akçayır & Akçayır, 2017). Furthermore, the active learning experience provided by AR catalyses students' skills development, especially when learning within a STEAM educational approach (Land, 2013), which could result in a more holistic and engaging education (Jesionkowska et al., 2020).

A study that was set to assess students' readiness and acceptance for AR technology found that they accept the usage of AR in construction technology education and the application meets their expectations of what AR could aid in the learning process. As for student acceptance, the result shows that students accepted the usage of AR as a learning tool. Moreover, the results regarding AR effectiveness on construction technology displayed noticeable improvements regarding student's pre-test and post-test results with 68% of students displaying improvements in their scores (Fauzi et al., 2019). On the hand, a study from higher education that used a mixed method approach (interviews and surveys) to get readiness and insights from both teachers and students to gain insight into end-user acceptability, value areas, barriers, and opportunities for the adoption of XR showed a general readiness for broad adoption of XR technologies in university education. However, although XR teaching applications were successful, few applications were continuously integrated into the curriculum (Kluge et al., 2022).

XR challenges in education

Despite their demonstrated benefits, the application of XR technologies in mainstream education remains limited, with many challenges, as reported in the literature. One of the challenges presented in a systematic literature review of AR in education (Akçayır & Akçayır, 2017) is that AR is difficult for students to use and the majority of issues were reported in location-based AR applications. On the other hand, challenges reported in another study (Alalwan et al., 2020) which interviewed teachers about such challenges included a lack of competency, limited instructional design, lack of focused attention, lack of time, and limited environmental resources. A further study that investigated the challenges in applying VR in medical education (Baniasadi et al., 2020), categorised them as generic and specific. Under the generic challenges it listed cost, reduce face-to-face communication, and users' attitudes, while specific challenges included designing, safety consideration, VR side effects, evaluation, and validation of VR applications. Other reported barriers were funding, infrastructure, ongoing support, and maintenance (Kluge et al., 2022).

As mentioned earlier, one of the many challenges of XR in education is how to obtain XR educational content and develop immersive learning platforms. VR for example, requires professional skills for content generation, full immersion, interaction, programming and implementation (Velev & Zlateva, 2017). As identified by (Meccawy, 2022), several possible approaches exist. One approach involves developing XR learning systems and content from scratch using game engines like unity, while another is accomplished through tools and platforms that require minimal coding, for example, Adobe Aero for developing AR content and InstaVR for VR. A third approach involves subscribing to existing educational or non-educational XR platforms such as Virbela, which was purposely built for educational usage, or AltspaceVR, which was designed for generic XR use.

Moreover, some XR companies provide complete hardware and educational software packages that can be deployed immediately in the classroom, such as ClassVR. Lastly, many educators might want to reach for simpler approaches, such as using available VR and AR applications on Apple's App store, the Google Play store, or the Oculus Quest store. An even simpler alternative would be to view XR educational content from providers such as NASA (NASA, 2022), the BBC (BBC, 2022), or National Geographic (NationalGeographic, 2022). Each of those options has its advantages as well as their drawbacks.

Teachers' experiments with XR technologies in the classroom

Many teachers are eager to adopt new teaching methods and use emerging technologies to enhance teaching and learning. This desire was highlighted during the Covid-19 pandemic with emergency remote learning, where teachers everywhere utilised emerging technologies to reach their students and keep the learning journey on track. Some even experimented with XR technologies, namely AR and VR, to achieve this goal (Mora-Beltrán et al., 2020).

For example, a study conducted with K–12 education teachers applying the STEM (science, technology, engineering and mathematics) educational approach (Martín-Páez et al., 2019) in VR environments showed that teachers experienced positive results with VR and appreciated its value for learning (Mystakidis et al., 2021). Moreover, these teachers demonstrated interest in participating in professional development activities and embracing gamified learning methods. Furthermore, another study conducted group interviews with representative stakeholders from the private and public sectors to investigate their experiences and opinions regarding the use of XR technology in Norwegian schools (Simon-Liedtke et al., 2022), and showed a need for 1) pedagogical integration, 2) teacher technical training skills in emerging technologies, 3) developing technological and methodological digital infrastructure to smoothly integrate XR technology into school systems, and 4) supporting schools in the procurement and funding process of XR projects. In addition, a study aiming to inform the process of implementing HMD VR in K–12 contexts by researching the preconditions and challenges of use from a teacher perspective was presented by (Fransson et al., 2020), and the findings were related to the economy and technology, initial learning barriers, organisation and practical legislations for teaching and learning, curricula, syllabuses, and expected learning outcomes, and teachers' competences, professional development, and trust.

Teachers introduced to VR via proper training are willing to apply it in the classroom. For example, in one study, after three weeks of training in VR, teachers could apply it in their teaching for two months (Yildirim et al., 2020). According to the teachers in this study, VR increased students' creativity and motivation, captured their interest, improved their IT skills and allowed them to comprehend complex concepts. However, the challenges included online safety and security, student access and technology gaps. Finally, a study where teachers' opinions were also sought using VR in several private schools demonstrated that, as with previous studies, teachers had positive reactions towards using VR and AR in the classroom in terms of engagement and the facilitation of learning. On the other hand, the challenges faced included the availability of data sources and the content changes based on the subject (Serin, 2020).

A study (Tzima et al., 2019) assessed the process of creating 3D models and the feasibility of AR application development by teachers and students in school settings. It showed that AR application development is feasible only under certain environmental conditions. The study listed the limitations of the curriculum as the main negative factor, compared to the teacher's personality and the willingness to collaborate with colleagues from different specialties as positive factors. When surveying preservice teachers about the possibility of future use of VR in their teaching, the results showed that they generally had positive opinions about using VR; however, a range of factors might limit or inhibit their use of the technology, such as the participants' self-efficacy in using VR as a pedagogical tool (Cooper et al., 2019).

Many teachers have stated that they would face limited instructional design when applying VR and AR content in the classroom, referring to the limited materials offered in VR and AR with no guarantees that the content would suit students' learning goals (Alalwan et al., 2020). Moreover, VR educational content's interoperability across platforms is difficult to achieve. Hence, VR is often delivered as a proprietary solution (Velev & Zlateva, 2017).

At a higher educational level, the opinions of university engineering professors in 15 South American countries regarding the use of VR in their teaching were surveyed. The results indicated that engineering teachers give high evaluations to VR as a didactic tool but show a certain lack of knowledge and specific training regarding its use (Vergara et al., 2022). Furthermore, a systematic literature review of immersive VR as a pedagogical tool in education to assess learning outcomes and experimental design, found that most studies found a significant advantage of using VR in education, however, these studies were mostly short interventions that did not examine information retention (Hamilton et al., 2021).

It can be concluded from this section that there is still a noticeable limitation of research in understanding teachers' interests and concerns regarding the application of XR technologies before implementation. Most studies reviewed here have focused on the actual usage of these technologies and their possible impact on students during or after their application. However, fewer studies have considered teachers' opinions, acceptance, or readiness for the use of XR technologies in education beforehand. Moreover, most, if not all, of these studies have overlooked the serious social and cultural aspects of XR technologies. Therefore, this study seeks to explore different aspects of the use of XR in education to assess the readiness of Saudi schools and teaching staff before designing a VR or AR learning experiments, which is crucial for a country like Saudi Arabia with a futuristic development vision (Vision 2030, 2022), which emphasises on technology, innovation, and modern learning.

Methodology

This research follows a qualitative approach to explore teachers' thoughts, ideas, and experiences about using XR technologies, namely AR and VR, in the classroom. It gives special attention to the approach teachers are likely to choose if they integrate XR immersive tools and platforms in their teaching experience soon. Notably, several interviews have been conducted online with educators in Saudi Arabia working at different educational levels (K–12 and higher education), as described in the subsequent sections. Therefore, semi-structured interviews were chosen for the data collection method as this study is exploratory, seeking a more in-depth understanding of a topic from teachers' perspectives. Collected data were analysed using a thematic analysis approach, and such themes have emerged. The diagram presented in Fig. 1 describes the research methodology.

Sampling

The sampling used in this study combined stratified sampling (for the trait of interest) and convenience sampling (for those close by). Stratified sampling was important to

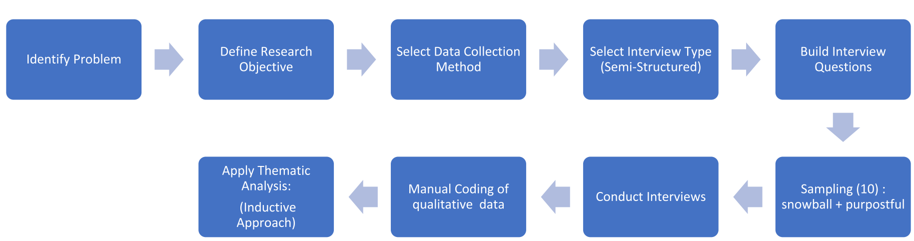

Fig. 1 Research methodology

Table 1 Teacher demographics

Number of participants	10
Gender	Female
Age	30–45 years
Teaching experience	6–20 years

Table 2 Schools and subjects

Teaching subject	Educational level	Type of funding	Number of teachers
Computer Science (CS)	Secondary	Public	4
Physics	Secondary	Public	1
CS	Secondary	Private (International curriculum)	2
CS	Secondary	Private (National curriculum)	1
CS	Intermediate	Public	1
CS	University	Public	1

focus on educators in Saudi Arabia with IT and computer science backgrounds since these teachers would most likely have basic AR and VR technology knowledge. Moreover, they would likely be familiar with what each content creation or acquiring option entailed for technical skills, time, and effort. The rationale was that if a computer science teacher was not interested in a programming approach using unity, it is unlikely that a History or English teacher would be. However, exceptions were made for science teachers with strong IT backgrounds who had applied AR and VR in the classroom.

For convenience sampling, the researcher utilised her network to secure interviews using the snowball technique. As a result, due to time and cultural norms in Saudi Arabia, the interviewees were all Saudi female teachers from all-girls schools, as educational institutes are segregated by gender in Saudi Arabia with few exceptions. The typical Saudi schooling system consists of six years of primary school (ages 6–11), three years of intermediate school (ages 12–14), and three years of secondary school (ages 15–17). University degrees are typically four years, with medicine, engineering, and computer science taking longer to complete.

Ten Saudi female instructors participated in this study, nine which were from the city of Jeddah and one from the city of Taif. Their demographics appear in Table 1, while the details of the subjects they taught, the type of school, and the level of study appear in Table 2.

Data collection instrument (semi-structured interviews)

Semi-structured interviews have characteristics of structured and unstructured interviews. A few questions are predetermined, while the others are unplanned, allowing follow-up questions with greater flexibility to explore the topic. Their use aligned well with the explorative nature of this study. Table 3 below presents the interviews' planned and structured questions (translated from Arabic), as well as some of the unstructured questions, unique to each interviewee, that had evolved during each interview session.

Table 3 Interview questions

Q	Questions
0	Demographic Questions: educational background, age, teaching experience (years, subjects, level)
1	Are you familiar with XR Technologies (AR, VR, MR)?
2	Have you used any XR technology on a personal or professional level? *Sub questions that have emerged: 2.1 If yes, which tool/app? 2.2 If yes, what is your impression? How would you rate your experience?
3	Would you be interested in using it in your classroom? *Sub questions that have emerged: 3.1 If yes, why? 3.2 How do you expect students to react toward applying XR in the classroom? 3.3 How ready are your students for the use of XR tools and platforms for learning purposes? 3.4 What is the educational value of using these XR technologies in the classroom? 3.5 From an educational perspective, what concerns you about XR?
4	With any software you use in teaching, do you normally develop it, buy it, download it for free, or subscribe to it, and why?
5	Does your institution cover software expenses?
6	Are you familiar with the following development platforms: unity, unreal, or WebEx?
7	Have you heard of any platforms or tools for using XR in education? *Sub questions that have emerged: 7.2 If yes, what are they? 7.3 If yes, did you try any?
8	What are the biggest challenges (or your main concerns) in introducing XR into your classroom? *Sub questions that have emerged: 8.1 How are the school conditions or environment that might support the use of XR technologies? 8.2 What are the pedagogical and curriculum changes or challenges that may need to be addressed to optimise their learning performance? 8.3: What are the social challenges concerning the use of XR in schools? 8.4 Do you have any other concerns about using XR in education?
9	When presented with the following options to create an XR learning experience, which is more likely to be your choice? Develop content from scratch using a game development platform such as unity Use platforms with minimal coding (a drag-and-drop approach) Subscribe to existing market solutions, either through purposely built platforms for educational usage or those built for general use Purchase complete hardware and educational software packages to be deployed immediately Use available XR applications available through online mobile stores or access immersive content made available by content providers such as NASA or BBC
10	Are you willing to be trained to use XR in the classroom? If yes, under what conditions?

Data collection procedure

All interviews were conducted at a mutually agreed time using Zoom videoconferencing software, with one exception where Google Meet was used instead, as this online method suited the work and family commitments of all participants. Moreover, all participants had been remotely teaching and working using these distance learning communication tools for almost two years and were comfortable with this setting. In addition, although most Covid-19 restrictions had been lifted by the time of the interviews, mask-wearing was still mandatory in most schools and learning institutes in Saudi Arabia.

Before the interview, all participants gave written (emailed) and verbal consent. Each interview lasted 30–45 min, conducted in Arabic mixed with English terms when necessary, as all participants had a good command of the English language because technical degrees such as engineering and computer science are taught in English in Saudi universities.

Data analysis procedure

All online interviews were recorded with the interviewees' consent, transcribed manually, and coded. Some quotes were translated. These codes were combined into relevant themes. An inductive approach (allowing the data to determine the themes) and a semantic approach (analysing the explicit content of the data) were used to analyze the semi-structured interview responses. Table 4 below, shows the codes that would create the themes described in the following results sections. Please note that codes are represented as CXR(x).

Results

Five themes addressing the research questions were as follows: (1) an XR level of awareness among teachers, (2) an XR content creation and acquisition approach, (3) teachers' readiness for XR, (4) students' readiness for XR, and (5) XR challenges for Saudi schools, explained through three sub-themes—(3.1) IT-infrastructure-related issues, (3.2) financial support, and (3.3) Health, social concerns, and school policy. These themes are explained in the subsequent sections.

XR level of awareness among teachers (T1)

As mentioned earlier, all teachers (i.e., eight computer science teachers, one computer science lecturer and one physic teacher) had come across one or more of the XR technologies prior to this study personally or professionally. Moreover, some might have occasionally used VR or AR games with children, family or friends, while others had seen colleagues use it as a self-initiative teaching tool (e.g., biology teachers using VR to show human anatomy). Moreover, some learned about XR technologies due to a new computer science curriculum (e.g., a lesson about future technology) introduced this academic year (2021–2022) but from a theoretical perspective (i.e., no hands-on experience). Others had taken the initiative to give their students hands-on XR projects, as was the case with the physics teacher, or to teach a practical VR elective course, as was the case with a computer science teacher at an international school. The following quotes were extracted from a few of the interviews (all translated from Arabic): "*I knew about AR and VR as I have briefly come across them for entertainment purposes. However, I have never been able to use them in teaching due to lack of tools and equipment*" (CS Secondary School Teacher, Public School). Moreover, a CS teacher from a private secondary school stated, "*I have knowledge of all three XR technologies, AR, VR, and MR, and I have used VR in distance learning during the pandemic lockdown to try and connect my students with real-life examples, especially in STEM projects, where students found some mathematical and physical concepts difficult to grasp*".

XR-content-acquiring approach (T2)

Teachers were presented with five possible approaches to create or acquire XR content or learning space, as identified and classified by (Meccawy, 2022): 1) create from scratch using programming languages and game engines such as unity, 2) create from scratch using drag and drop XR development platforms and environments (e.g.,

Table 4 Codes and categories

Code	Category	Description
CXR1	Prior experience	Refers to teachers' experiences with XR technologies whether in an educational-related or personal context
CXR2	Knowledge of XR	Refers to current teachers' knowledge of XR development tools (e.g., Unity), ready platforms (e.g., Virbela), or mobile stores Apps
CXR3	Technical experiences	Refers to the teacher's practice of programming and software development on her job since graduation
CXR4	Limited instructional design	Refers to limited resources available for XR content, that might or might not align with course objectives, learning outcomes, or student goals. This includes limited validated assessment tools. Also, lack of knowledge of how to measure the learning outcomes
CXR5	Lack of time	Refers to the lack of time by teachers to learn and create XR educational materials
CXR6	Limited competency	Refers to limitations in terms of teachers' competency to apply XR tools in the classroom or create XR content without prior training
CXR7	Lack of training	Refers to teacher's limited funded training opportunities
CXR8	Training and motivation	Refers to teachers' willingness and enthusiasm to participate in XR training and their motivation to apply XR in the classroom
CXR9	Impact of Covid-19	Refers to the positive impact of the Covid-19 lockdown on online distance learning. It boosted government investment in this sector and made electronic devices available to every student. In addition, this nationwide experiment that lasted for almost two years made society (teachers, parents, and students) more accepting of this type of digital learning. This would most likely apply to the use of XR in education
CXR10	Teachers expectancy	Refers to teachers' beliefs that their students will accept and excel when using XR technology This is based on Vroom's Expectancy Theory (Bates, 2019) which states that: *"a person will behave in a certain way based on their belief (expectation) that a specific act will be followed by a desired award (valence) once that act has been completed satisfactorily (instrumentality):* *Motivation = Expectation * Valence * instrumentality"*
CXR11	Collaborative learning	Refers to teacher's expectation that students will have increased motivation when working together on activities or learning tasks in a small group within a VR environment or through an AR project. For example, within STEAM types projects
CXR12	Limited IT resources	Refers to issues related to computers with outdated software and hardware, lack of or limited internet connections, low-speed networks, inadequate IT labs to support large classes (40 students), the lack of any portable devices for AR or VR headsets, in addition to limited or no IT support
CXR13	Limited financial support	Refers to teacher's limited finical resources for applying XR tools and technologies in the classroom
CXR14	Social restrictions and BYOD (Bring your own device)	Refers to the current policy against BYOD, which does not allow students to being their portable devices into schools. As a result of the Covid-19 lockdown and almost two years of online learning (2020–2021), most if not all students have access to a computer or portable device. Those who couldn't afford it were given devices by the government. Yet, those students are not allowed to bring these devices into schools, due to social norms that puts heavy emphasis on the misuse of cameras, especially in the female context in an all-girls school, where teachers and students alike, would not be covering their heads (as no male is present) as required by the Islamic faith
CXR15	Health issues	Refers to the possible negative impact of XR technologies on students if used for extended periods
CXR16	Data privacy	Refers to teachers concerns regarding the collection, storage and usage of biometric data

InstaVR), 3) subscribe to educational (e.g., Virbela) or non-educational (e.g., Engage) readily available virtual reality environments, 4) purchase a complete software and hardware solution such as the case with ClassVR or 5) download XR Apps into mobile devices (free or relatively inexpensive compared to the other options) or access websites of XR educational content providers such as the BBC. The given answers by teachers varied. While all teachers agreed that the fifth option was the easiest, less time-consuming, and one of the cheapest, most teachers also agreed that the apps might not be of great educational value or properly align with the subject or course's curriculum objectives or address the desired learning outcome. Nevertheless, they might serve a purpose as an entry point for teachers into the VR or AR realms, especially with teachers having limited free time and in the absence of sufficient funds. Except for two teachers, most did not favour the first option of programming using unity or similar software due to time limitations, work, and family commitments and limited to no involvement in developing software since their college graduation. As one secondary CS teacher explained, "*I don't have time to develop any XR content and make sure it aligns with the curriculum. I think a trusted educational body within the Ministry of Education should create XR learning content and platforms and have it available for us to use*". However, many expressed that if they were assigned intensive hands-on training by their school, they might consider the option. In comparison, several teachers were interested in trying the second option, simply and quickly developing via development platforms that apply a drag/drop approach. This option would give them enough flexibility to create learning content while not requiring programming efforts or time consumption. Furthermore, opinions were divided about the purchasing options. For instance, teachers at public schools thought they might consider paying for the software if it was reasonably priced, but they were highly unlikely to pay for hardware, while private school teachers would not do so if their relative departments did not approve their request for purchasing. The following is a quote from a public secondary school teacher: "*It has been a long time since I programmed anything from scratch other than the coding examples for my lessons. If I need a certain piece of software, I download a free version, and if I like it, I will purchase it. I will do the same with XR*". Due to the large number of students in public schools and the expected high costs, the fourth option of purchasing a complete package was not selected by any teacher as a self-initiative, which school authorities could only purchase with government or private funding.

Teacher readiness for XR (T3)

Teacher readiness refers to teachers having the necessary skills to practice effective teaching with the required knowledge of the subject matter, which in this case is XR concepts, hardware, and software, platforms, tools, and technologies. While most of the interviewed teachers had little in-depth knowledge of the subject, let alone demonstrated technical ability, the scene was promising. For example, a physics teacher applied AR and VR to her student projects; she was self-taught in IT and computer science, including programming and XR. Another computer science teacher created an elective practical VR course for final year students from scratch, immersed in the self-learning of VR tools and technologies to teach them to her students. These two examples demonstrate teachers' ability to adapt to new situations and sudden changes, such as during the pandemic, with self-learning and high motivation to improve their knowledge and skills. They have the drive to bring the latest technologies into their classrooms.

Moreover, when asked if they were offered paid in-depth XR training that would require high investment in time and effort, not only did they show interest, but one said that she would "jump" at such an opportunity, while another enthusiastically stated, "*I will be the first in line to attend such training*". However, they did say that they required sufficient time before XR became an integral part of the learning process, not only for learning the technical aspects but knowing how to effectively use them educationally. For example, they would need to learn how to align the technology with learning outcomes and measure its educational impact.

Student readiness for XR (T4)

Student readiness means that a student has an open mind and willingness to learn in addition to the necessary basic skills that will allow them to learn the course material with confidence. All teachers interviewed in this study, have communicated great confidence in their students' abilities and motivation to comprehend XR concepts, use any XR tools adequately with training, and learn different subjects through XR platforms. Evidence is drawn from students' prior experiences with new technologies as was the case during the pandemic. Most students would have access to the required hardware at home, at least for non-immersive experiences, with a good internet connection. Moreover, students in high-end private and international schools will also have those privileges at school.

XR challenges for Saudi schools (T5)

IT infrastructure

Any technology requires good IT infrastructure, including computer labs, local area networks (LANs), up-to-date software, and reliable and high-speed internet. However, these requirements are more crucial for XR and its 3D models, high-resolution graphical interfaces and wireless devices. Teachers from private and international schools and the university lecturer expressed their satisfaction with the IT infrastructure at their institutes. They believed their respective schools and colleagues had the IT readiness required by XR technologies. However, the opposite was expressed by many teachers from public schools, except for those at schools with the National Programme for Gifted Identification (The National Program for Gifted Identification, 2022). Teachers expressed their concerns in terms of the current state of the IT infrastructure in their schools. Many agreed that most computer labs had outdated hardware and software. For example, some needed constant maintenance and software updates, while others required hardware replacements. Moreover, some schools lacked LANs to allow teachers to communicate and control the students' devices for educational purposes, while other schools lacked reliable internet access for all students and staff.

Financial support

XR is not affordable to many, especially for achieving full immersion, which requires VR HMD (head-mounted display) devices. The price for a single Oculus Quest 2 headset starts at £399 (as of March 2023). Hence, adequate financial investment from governments or school owners is required for reliable hardware and software, teacher training, and upgraded IT infrastructure. Teachers in private and international schools had different input on this matter than their colleagues in public schools. Nonetheless, those in the high-end private and international schools had adequate yearly budgets for IT and teacher software demands. Therefore, teachers only needed to justify how the expenditures would positively impact the educational process to be granted the necessary funding. However, these same teachers agreed that it was not always the case for reasonably priced items likely to be used by many students for a relatively long period. Therefore, getting the school management to agree on purchasing expensive XR hardware and software might not be straightforward. Thus, the school governors would need to be assured that the technology was worth the investment for efficiency, effectiveness, educational value, and durability. In contrast, teachers from public schools did not have the same luxury of financial support from their schools. These public schools' teachers explained that if they needed to purchase software or hardware to enhance their teaching and support students' comprehension, they alone would bear the expense. However, in the case of XR equipment, no teacher could finance such a project entirely since classes have 30–40 students.

Social, health, and school policy

When the challenges of introducing XR in the classroom were discussed, the two most popular issues were infrastructure and its costs (Alalwan et al., 2020). However, the social impact of these emerging technologies and school and government policies were equally important to consider. Teachers agreed that the online distance learning that lasted for approximately two academic years in Saudi Arabia had made parents much more accepting of the essential role of technology in their children's lives. However, having a fully immersed experience through headsets and handheld controls would be on a different level, so many teachers believed that it would raise parental concerns. For example, some parents might see it as a game and a waste of time, while others might not feel comfortable having their minors roam a virtual world that the parents could not access. Another group might be worried about the physical well-being of their children: How heavy are those headsets? Will they cause motion sickness? Could they affect mental health? Are they addictive? Will they make my child isolated and withdrawn? However, it could be argued that many teenagers already play digital interactive games online and offline, some with VR elements, so students are familiar with headsets and controllers. While this statement is true, these students are in the minority, and it was their family's choice to allow them to do so. It is a different scenario when it comes from a higher authority such as the school. Only one participant expressed concern about information security and data privacy in such an immersive system, especially virtual reality worlds where subscribing to external platforms as teachers and students interact would produce rich amounts of personal data: Who would own this data? How would it be guarded? However, no other teacher raised the issue during the interviews. As for schools' policy regarding technology, the main concern raised by all school teachers was the policy on personal laptops, smartphones and tablets that prohibits students from bringing their personal devices to school for fear of misuse, such as taking photos of fellow students or teaching staff without consent and sharing them on social media. Private and international schools have a more relaxed policy on this front, allowing tablets for educational purposes but not smartphones. AR applications, in particular, require AR devices, such as Microsoft HoloLens, which is expensive and might not even be found at universities, or mobile devices, such as smartphones and tablets. With the absence of both, this technology would be impossible to apply in the classroom. However, teachers tried to find ways to manoeuvre around these policies for educational purposes. For instance, one teacher mentioned bringing her devices from home (three or four), dividing the students into groups, and sharing a device between group members. Another teacher obtained a special permit from the school's administration allowing students to bring their devices for the day under her supervision. Thus, she asked students to leave their devices with her during the school day since they were only allowed during the intended learning activity. Then, the devices were returned to the students as they left school. Figure 2 summarises the main themes that emerged from this study.

Discussion

This study set out to address several objectives, as described in the methodology section. The first objective was to assess the level of awareness among teachers regarding XR technologies and their use in education. The teachers interviewed in this study had varying levels of awareness and experience with XR technologies: all were aware of their existence and application educationally. However, only a few had used them in the classroom or had technical hands-on experience as explained in the first theme (T1). Nevertheless, all teachers expressed their interest in introducing AR or VR tools and applications in their classroom, provided the technical obstacles were removed, and adequate training was provided as stated in the third theme (T3). The main reason for teachers' interest in those technologies is their belief in their students' readiness and their expectations that students would perform well when XR is applied as it would have a major impact on their motivation, collaborative work and engagement, as has been presented in the fourth theme (T4).

The second objective focused on exploring which approach teachers were likely to take to include these technologies in their classrooms. All teachers agreed that the fifth approach was the easiest, using available XR apps and online content that was free or relatively inexpensive. This affordable option was seen as less time-consuming, but the teachers were aware of possible lesser educational value or little flexibility. However, this option might serve a purpose as an entry point into the realms of educational VR and AR. Applying an approach that involves minimal coding was also a popular option as it

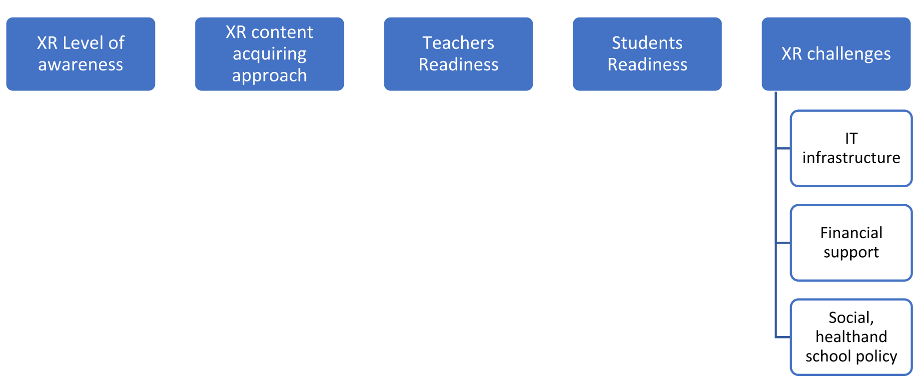

Fig. 2 Research output themes

was less expensive than other options and required less time and effort than developing a solution through unity, for example. This was elaborated by the second theme (T2).

The third objective was concerned with exploring the challenges that might hinder teachers' applications of XR technologies in the classroom. The fifth theme (T5) addressed this objective with three primary challenges that required consideration: 1) IT infrastructures in schools, 2) financial support, and 3) social norms, health, and school policy. Unless these challenges are addressed, it is unlikely that AR or VR technologies will soon be part of mainstream education in Saudi schools. However, it is more likely that private and international schools already have the edge over public schools, most likely leading the way in this regard.

Some of the findings of this study have echoed what has been presented by other studies in the literature (Fransson et al., 2020; Simon-Liedtke et al., 2022). For example, technical infrastructure and limited funding are issues to be expected when introducing XR into the classroom, especially in government-funded schools. In addition to the crucial need for teacher training and XR instructional design content. However, this study was unique in that it was carried out in all-girls schools in a conservative middle eastern country. This brought to the seen all new social matters that are rarely examined in the literature. Ideally, students would either have access to VR headsets for a fully immersive experience, and tablets for AR in school, or they would have to use their own devices and perhaps use a cheaper option, each option comes with its challenges. The first option is expensive and not affordable in large classes where the number is between 30 and 40 students. On the other hand, students bringing their own devices and using cheaper options such as Google's cardboard, highlights the BYOD issue and schools, in general, have a policy against complying with social norms. This policy also applies to boys' schools, however, it is much easier to bend or change the rules in an all-boys school, as males are not religiously required to cover their heads or faces, and hence a leaked picture would not cause a stair. Nevertheless, there are some alternatives such as a non-immersive VR via computer labs desktops or resorting to some creative solutions as described by the teachers, for example, a teacher bringing her own devices and splitting the class into teams, where each team can use one device.

Teachers in this study believed that XR might be suitable in an online learning environment within a blended learning approach expected to be applied by the Ministry of Education in the future. In this case, while at home, most students will have full access to their portable devices connected to reliable and high-speed internet, although exceptions are expected in rural areas and for low-income families.

Practical implications

The following implications result from this study:

- The outcome of this study provides insights for school and college administrators, management, and policymakers on how to plan and implement their strategy for using XR technologies in education.
- AR and VR have several opportunities and challenges when applied in an educational context. Teachers' awareness of these matters as well as technical skills can be improved through training, which most teachers would be interested in.

- The Covid-19 lockdown created a global online distance learning experience that has resulted in a positive impact in terms of both students' and teachers' readiness for virtual learning through means of technology.
- The new generation of students is technologically savvy and instantly ready to learn and apply new technology.
- At the beginning of their XR journey, unless advised and supported by a higher authority, most teachers would resort to using freely available XR educational content to experiment with the technology through an approach that is free or inexpensive, less time-consuming, and easier to deploy and use.
- One of the major limitations of most available XR learning materials is that they are, with few exceptions in case they were tailor-made, not aligned with the curriculum's learning objectives and it is not clear how to measure the learning outcomes.
- The level of immersion required within a given educational context, coupled with the number of students in the class, significantly affects XR financially, technically, and socially.
- Social constraints and privacy concerns exist in school policies regarding BYOD (bring your own device), which allows students to bring their portable devices into the classroom.
- A robust technical infrastructure is needed alongside adequate funding for XR to be successfully implemented and utilised in schools.
- In the current situation in Saudi public schools, XR technologies are best applied within a blended learning teaching strategy, where students can access these technologies at home to bypass technical and social barriers at school. However, students from less advantaged backgrounds must be considered in this scenario, including students with special needs.

Conclusion, limitations, and future work

Multiple online studies have investigated using XR technologies in teaching and learning. However, most have focused on the actual usage of these technologies and their possible impact on students during or after application. Teachers' beliefs, interests, and concerns shape their following decisions of using XR. Therefore, education researchers should explore teachers' perceptions or attitudes before examining the technology's effect on students' learning outcomes. As is the case with this study, fewer studies have sought teachers' opinions beforehand. Therefore, this qualitative study explored teachers' perceptions of XR technologies, AR and VR, and their possible usage in the classroom. This work identifies thematic elements present across two subject areas; science and computer science, school districts, learner educational level (intermediate, secondary and higher education), and socio-economic situations (private as well as public schools). These themes included 1) teachers' awareness of the use of XR technologies in education, 2) an XR-content-acquiring approach by teachers and 3) teacher readiness for XR technologies, 4) student readiness for XR technologies, and 5) challenges for schools, including IT infrastructures, financial support, and social norms and school policy. The social challenge in particular explains an important issue that is often overlooks and sheds some light on schools' policy regarding BYOD.

This research provides a directive to educators in general and those in Saudi in particular, who are considering introducing XR in their school in-class or remote learning experiences using these themes created from participants' responses and insights. Moreover, Saudi Arabia shares many economic, social, and cultural aspects with the five neighbouring GCC countries (The Cooperation Council for the Arab States of the Gulf also known as Gulf Cooperation Council), which includes Saudi Arabia, Kuwait, Qatar, Oman, Bahrain and United Arab Emirates. These six countries are all geographically part of the Arabian Peninsula; they share the same Arabic language, Islamic faith, ethnicity, social traditions and customs, governance system, infrastructure, and standards of living. Gender segregation in education is dominant in most if not all public schools and universities. Hence the finding of this research might be applicable, fully or partially, to policy makers in these countries as well, especially in regards to the social aspects, for example, the allowance or prevention of the use of mobile devices in schools.

The study also highlights a gap between public and private schools and learning institutes regarding the overall readiness for XR technologies, which has been previously reported in the literature between private and public learning institutes, albeit at a university level (Vergara et al., 2022).

The main limitation of this study is its grounding in the experiences of ten teachers. However, the fact that they came from different schools, in terms of educational level, curriculum, and funding, allowed for an acceptable generalisation of the possibility of teaching in an emergent field and conducting further studies with more participants. Another limitation is the fact that all participants were female, although both male and female in Saudi Arabia teachers are employed by the same Ministry of Education, teach the same curriculum, and regardless if they were working in public, private, or international schools, they would have received the same amount of funding accordingly.

As it becomes clear what the benefits and limitations of the potential use of XR in Saudi educational systems, practical experiments can be conducted to measure students' motivation, engagement, collaboration, or learning outcomes. Future work involves communicating closely with some of the teachers interviewed to design and implement an XR learning experience for their students to assess the educational benefit of these emerging technologies through empirical studies.

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Availability of data and materials
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Declarations

Ethics approval and consent to participate
Informed consent was obtained from all individual participants included in the study.

Competing interests
The author has no competing interests to declare that are relevant to the content of this article.

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Publisher's Note

Maram Meccawy is an Associate Professor at the Information Systems Department at King Abdulaziz University, Saudi Arabia. She received her PhD in Computer Science from The University of Nottingham (2009), her MSc from the University of Hertfordshire in Distributed Systems and Networks (2003), and she obtained her BSc in Computer Science from King Abdulaziz University (2002). She has worked for a few years in the industry before returning to academia and has more than 15 years of experience of research related to EdTech with many publications in reputable academic conferences and journals. Her current research interests include: adaptive learning, gamification and GBL, MOOCs, emerging technologies in learning and the application of XR (AR & VR) in education.