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# The potential of extended reality in Rural Education's future – perspectives from rural educators

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**Abstract**
Technology-enhanced education can potentially enhance teaching and learning outcomes for rural educators since they face limited educational resources and low job satisfaction. Recently, there has been a surge in extended reality (XR) as an immersive learning technology to improve teaching and learning in rural areas, but without focusing on rural educators' perspectives. This study aims to bridge this gap by investigating rural educators' interactions with XR educational applications and exhibiting their insights on using XR education to improve education quality in rural areas. After educators' hands-on experiences in a pre-designed XR education workshop, qualitative data was collected from their discussions in focus groups. As a result, educators believed that XR could transform traditional educational practices and create opportunities for new patterns of rural education (e.g., public engagement with rurality and rural vocational education). Limitations include a lack of school infrastructure to apply XR and an absence of well-structured curriculum design to use XR in the classroom setting. We suggest that future studies explore the integration of effective XR practices into primary and elementary education in those areas with limited educational resources.

**Keywords** Rural educators · Extended reality · Educational Design · XR education · Rural Education

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## 1 Introduction

Educators play one of the most critical roles in student learning, and rural educators represent a unique group of educators who often have a more crucial impact on rural students' lives (Starrett et al., 2021). Rural educators work in schools in rural or remote areas with lower population densities and limited access to urban amenities. Rural educators usually have different teaching experiences than larger schools with more diverse student groups since rural schools often have smaller student populations, smaller class sizes, and a closer school community (Kantabutra & Tang, 2006; Tran et al., 2020). In the meantime, rural educators often take on multiple roles in their teaching and working responsibilities due to limited resources and staff. For example, they may teach various grade levels or subjects, serve as coaches or advisors for extracurricular activities, and handle administrative tasks beyond their primary teaching activities (Croft, 2021).

Moreover, rural educators are often deeply committed to the success and well-being of their students (Starrett et al., 2021), going above and beyond to provide individualized attention (Olthouse, 2015), support, and personalized instruction to meet students' needs (Waller & Barrentine, 2015). Also, rural educators can contribute greatly to rural education research as they are familiar with local resources, communities, and the environment (Starrett et al., 2021). They have been seen as a group of people who can address the specific needs of rural students (Brenner, 2016), foster parent and student engagement (Coady, 2019), and promote local cohesion (Hemming, 2018). Their dedication and commitment are vital in improving educational outcomes and empowering students in rural areas.

However, rural educators are often under-appreciated and overlooked within mainstream education (Gagnon, 2016). Their voice has been marginalized in the education sector, and some teachers are labeled as having lower education levels and less experience (Zhang & Campbell, 2015). Similarly, while rural education faces systematic transformation, rural educators have been regarded as unwilling to change, dissatisfied with their status, and resistant to reform efforts (Howard, 2013). This neglect has partly resulted in persistent disparities in educational outcomes and inadequate support for rural schools, leading to a vicious cycle of poverty and disadvantage in rural communities (Altun, 2017; Iwu et al., 2018). On the other hand, research has shown that rural schools often receive fewer resources and face more significant challenges than their urban counterparts (Wang et al., 2022a, b, d). Many rural schools have limited access to technology and advanced course resources (Tadesse & Muluye, 2020) and are only able to offer lower salary levels for educators (Wang et al., 2022a, b, d), which results in teacher shortages in many rural schools (Echazarra & Radinger, 2019). Without access to sufficient resources and adequate salaries, teachers may struggle to provide the high-quality education that all students deserve (Wang et al., 2022a, b, d), and students in these areas may receive lower-quality education than their peers in better-resourced areas.

Rresearch suggested that investing in technology-enhanced educational training for rural educators can potentially enhance teaching and learning outcomes (Blanchard et al., 2016; Wu et al., 2022). Various Information Communication Technologies (ICT) based training (e.g., general computer literacy, the competence to use educational software, online live lessons, and open resources online) can provide rural teachers with opportunities to access essential knowledge and skills (Wu et al., 2022). Some of these ICT-based training also includes skills in classroom management, strategies for motivating children, and various teaching methods and techniques (Rana et al., 2022), Rana et al. (2022) indicated that after the series of ICT-based training, teachers reported that they did a better job in their classroom teaching. Kalonde (2017) noted that rural teachers who are upskilled through ICT training could often use technology-enhanced pedagogy to improve students' learning and performance.

Moreover, due to a lack of resources and geographical remoteness, technology-enhanced education has been considered an effective way to compensate for the shortage of qualified educators and insufficient educational resources in rural education (Dube, 2020; Li et al., 2020). For example, teachers from advanced regions can deliver online classes to students in rural areas (Yang et al., 2018). Rural teachers can collaborate online with urban teachers to share the teaching materials and deliver classes jointly (Zuo et al., 2019), which allows them to share the workload and draw on each other's expertise. Hence, utilizing technology in teaching and learning has the potential to support rural teachers' work with the rural community (Ghavifekr & Rosdy, 2015), reduce the difficulty of retaining in-service educators, and enhance education quality in rural schools (Blanchard et al., 2016). With the rapid development of educational technology, the convergence of education with the newest cutting-edge technologies, e.g., extended reality (XR) technology, has presented innovations and motivation for making E-learning an important, convenient, and affordable model in education (Pears & Konstantinidis, 2022; X. Wang, M. Quirke et al., 2022; Yu, 2021).

XR is an umbrella term that encompasses various immersive technologies that merge the physical and virtual worlds, creating a blended reality experience. It combines with virtual reality (VR) - a technology that creates a simulated digital environment to simulate the real world. It typically involves wearing a head-mounted display (HMD) or using a VR device to enter a fully immersive virtual world, shutting out the physical surroundings; augmented reality (AR) - a technology that overlays digital information (e.g., images, videos, or 3D objects) onto the real world to enhance users' perception and interaction with their environment; and mixed reality (MR) a technology that blends of physical and digital worlds, unlocking natural and intuitive 3D human, computer, and the environment (Microsoft, 2023) (Fig. 1).

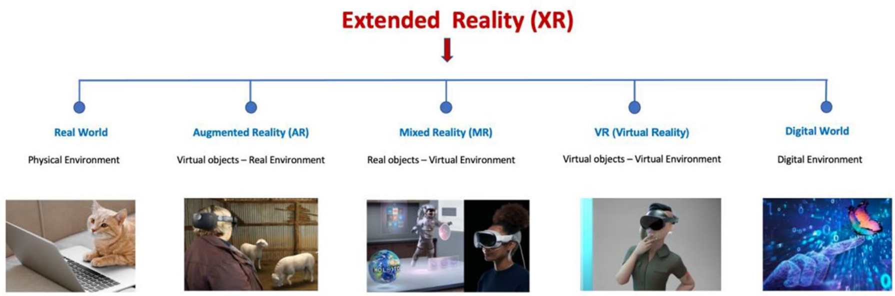


**Fig. 1** XR explained by the Virtuality Continuum (Milgram, P. et al., 1995)

Using XR for learning, also called immersive learning, provides immersive and interactive learning experiences with the latest technology developments (Dengel, A., 2022). XR has the potential to make education more accessible and inclusive. By providing customizable experiences and adaptive interfaces, XR learning pedagogies can accommodate different learning needs, ensuring that students with diverse abilities can fully participate in the learning process (Alam, A., 2021). XR technology presents immense potential as a learning tool, providing unparalleled opportunities to captivate learners, deepen comprehension, foster collaboration, and deliver personalized learning experiences (Mourtzis et al. 2022). With its immersive nature and adaptable capabilities, XR represents a valuable asset in the educational realm, revolutionizing teaching and learning methodologies (Kluge, M. G.et al., 2022).

## 2 Related work

In education, using XR for learning is gaining popularity in teaching and training activities (Zahid Iqbal & Campbell, 2023). For example, there is a growing utilization of XR in remote education (Young et al., 2023), teaching training (Gandolfi et al., 2021), industrial manufacturing (Fast-Berglund et al., 2018), medical practice (Andrews et al., 2019), special education (Wang et al., 2021), and soft skills training (Wang et al., 2022a, b, d). In the educational setting, students can behave and respond in undifferentiated ways within their environments from what they do in the real world since XR generates realistic and credible scenarios and interactive settings (Howard & Gutworth, 2020; Maruhn et al., 2020). XR allows students to acquire hard and soft skills in a safe, realistic simulated, controllable, and interactive setting and practice their acquisitions in real life. Also, research has indicated that XR can be utilized to improve educational designs (Johnson-Glenberg, 2018), immersive content authoring (Dengel et al., 2022), students' all-around performance (Faridi et al., 2021; Makransky & Mayer, 2022; Petersen et al., 2020).

Furthermore, XR has been applied to improve teaching and learning in schools in rural areas. One instance is that UNESCO (2004) conducted a pilot study using quasi-XR simulations (non-immersive visuals) for adult education in Uganda and South Africa with 280 students and 32 teachers. The project's learning goal was to use interactive visual simulation to demonstrate basic hygiene to rural communities, focusing on sanitation, water, and disease prevention, e.g., malaria, bilharzia, dysentery, and cholera. The outcome showed that with computer visuals, classes were more pleasant for students to learn, easier to recall, and more suited to different lessons with well-designed topics. At the same time, teachers were optimistic that XR was an effective teaching tool that could be integrated into courses. All teachers considered that XR could be an effective method for teaching their topics in the near future (UNESCO, 2004). Another case study is that Liao et al. (2023)tried to use an XR Learning application called "StemUp" to improve rural students' English learning performance and motivation. These results show that this application can help participants gain more knowledge in English vocabulary, speaking, and listening; students also commented that the course became more engaging and less tedious. In addition, Rasheed et al. (2015) conducted a study to investigate the efficacy of virtual reality in improving spatial awareness and student engagement with history as a subject in rural Indian schools. The outcome revealed that students interpreted factual information more accurately when presented through traditional teaching methods. However, there was a notable increase in learning in color perception, orientation, and size estimation using the XR-based system (Rasheed et al., 2015).

Despite previous efforts to leverage XR to reduce education inequality for under-represented groups, little research has focused on broadcasting the voices of a minority group to the public – rural educators – and interviewing their perspectives on issues of critical importance. For example, have they also experienced XR's changes to education? Do they like this change? Do they believe that XR can improve the quality of rural education and reduce educational inequity? These valuable voices are not being heard and noticed by the majority.

Moreover, according to the United Nations, 3.4 billion rural residents live worldwide, accounting for 43% of the total population (UNDESA, 2018). Rural students often have fewer educational opportunities than their urban peers, whereas rural educators can work with families and local communities to improve outcomes. Therefore, educators' attitudes towards XR technology may be critical in integrating XR in the classroom for teaching and learning. Whether rural education quality can be systematically reformed and improved depends on educators' motivation and determination to work towards this goal (Chiu, 2022; Sinagatullin, 2001). In other words, rural educators' inclinations and actions can directly affect the future human resources and sustainable development of other under-represented countries/regions, which further benefit these areas to deal with the challenges of globalization and diversification in the future. Thus, rural educators' voices are precious for regional and global sustainable development of quality education.

### 2.1 Research gap and questions

Having reviewed the presented evidence, we identify that rural educators have not received enough attention from the mainstream research community compared to numerous studies related to XR education. Secondly, little research has focused on rural educators' perspectives on utilizing XR to improve quality education in remote rural areas. To bridge these gaps, we proposed the following research questions (RQs) and aimed to investigate the interaction between educators from rural regions and XR education.

**RQ 1.** What are rural educators' perspectives based on the XR education workshop?

**RQ 2.** How could XR influence education design in the context of rural education?

**RQ 3.** Can XR education improve rural education quality?

This is the third phase of a longitudinal research project - "Applying XR Education in Rural China." The first phase of the project explored using VR to enhance social competence education and perceived social support for children who live in rural China by delivering well-designed educational sessions through Floreo VR and

Google Arts & Culture. A total of 90 children from China's remote rural areas were involved in the first phase study (Wang et al., 2023b). The second phase of the project explored using XR-enhanced education, including classroom atmosphere to improve classroom teaching and learning quality in rural China by delivering well-designed geography and astronomy lessons through Google Earth, and a total of 70 children from China's remote rural areas were involved in the second phase study. The result showing students' believed VR and XR are promising tools to bring quality classroom learning. In addition to these research outputs, this third phase study further discusses whether XR education can benefit rural education and educators' views on using XR education in future teaching activities.

In this study, the primary objective is to introduce XR as a modern pedagogical tool to rural educators and rural education as a pilot case study. Although many rural educators may currently be unfamiliar with XR, it can be a transformative approach to make their future classrooms keep pace with the advanced region and also be locally relevant. XR can simulate real-world scenarios (Andrews et al., 2019), connect educators and students with global experts (Dwivedi et al., 2022), and foster information and resource exchanges (Wang et al., 2023). When rural educators' awareness and accessibility of this technology grow, they can easily blend traditional teaching with futuristic tools to create meaningful teaching and learning (Wang et al., 2022a, b, d). Moreover, despite the predictable challenges, such as the cost of XR devices and the feasibility of technological training (Wang et al., 2021), it is vital to take the first step and provide rural educators with the opportunity to know this technology, get free access, and experience high-quality XR-enhanced education. In doing this, rural schools in the future may reform traditional barriers and offer students quality learning opportunities and digital skills that were previously exclusive to well-resourced urban schools. Ultimately, the goal is to level the educational playing field, ensuring rural schools, regardless of geographical location, have the opportunity to benefit from the advanced pedagogical tools and methodologies available.

## 3 Methodology

This study first invited rural educators to attend an XR workshop for hands-on experience acquisition. Because unlike urban schools in China with certain opportunities to access XR education (Chen & Chan, 2019; Wei et al., 2015a), only few studies have allowed rural students and educators to have such experiences (Wang et al., 2023). In research cases like the study by Fan and Antle (2020), researchers rather than rural teachers taught English grammar to rural students; this approach may not be replicable in a real classroom setting, and the lack of active participation in XR can minimize its effectiveness among educators (e.g., rural educators' limited skills to operate XR devices) (Hennessy et al., 2022). Therefore, providing rural educators with hands-on XR education experiences is essential. This exposure will allow educators to understand the advancement of XR technology and how it can be primely integrated with educational resources by tech giants (e.g., Google), which eventually become free resources accessible to the public, especially people in remote areas to visit.

To achieve this goal, we delivered a workshop called "Extended Reality and the Future of Rural Education" for these rural educators, and provided hands-on XR experiences in teaching and learning to ensure the validity and reliability of the collected data. A workshop is where things are created or fixed (Graham et al., 2015). Converting this concept to a research methodology, we can use the "workshop" paradigm to explore domain-based issues, present relevant literature, provide background knowledge, and deliver real-world demonstrations(Ørngreen & Levinsen, 2017). After the workshop, we had a focus group with the educators to understand their insights into the feasibility and potential of using XR education in their rural schools. All the ethics applications related to this research have been approved by the research institution's ethics committee. There was no predetermined negative result found by the research team prior to the commencement of the fieldwork.

### 3.1 Extended reality and the future of rural education workshop

Before the formal data collection began, even though all participants were trained to use digital classroom technology, such as interactive whiteboards and classroom PCs, we surveyed all participants (n = 13) to investigate their prior knowledge or experience in XR technology. The result showed that 61.5% of participants had never tried XR technology, and none had ever had the chance to explore XR educational applications in practice extensively.

This workshop aimed to understand rural educators' perspectives on employing XR technology and its applications in rural education's future. Participants were recruited via (1) disseminating workshop posters, (2) posting a call for participants with information leaflets on social media platforms, and (3) messaging educators directly via online group chat. The workshop included four topics relating to XR education:

I. A presentation of "What is XR?"
II. An introduction to XR applications designed for education.
III. An exploration of two guiding questions generated by group discussions:

   a. How can XR help to teach and learn in the rural classroom setting?
   b. How can we use XR to have effective interaction with students?

### 3.2 Workshop procedure

Under the three areas outlined, we presented the workshop overview and demonstrated several XR devices and related educational materials to all participants. The workshop process diagram is shown below (Fig. 2). The workshop devices consist of two Meta Quest 2, two iPads, two iPhones, and three Cardboards, and the total value is equivalent to $3,824.73 (USD), and all the equipment are sustainably being used to support various studies under the project of *Applying XR Education in Rural China.*

A total of 13 rural educators from six rural villages in Western China were invited to participate to experience two VR HMDs (Cardboard VR and Meta Quest 2) and

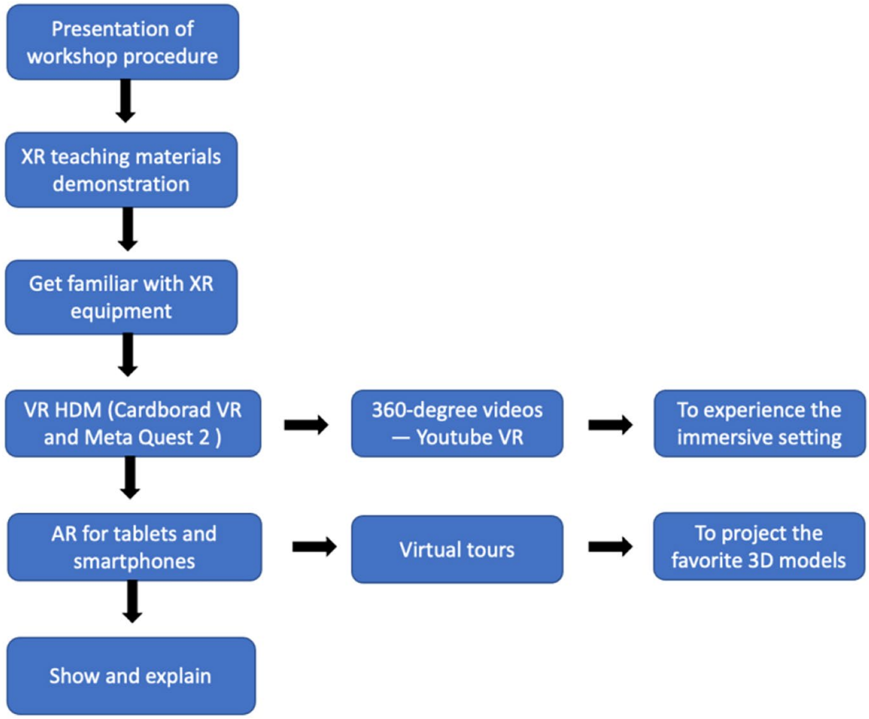


**Fig. 2** The workshop procedure

watch 360-degree videos through YouTtube VR. After this, those educators were asked to try AR with tablets and smartphones and go on virtual tours in museums and scientific labs through Arts & Culture and Google Earth. Thirdly, educators were asked to project their favorite 3D models (e.g., paintings, crafts, and animals) through the device's camera and Arts & Culture's AR function, showing and explaining their immersive experience and 3D models to other participants as a teaching demonstration.

The workshop was administered in the educator's break room (Tea Room) during school hours and at a time that suited the participants with no disruption in their regular schedule. Each workshop lasted 60 to 90 min and was limited to four or five participants maximum to allow for a suitable demonstration time and open discussion. After each seminar, a follow-up focus group was executed to understand rural educators' perspectives on using XR applications in future teaching activities. These groups consisted of two groups of four and one of five educators. As a result, our educators comprehensively experienced using VR headsets, tablet-rendered AR, various XR educational applications, and XR-led teaching activities. For instance, as presented in Figs. 3 and 4 and a rural teacher was trying a VR headset and successfully projecting a 3D model by tablet AR.

**Fig. 3** Using VR with Meta Quest 2

### 3.3 Focus group with rural educators

Following the workshop and hands-on training experience, a follow-up focus group was conducted to examine the proposed research questions. To gather more in-depth information, the researcher suggested that educators participate in discussions and provide their insights on XR education by answering the following sub-questions. In this way, educators could reflect on their experiences with XR technology and offer constructive feedback on the effectiveness of XR experience and XR technology in education.

1. Have you heard of or tried XR (VR, AR, and MR) technology before? If yes, what was that experience with it?
2. What did you like or dislike about the workshop?
3. What are your thoughts on using XR technology in the classroom after the workshop?
4. Did you like or dislike using the presented applications as teaching resources?
5. In what ways do you think XR technology could influence teaching and education design?
6. What is XR education's limitation?
7. Do you think XR education can improve rural education?

**Fig. 4** 3D model projected by tablet AR

### 3.4 Focus group participants

After the workshop phase, one participant withdrew from attending the focus group due to unforeseen circumstances. As a result, 12 rural educators were included in the focus group phase. To accommodate participants' schedules, we conducted three rounds of focus with rural educators, each with four participants. These focus groups were recorded with the participant's consent for post-task data analysis. All identifying information of individuals or schools was removed to ensure anonymity during transcription. Additionally, all participants were encouraged to ask further questions and share their opinions openly to provide valuable insights for the study.

## 4 Data analyses

A thematic analysis was performed on the transcriptions to identify related themes and subthemes from the three focus groups. Two investigators individually analyzed the data to identify emerging themes and subthemes. After independently reviewing transcripts, the results were combined to ensure consensus while highlighting all possible themes and subthemes with an inter-coder agreement (Kappa = 0.8).

### 4.1 Demographics

Twelve rural educators (mean age=27.92, SD=3.34; Male/Female ratio=50:50) eventually participated in three focus groups over two weeks. Eight of them were educators with fixed-term contracts, hired through the Special Position Program, which was an action to encourage graduates from top universities to serve in remote rural schools for two or three years. The four remaining educators who participated in the study were permanent rural educators with more extensive teaching experience in rural areas than fixed-term educators. Each focus group session ranged from 38 to 57 min (Table 1).

Based on the length of participants' statements, each of their sentences was coded with 1–8 labels to be categorized into specific themes. Summarized codes from three focus groups include 827 statements, concluding in 437 unique codes for data analysis. All data coding and categorizing were performed using Quirkos (2.5.2).

### 4.2 Qualitative coding

A hierarchical framework was employed to code the focus groups' transcripts (Saldaña, 2021) (Fig. 5). The first level involved gathering all useful information from focus groups. The second level presented two primary categories — discussions on XR technology and education. The third level dug deeper into the secondary categories — the topics associated with the primary themes. During the data analysis process, a codebook was used to keep track of all codes. Each code had a label for its characteristics and a description of each subcategory and theme. In addition, specific dates, times, and intercoder were also noted for a more detailed analysis.

**Table 1** Participants' Information (n=12)

| Participants Code | Age | Gender | Subject | Education Level | Employment Type | Technological Knowledge Level | Willingness to Participate (Yes/No) |
|---|---|---|---|---|---|---|---|
| FM66 | 27 | M | Culture | Bachelor | Contract | Intermediate | Yes |
| 87ZP | 24 | F | English | Bachelor | Contract | Intermediate | Yes |
| PP88 | 34 | F | ICT | Master | Contract | Advanced | Yes |
| C2V9 | 30 | M | Fine Art | Master | Contract | Intermediate | Yes |
| FD53 | 29 | F | Science | Bachelor | Permanent | Basic | Yes |
| WH29 | 27 | M | Science | Bachelor | Contract | Intermediate | Yes |
| PM75 | 23 | F | Literature | Bachelor | Contract | Advanced | Yes |
| VC37 | 26 | M | PE | Bachelor | Contract | Basic | Yes |
| NR38 | 25 | M | Geography | Bachelor | Contract | Intermediate | Yes |
| QP11 | 32 | M | PE | Bachelor | Permanent | Intermediate | Yes |
| NH32 | 27 | F | Physics | Bachelor | Permanent | Intermediate | Yes |
| LY96 | 31 | F | Psychology | Bachelor | Permanent | Basic | Yes |

Note. ICT=Information communication technology. F=female, M=male

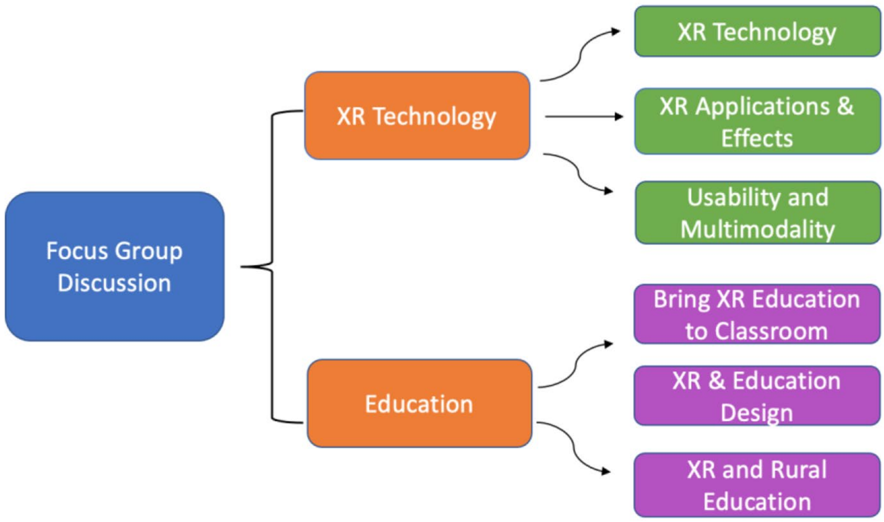


**Fig. 5** The hierarchical framework for the coding process

# 5 Results

## 5.1 Themes and subthemes

As a result of the preliminary data analysis, six core themes and four subthemes emerged from the focus group. Theme 1 indicated that educators generally had a positive impression of XR workshops amongst educators. They characterized this workshop as an innovative and eye-opening experience. Four subthemes accompany Theme 2. Subtheme 1- Learning Content Design and Subtheme 2 - Learning Motivation & Vocational Training suggests that XR could inspire novel educational design approaches, improving engagement and providing abundant resources to access. However, Subtheme 3 - A Toolkit to Support Multiple Disciplines and Subtheme 4 - The Suitable Device for Rural Education presented concerns about the affordability and suitability of XR devices for rural education. Next, Theme 3 exhibited educators' comments on different XR devices, and Theme 4 stated rural educators' positive feedback on leveraging XR for future rural education. Theme 5 showcased XR education's potential benefits and limitations related to internet access stability, physical discomfort from extended device usage, and the suitability of XR for structured classroom learning emerged. Finally, In Theme 6, educators pointed out the utility of XR in certain circumstances. Also, potential limitations regarding its effectiveness in fostering abstract understanding were reflected. Consequently, they are unsure that XR education can be a revolutionary tool to uplift rural education quality shortly. We use Table 2 to show an overview of these core themes and subthemes to visualize the critical information.

**Table 2** Core Themes and subthemes overview

| Core Themes | Description | Subthemes | Description |
|---|---|---|---|
| Theme 1: Workshop Impression - Immersion and Presence | Educators were generally positive about XR workshops. They believed that the presented content and experiences were innovative and enlightening. | | |
| Theme 2:Inspiration for Education Design | This theme is related to educators' perspectives on designs in education, including four subthemes as noted. | *Subtheme 1*: *Learning Content Design* *Subtheme 2*: *Learning Motivation & Vocational Training* *Subtheme 3*: *A Toolkit to Support Multiple Discipline* *Subtheme 4*: *The Suitable Device for Rural Education* | Subtheme 1: XR could inspire novel educational designs, improve engagement, and provide access to non-local resources. Subtheme2:XR could enhance students' passion for learning, specifically, in interactive vocational training or a practice-based approach for particular educational models. Subtheme 3: XR has powerful functions for multiple disciplined teaching and learning. Subtheme 4: Concerns about affordability and suitability of XR devices for rural education. |
| Theme 3:Usability and Multimodality | Educators reported that tablet-rendered AR was considered the simplest to operate, cardboard was user-friendly, and Meta Quest 2 provided a sense of immersion. | | |
| Theme 4:Leveraging XR for Future rural education | Educators expressed optimism about leveraging XR for future rural education, offering unique opportunities to raise public awareness about the disparity between rural and urban education in China. | | |
| Theme 5:Limitations of XR Education | Limitations of XR education are unstable internet access, potential discomfort from extended device usage, and challenges in adapting to structured classroom learning. | | |
| Theme 6: Can XR Education Improve Quality in Rural Education? | XR can be an innovative learning tool, yet it may not be conducive to supporting a competitive educational system in rural China. | | |

#### 5.1.1 Theme 1 – workshop impression - immersion and presence (RQ1)

Apart from two educators who had never heard about XR technology, the educators had some knowledge of VR but not AR. This previous knowledge stemmed from immersive technology being widely used in the game industry and entertainment rather than education. Participants previously involved in an XR workshop confirmed their sense of immersion, presence, and positive interactions with the blended space and virtual settings. (FM66, WH29, and PM75). Most rural educators agreed that the XR education workshop was well-designed and easy to understand. It was an innovative form of technology they were unfamiliar with, and the XR educational workshop was “an eye-opening experience” (VC37). Some educators were surprised to learn how much XR technology could do for education today (FM66, 87ZP, VC37, QP11, and LY96) and focus on the teaching experiences they cannot achieve on their own or without the support of technology. They agreed that the workshop offered rich teaching and learning content (e.g., a creative curriculum, open teaching models, and Google’s powerful educational resources), and the presence of XR education was surprising. It exceeded their expectations (FM66, PP88, and NR38).

*“To be honest, today’s workshop reminds me of an ideal form of education. This idea is something I cannot do with my current expertise.” — (VC37).*

### 5.1.2 Theme 2 – inspiration for education design (RQ2)

**5.1.2.1** ***Subtheme 1- learning content design*** Many educators believe that XR can be used to create immersive educational experiences that transport students to locations they may not be able to visit in person, such as historical sites, natural landscapes, or even other countries. This virtual field trip experience can help to make learning more engaging and memorable. On the other hand, in rural schools, educators can use specific VR and AR to provide access to resources and educational materials that might not be available in the local area. For example, VR can provide virtual field trips to museums or science centers or give students access to educational videos and interactive simulations. AR can visualize complex concepts in the physical setting so students can closely observe the provided learning content (LY96 and NH32).

Another way to use XR for rural areas education is to provide remote learning opportunities. This can be particularly useful for students in remote or rural areas who may not have equal opportunity to access the same educational resources as their peers in advanced urban areas. XR has the potential to connect students with teachers and other students for virtual classes and group projects, allowing them to collaborate and learn together even if they are physically separated (PP88).

Educators believed that the presented XR education apps provided ample and world-class educational resources, whereas lacking tailored curricula and subjective design for primary and secondary level education. The exhibited learning content was creative and could broaden rural students’ horizons, yet it needs to increase structured education for logical rigor in a rural classroom scenario (FM66). In addition, it was suggested that the design of XR education materials could be improved because many virtual tours lack user guidance (87ZP and C2V9).

*“Google, it seems, has a powerful team to support this work (Google Arts & Culture and Google Earth), which is very meaningful. I believe it can make students happy in learning, rather than using textbooks to teach them relatively*

*rigid knowledge as we do in the classroom. And the topics include time, space, geography, arts, and culture. These subjects are wide and integrated and can be presented to us with Extended Reality technology." — (QP11).*

**5.1.2.2** ***Subtheme 2- learning motivation and vocational training*** XR Education reminded the rural educators of previous field trips they had experienced "in the wild." The participants thought this approach could help organize various educational materials in advance and then impart knowledge to students, which also stimulates students' interest and passion for learning. It was also suggested that XR education could be ideal for interactive vocational training or a practice-based approach for particular educational models. At the same time, it was considered an effective exploratory platform. Students could explore unknown knowledge and skills presented within an XR setting rather than non-interactive approaches, such as reading books or watching videos. It was suggested that XR allows students to work within various scenarios and locations, and the cost of this technology was relatively affordable.

**5.1.2.3** ***Subtheme 3 - A toolkit to support multiple disciplines*** The educators participating in the evaluation valued that Arts & Culture and Google Earth are potentially influential learning platforms providing many beneficial educational resources. Moreover, XR can establish a robust support system for subject learning and deliver learning content and scene simulation. Along with the development of XR technology, it could also serve different disciplines with peculiar technical support and present creative teaching models for educators (FM66, C2V9). Educators believed that this hi-tech-assisted education would become a trend for future education. However, while XR was suitable for visualizing complex ideas, it may limit some students' competency to concrete abstract concepts (e.g., spatial imagination) (VC37). Therefore, not all technologies (e.g., VR, AR, and XR) with rich video resources would be suitable for education. Instead, educators must consider which disciplines need technology and to what degree.

**5.1.2.4** ***Subtheme 4 – the suitable device for rural education*** Rural educators were introduced to three XR platforms (i.e., affordable cardboard VR, a VR HMD (Meta's Quest 2), and tablet and mobile phone-rendered AR) to explore immersive vs. non-immersive XR. The participants discussed the platform that could be more suitable for rural education. They concluded that cardboard and HMD VR could present immersion on varying levels, with some educators preferring the immersive experiences provided by Meta Quest 2 (87ZP and NR38). Nevertheless, immersive devices are still prohibitively expensive for rural educational systems. This fundamental drawback makes their use in future rural education unfeasible (C2V9, FD53, WH29, NR38, QP11, and LY96). Secondly, it would be inconvenient to wear VR HMDs if the students are myopic. In this case, the student may be unable to see clearly, or at least not with cardboard, which was somewhat inconvenient (C2V9). Cardboard VR was affordable and compatible with smartphones, making it easy to present novel content. Also, the tablet-rendered AR allowed more students to participate, as they experienced from the workshop — an instructor showed the participants the demo lesson via one tablet. As a result of the focus group, cardboard VR and mobile phone-rendered AR are more cost-effective and accessible solutions for Meta Quest 2.

#### 5.1.3 Theme 3 – usability and multimodality (RQ1)

Participants reported feeling more familiar and at ease when handling the XR devices provided after completing the workshop. Specifically, tablet-rendered AR was considered the simplest to operate, while cardboard VR was also reported as user-friendly. The Meta Quest 2 headset was particularly noteworthy due to its responsive controllers (C2V9). Educators found that the controllers provided detailed and timely responses to their movements. At the same time, the haptic feedback function created a sense of immersion that allowed them to feel like they were interacting with the virtual world. This area is a significant development for XR technology, as it allows for greater integration of human movements into virtual experiences, which has numerous implications for education and training (FD53). Rural educators expressed a desire for more wearable equipment that could be integrated into immersive experiences, such as wearable devices for legs or other body parts. There is a growing interest in developing more advanced and diverse forms of XR technology that can provide a more holistic and integrated learning experience (WH29 and FM66).

> *"It is not the same as the XR equipment I used before. The controllers' vibration is exactly where you want to experience it. In other words, it makes my hands and limbs realistically interact with this virtual world through touch." — (FM66).*

#### 5.1.4 Theme 4 – leveraging XR for future rural education (RQ3)

In investigating the possibilities of using XR technology and applications in rural educational settings, both traditional classroom education and the macro level of education must be considered. The complexity of unequal education in urban and rural China and the specialty of educators' roles provoked rural educator's thinking that XR-assisted teaching and learning can be developed to a more significant level of education to promote public awareness of the fact that China's rural education is far left-behind China's urban education (FM66, VC37, NH32). Meanwhile, educators also suggested that VR is good for educational purposes and can be used to release rural power – showcasing rurality to the public in various ways (87ZP), for example, utilizing XR to create immersive and haptic experiences that allow users to virtually sightsee the rural environment, which can be helpful in providing context or additional rural areas information to outsiders, displaying historical and statistical data of rural landscapes, farms, and villages, and turning it into a visual presentation to comprehensively explain the rural schools and education's dilemma (87ZP, WH29).

XR can be used to create virtual tours of the school and community, giving prospective teachers a sense of what it would be like to live and work there. An educator said, “Although rural schools lag far behind urban schools, not every rural school is in poor condition, and there are some well-developed rural schools. However, many pre-service teachers think the countryside is underdeveloped and not conducive to career development; thus, many of them are unwilling to come (QP11). Relevant XR simulations could attract public attention and motivate teachers to consider a career in rural education. Positively speaking, after an understanding of the rural communities and formed with empathy and compassion, these teachers may be able to overcome some of the misconceptions and negative stereotypes often associated with rural schools. Moreover, an innovative virtual community may create a powerful influence and lead to more aid from the authority and private sector.

Additionally, XR can also be used to connect rural students with remote mentors and instructors, providing them with access to expert knowledge and guidance (LY96 and PP88). Additionally, XR-assisted vocational education could help prepare rural students for rural employment-based opportunities, such as agriculture, animal husbandry, and manufacturing (NH32, FD53, 87ZP, and PM75).

### 5.1.5 Theme 5 - the limitations of XR education

XR education was criticized because it is challenging to adapt to structured classroom learning (PP88, PPM75). Fundamentally, many rural schools have issues with the internet, and XR education cannot be employed without stable internet support. Hence, this will be problematic to implement in the classroom. Additionally, it was felt that educators' and students' experiences might be negatively impacted by the low clarity and fidelity of basic XR technology (C2V9). Some rural educators reported feeling uncomfortable (eyestrain and dizziness) after using the cardboard VR headset for more than 10 min. They also commented that XR education by cardboard might not be suitable as a well-prepared traditional class if they could only use cardboard VR for teaching for 10-minute intervals (VC37, LY96).

For example, educators also pointed out that many rural students are addicted to online video games. Compared to the virtual world or the game world, the physical world is complicated and sometimes cruel due to the underdeveloped rural environment, low-quality education, and parental absence. Rural students may obtain more negative influence or setbacks in real life than students living in urban areas. However, these hardships can raise their self-resilience, plasticity, and problem-solving ability. If XR classrooms are generalized in the rural classroom in the future, students may become addicted to the technology with exaggerated effects, which may impact their studies (FM66 and NR38).

### 5.1.6 Theme 6 - can XR education improve rural education quality? (RQ3)

XR can be an innovative learning tool that offers various approaches to educational activities. Educators indicated that XR could support continuing learning under particular circumstances or global crises. For instance, many students were forced to stop classes due to school closures during the Covid-19 pandemic. Even without an epidemic, most rural students find it challenging to travel. However, students need to travel and acquire real-life experience in reality, which is equivocally vital as they gain knowledge from textbooks. Therefore, XR can benefit learners who need real-world expertise but cannot obtain it. For example, students can at least experience a small portion of the outside world and natural life in a virtual environment through XR applications like Google Earth. Thus, this experience can stimulate their academic motivation and achievement. Furthermore, the mission of education is to help further student development, and XR can contribute to this goal in ways more than its teaching-aided function. Therefore, it was agreed that XR could theoretically improve rural education (PP88, VC37, and NH32).

> *"Based on today's discussions, I predict XR education can enhance rural education's quality in the future. Because technological education has become a worldwide tendency." — (LY96).*

However, XR can be a limitation for subjects that need abstract understanding because it may lead to over-presented learning content and make students over-exposed to the immersive effect. This issue will not be conducive to developing students' abstract or conceptual thinking and integration skills (FM66). Moreover, rural students are constantly concerned about passing exams with higher grades. Hence, XR education may not be able to adopt the competitive education system in rural schools. XR education is more likely to support interest-oriented or exploratory education, such as lab experiments and science museums (C2V9, LY96).

> *"Technology-assisted learning is conducive in the field of Culture and Art. Because XR education is novel, it can pique students' curiosity in creative learning. However, one big problem with rural education is its structure. It is a competitive system with regular exams that puts much pressure on students and provides few interesting classes. So, I do not think it will improve the rural schools' educational quality." — (C2V6).*

## 6 Discussion

### 6.1 Implications of rural education design

With the active participation of tech giants (e.g., Google and Meta) in the education industry, XR education can provide rich, immersive, and multi-functional teaching resources (Dwivedi et al., 2022). It could be seen as an ideal way to practice the *Pedagogy of Technology* and may transform future education — however, no professional manuals and handbooks to guide the teaching activity in detail. The design of XR education applications also lacks professional educational support, which makes it more like a rigid display of the content developed by the XR applications. As Dwivedi et al. (2022) pointed out, it is essential to constantly develop platforms through collaborations between technical developers and an upper-edge expert group to improve the application and use it. Moreover, the platform design must consider the adaptability of different environments and contexts for long-term usage.

XR generates strong and infectious effects, presents appealing senses of immersion and interaction, and the content and the nature of the education tasks play a critical part in drawing users' attention and engaging them in meaningful learning (Barab et al., 2010). Meaningful learning can influence learners' emotional processes, motivation, enjoyment, and immediacy of control (Makransky & Lilleholt, 2018). Nevertheless, unlike other studies suggesting that XR allows users to engage in complex verbal communication (Davis et al., 2016) and that students have gained significant oral communication competence (Tai et al., 2022), rural educators argued that XR is insufficient for classroom communication. We infer that was because our instructional design (the XR education workshop) requires a lot of concentration rather than communication.

### 6.2 Improvement of public awareness and engagement

In addition to the possibility of bringing transformative changes to the future rural education design, XR holds great potential to provide a platform for under-represented groups (e.g., rural educators and rural residents) to share their stories and experiences in a way that is immersive and impactful. Since rural education systematically lags behind urban education is an invisible fact that is barely known to the Chinese public (Rozelle & Hell, 2020), and rural educators are rarely mentioned and paid attention to by the public; XR can be used for raising public awareness, giving the majority a deeper understanding of the challenges faced by rural educators and students, promoting public's right to know and compassion.

In the meantime, as an "empathy-making machine," XR seems can facilitate users' perspective-taking (Young et al., 2021) as XR can be used for training and simulations that help people understand and empathize with the experiences of under-represented groups, which can help break down barriers from different groups and promote urban citizen's concern of educational inequalities in rural areas. Further, XR can develop a virtual community to net stakeholders and provide valuable resources, forming a sense of connection to engage citizens through emotional means (Gruenewald &Witteborn, 2022).

### 6.3 XR and vocational education for rural students

In rural China, the dropout rate of students is drastically high; for example, middle school students' dropout rate is approximately 25% of the local population in disadvantaged rural areas (Shi et al., 2015). Many of these dropout students from mainstream schools either choose to continue their education with vocational schools in urban China (Guo & Wang, 2020) or directly migrate to prosperous cities and become labor-intensive workers without any vocational training (Rozelle & Boswell, 2021). Based on this fact, XR simulations allow students to visualize and interact with complex concepts (Wang, Hodgers et al., 2022), e.g., how a machine works or how to perform a specific task (Hunde & Woldeyohannes, 2022), which can be especially beneficial for students from remote areas who may not have access to the same resources and opportunities as their counterparts from more prosperous regions.

### 6.4 Limitations

Although this study was an XR-related educational experiment executed on a small scale, rural education workers have presented significant insights that can represent the typical educator group in primary and secondary education. Thus, we extrapolate these results beyond the given cohort and conclude current limitations in XR education. First of all, a clear distinction exists between the utilization of XR in higher education and primary or secondary education. Unlike higher education institutions with sufficient funding to pilot XR disciplinary and trans-disciplinary education, primary or secondary schools lack the resources and infrastructure necessary to implement XR in substantial subject education. Secondly, many existing XR education applications are few and more focused on extra curriculum outside of structured learning and with entertainment features, such as virtual field trips and interactive educational games.

### 6.5 Conclusion & future work

The emergence of XR as a learning technology transforms traditional educational practices, creating new opportunities for engaging and practical learning experiences. This research has provided in-depth exploration using XR as an educational resource by educators working in rural areas. The results present challenges and opportunities for educators in rural areas to take XR-assisted learning into formal classrooms. As XR advances, educators expect more innovative applications and content tailored to different educational levels and subjects. This advancement can further enrich the education experience in rural schools and developing rurality. XR developers may assume the product can be easily applied to schools and used by educators from different backgrounds, yet this lack of necessary structured design and educational thinking could lead to XR apps that are not well-suited for the classroom setting or do not align with current academic standards for mainstream schools. Therefore, we suggest that future studies focus on how XR education can bring good practice in primary and elementary education, especially for areas with insufficient budgets and limited educational resources. Additionally, this research study recommended that future studies encompass a broader range of under-represented communities to gain insights and perspectives. There is a need to explore how XR can effectively support and empower diverse groups of educators on a larger scale.

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**Data Availability** Data from the corresponding author is available upon request.

## Declarations

**Conflict of interest** The authors declare that there is no conflict of interest regarding the publication of this article.

**Research Ethics** This research has been conducted in accordance with ethical principles. This involves ethics of respect for cultures, communities, the individual/person, and independent knowledge.



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