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The Utilization of Extended Reality to Facilitate Quality Education and Reduce Inequalities

A Doctoral Thesis

presented by

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to

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Abstract

Educational inequalities pose a significant global challenge, as they hinder sustainable development and perpetuate disparities in opportunities and outcomes for different populations. To address this dilemma and offer potential solutions, this Ph.D. project pilots practices of *utilizing extended reality to facilitate quality education and reduce inequalities*. The core research questions (RQ) of this Ph.D. project are: RQ1 – Can virtual reality improve rural children’s social competence and perceived social support? RQ2 – Can virtual reality facilitate quality education by improving the classroom atmosphere? And RQ3 – What are rural educators’ perspectives on utilizing extended reality enhanced teaching and learning? To answer these research questions in a scientific manner, I conducted a series of fieldwork “into the wild ” (rural China), as well as designed and executed extended reality assisted learning sessions and/or interventions with the rural residents. Three studies were developed as three chapters to showcase the main components of the entire research project.

As a result, all studies suggest that leveraging extended reality technology as a means to reduce educational inequalities is not just a pipe dream. Extended reality technology has the potential to reduce educational inequalities in underdeveloped regions. The potential between extended reality technologies and educational activities that are adaptable to a variety of contemporary learning environments is also highlighted. Findings also implicate the importance of evidence-based development of extended reality solutions in education to address the diverse needs of learners in our society. However, limitations exist due to small sample sizes and pandemic restrictions, and future research should consider these factors. The final conclusion calls to embrace XR technology as a tool to create a more equitable educational landscape. Future research should focus on technology enhanced teaching and learning to ensure inclusivity, empowerment, and transformation in education.

Keywords: *Quality Education, Reduce Inequalities, Extend Reality, Virtual Reality, Rural China*

Declaration

I sincerely declare that:

I declare that this Thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work. I agree to deposit this Thesis in the University's open access institutional repository or allow the Library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgment.

Name : Xining Wang

Signature :

A handwritten signature in black ink, appearing to be 'Xining Wang', written in a cursive style.

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Acknowledgments



Many years ago, when I was going to run a summer camp with colleagues in a remote school, the headmaster picked me up by his rattletrap tricycle, and told me, look, endless mountains with poor living conditions, this is going to be our fate.

His belief in this fatalism shocked me more than the poverty I have seen all the way. And when I arrived at that school, apart from the shabby campus, there was only a headmaster, a director, and a teacher with more than one hundred students. That was the first time I realized how our national education could be so disparate to students who live somewhere like this – remote, disadvantaged, and invisible to the public, even though they were born in the same country as students who ranked No.1 in the OECD’s Program for International Student Assessment (PISA, 2018).

After this journey to the West (of China), I started to ponder that this inequality might not be their fate. But how? After years of studying in education, I try to partly answer this question, perhaps by presenting the current research project.

Therefore, as this Doctor of Philosophy thesis is completed, I would like to thank this headmaster, the teachers, the students, the villagers I have met, and the opportunity offered by Acacia Spring Foundation. I would also like to thank my funding body, supervisors, and colleagues in Ireland, China, and Denmark, who have contributed to supervision, collaboration, and camaraderie. Besides, my parents’ care and affirmation made my Ph.D. work a little bit easier.

Finally, I would like to thank my education, life experience, and faith, which solidified my belief in sincerity, justice, fearlessness, and compassion on this research topic.

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Chapter 1

Overview

1.1 Introduction

Educational inequalities pose a significant global challenge, as they hinder sustainable development and perpetuate disparities in opportunities and outcomes for different populations. Despite education being a fundamental human right, students from under-represented backgrounds, particularly those in rural and remote areas, often face limited access to quality education. In light of this dilemma, this Ph.D. project examines how technology, particularly extended reality, can play a critical role in enhancing quality education and reducing inequalities. The research concentrates on children in rural China as a representative sample, investigating the potential of utilizing extended reality to bridge the gap and provide more accessible educational opportunities.

As the opening, this chapter commences with a positionality statement acknowledging the researcher's background and subjective perspectives as well as the steps taken to mitigate potential negative influence on the research. Next, an in-depth introduction illustrates the pressing issue of global educational inequalities, showing the various factors contributing to disparities in educational access, resources, and outcomes. It aims to elucidate the complexities of this multifaceted challenge and highlight the importance of addressing these inequalities in pursuing sustainable development and social advancement. Furthermore, the final section presents a summary of all studies within this project, ensuring readers gain a clear understanding of the overall structure of this research project.

1.2 Positionality Statement

1.2.1 Personal Background

As a novice researcher embarking on the Ph.D. journey, I have realized that my subjective perspectives are integral to my study. I cannot observe my research impartially from a distance. Here, I recognize my background and motivations and their potential impact on the

investigation contained within this thesis. This recognition necessitates an examination of my gender, race, beliefs, socioeconomic status, age, cultural background, and political views and how they may shape the research. Accordingly, in this introductory section, I will delve into my positionality in the context of my research project's subject matter.

This research project's initial motivation was to respond to the Sustainable Development Goals from the United Nations Agenda (UNSDGs), a plan to build a better world for people and our planet by 2030. Goal Four of the SDG's (Quality Education) aims to ensure inclusive and equitable quality education and promote life-long learning opportunities for all. Therefore, pondering this topic critically, I want to begin this positionality statement with my self-identity. I am a Chinese person working on this research project in Ireland, China, the US, and Denmark for my Ph.D. study (2019 - 2023). What I do, work, learn, and experience are full of memories of cross-cultural comparisons, senses of racism, diversity, and inclusion, evolving language barriers and different levels of communication, self-perceived adaptability and flexibility, and the COVID-19 pandemic. These complexities gave me valuable insights and perspectives shaping this dissertation's research projects and studies. This unique life journey shaped my view on the subject matter.

Based on my previous analysis, working and voluntary experiences, and personal interests, I have focused on three main topics: (i) immersive technology, (ii) individuals from under-represented backgrounds, and (iii) quality and equality in education. Through recognizing and analyzing these introspective observations, I comprehend that my evolving senses of identity have significantly contributed to the initiation of this research endeavor. It is also crucial to acknowledge the possibility that these factors might predispose me to potential biases or partiality (e.g., culture, background, and self-identity) towards the data and other elements in this work. However, by critically reflecting on these slants and/or prepossessions, I was enabled to cultivate an objective awareness (e.g., persons and circumstances in different contexts), which is instrumental in mitigating any potential influence that may exert on the research process.

1.2.2 Academic Background

As an early career researcher in both Education and Computer Science, being involved in different teaching, learning, researching, and working styles in other countries makes me realize there is no perfection in education. However, many education models can be improved upon — for example, the existence of the educational chasm between urban and rural China. Education in rural China has serious problems, such as inadequate educational resources, teacher shortages, outdated curricula, and numerous "left-behind" rural children. Unfortunately, most people would not believe that equitable quality education has not been achieved in China — a country with the world's second-largest gross domestic product (GDP).

As human beings, our curiosity and inquisitiveness drive us to explore the world; as a

researcher with the observation of a series of issues (e.g., educational inequalities, evolving education systems, and educational technologies), I chose to investigate topics that I found relevant, meaningful, and for which I understand that answers are needed in current societies. To pursue this goal, I set out to identify problems that I felt were particularly pressing and in need of attention. With my sights set on proposing a novel approach that would not only contribute to the broader field of research but would also satisfy my own inner motivations for pursuing this topic.

As a result, I hope to contribute to the understanding of the complex interplay between culture, education, and human development through my research. In the meantime, technology, education, and human-computer interaction are increasingly crucial for education today. It is hard to judge whether technology is good or bad. Still, it is changing how we interact with the world, particularly evident during the Covid-19 pandemic. It also changes traditional education and how we study human behavior. Therefore, concerning this research, it was clear that I must conduct my research studies "in the wild." In this way, I could use cutting-edge technology for a novel, creative, and interdisciplinary approach to improving rural education and supporting rural children while avoiding the over-appreciative trend toward using unnecessarily advanced technology in the classroom.

I am self-aware enough to know that a lack of objectivity might occur when a researcher's prior beliefs or perceptions influence the outcome of their study, and I wish to address this issue openly. Scholars argue that quantitative methods are good at providing objective data that can be analyzed statistically. In contrast, qualitative methods are good at providing rich, detailed descriptions and explanations of complex phenomena. Hence, combining both approaches can avoid the lack of objectivity and lead to a more robust and nuanced understanding of a research problem. Further, in my opinion, given that using a mixed methodological approach to develop the studies would be an all-sided way to investigate human-based research topics (e.g., topics related to students and educators), this research project was designed around three independent studies, including one quantitative, one qualitative, and one mixed-methods study.

Conducting and separately reporting upon three studies on education and immersive technologies has several advantages over a traditional thesis structure. Firstly, each study can focus on a specific aspect of the research, providing a more comprehensive and in-depth examination of the research questions. For example, in this research, Study One focuses on virtual reality (VR) enhanced social competence education; Study Two examines the effectiveness of VR-enhanced quality education and learning environments; and Study Three is related to the educators' insights into utilizing extended reality (XR) for future education. By focusing on one specific aspect of each study, the research can ensure that all studies are designed to answer a particular research question in detail. Also, this research can present well-structured work and formally written chapters to the readers. Doing so requires more rigor and methodological sophistication than a traditional thesis structure. Each study uses

different validated research methods and techniques, ensuring a more comprehensive examination of the research questions explored. This approach results in higher quality research and contributes to the advancement of the field. Furthermore, all these studies can be ready to be published in reputable peer-reviewed journals, adding credibility to the research and increasing its impact. For example, at the time of submission of this thesis for examination, all the studies will have been published, or externally reviewed by international subject experts - via conference submissions and presentations, and manuscript submissions to high level journals. In the final section of this chapter, details of the relevant publications will be provided for your reference.

In this research project, technology is a means to assist people. Therefore, the fundamental motivation for exploring this research topic is how to use immersive technology to improve under-represented groups' well-being. Such a study of people and society can contribute to colleagues, scholars, and the broader community only when it is finally published, given that publishing research findings are a critical step in sharing knowledge and enhancing the visibility and impact of the research. Otherwise, my four years of Ph.D. study and related outcomes are invisible to the public, equivalent to never existing.

1.2.3 Practice Background

In response to sections of the UN's SDG Goal 10 (Reducing Inequalities) and SDG 4 (Quality Education), I take China's unequal education system between urban and rural areas as a working case study example, applying immersive technology-enhanced educational experiments as pilot studies, and examining the feasibilities and efficacies of various research methods mentioned. A background introduction to China's education inequality and a review of immersive technology-enhanced education was essential to do this. Therefore, based on an understanding of the research and applied practice interest of the researcher, there were "a priori" of research questions (PRQ) guiding me in drafting the background and context of China's education system:

1. What are the backgrounds of rural China and the "two-track system" in education and the "Hukou system"?
2. What is the difference between China's urban education and rural education?
3. How does the related environment influence China's education system?

These formative research questions focused on understanding the more comprehensive macro-level contextual factors essential to the research. These questions played a crucial role in developing the Background Chapter and helped its structure and content, which followed the one added Bronfenbrenner's Ecology Systems Theory (Bronfenbrenner, 1979a). Next, given that immersive technology (e.g., Virtual Reality, Augmented Reality, Mixed Reality, and Extended Reality) is an emerging intervention applied to many fields, the literature review focuses on two themes — immersive technology and education.

Thus, more nuanced and directive research questions (RQ) were developed through the evaluation of related works and subsequently directed fieldwork. As a result, three RQs are:

RQ1 – Can VR improve rural children’s social competence and perceived social support?

RQ2 – Can VR facilitate quality education by improving the classroom atmosphere?

RQ3 – What are rural educators’ perspectives on utilizing XR-enhanced teaching and learning?

It is worth noting that the above questions repeated the early thoughts of this research project and are revisited throughout the literature review. I have strived to maintain objectivity by following best practices in the chosen research methodology to avoid any biases that may influence the outcome of my study. Ultimately, my goal is to make a modest contribution to improving this under-represented cohort’s educational well-being.

1.3 Global Educational Inequalities

According to the 17 United Nations Sustainable Development Goals for human development, education is a fundamental human right for global citizens to achieve personal success and sustainable development (Assembly et al., 1948; R. King, Marginson, & Naidoo, 2011; McCowan, 2010). However, global educational inequalities have become a significant issue today (DESA, 2022; W. Rosa, 2017; X. Wang, Hodggers, McGuckin, & Lv, 2022). Significant disparities in educational opportunities and outcomes exist between and within countries, regions, and populations. These disparities are used to guide policies and practice. Henrich et al. (2010) (Henrich, Heine, & Norenzayan, 2010) conceptualized this problem using WEIRD (Western, Educated, Industrialized, Rich, and Democratic). Most of the world’s population are not WEIRD (Western, educated, industrialized, rich, and democratic) and live in developing countries with a current population of around 6.74 billion, representing 85.43% of the world’s population (Sciubba, 2022). Approximately 258 million children (17% of potential students) do not attend school worldwide (Deloumeaux, 2019).

Educational inequality is a severe social challenge for most developing countries, leading to long-term instability and stagnation at the macro level (Cingano, 2014). Although SDG 10 (Reducing Inequalities) has advocated that each country should seek to reduce inequalities in all forms and ensure that no one is left behind in society, educational inequality exists within and among countries (Chzhen, Gromada;, Rees;, Cuesta;, & Bruckauf;, 2018; López-Roldán & Fachelli, 2021). SDG 4 (Quality Education) states that the right to have quality education directly affects global human resources and future human prosperity. In contrast, chronic inequality and low-quality education can trap children in trans-generational poverty and immobility without equal and quality education (UNDESA, 2018).

SDGs 4 and 10 emphasize the importance of equitable and high-quality education for

everyone because it is essential for achieving sustainable development in the world by 2030. However, the UN has also pointed out that quality education among countries has far-reaching gaps, especially in developing countries and regions far from their developed counterparts.

Specifically, quality education has the potential to drive economic growth (Solihin, Wardana, Fiddin, & Sukartini, 2021), improve social justice (Pantić & Florian, 2015), and political stability (Rozelle & Hell, 2020). The case of South Korea's economic prosperity presents a useful example of the impact of investment in quality education. South Korea has transformed itself from a developing country to a global economic powerhouse in a relatively short period, and the quality of its education system has played a significant role in this transformation (Vandell, Larson, Mahoney, & Watts, 2015). The "science high school system" in South Korea focuses on Science, Technology, Engineering, and Mathematics (STEM) education, which has helped drive the country's development by producing a highly skilled and educated workforce. Moreover, it has been seen as critical in making South Korea a hub of technological innovation and economic growth.

On the other hand, low-quality education can perpetuate a cycle of local poverty and result in inevitable disasters for future human resources and sustainable development. Schools in poor communities with constant low-quality tuition can entrench generational exclusion and marginalization. A useful example here can be South Africa. According to Burger et al. (2017)(Burger, Van der Berg, Van Der Walt, & Yu, 2017), South Africa achieved the lowest average scores in Mathematics and Science out of 46 countries. The Department of Education's result showed that most children tested below the standards required by the national curriculum. Also, their rural children's academic performance lagged far behind that of other African countries - rural South African students came 13th in reading and 12th in mathematics out of the 15 African countries' educational evaluations (Van der Berg et al., 2011). As a result, students who received low-quality education were less likely to obtain good and stable employment (Van der Berg et al., 2011), which is also a reason for the country's ongoing racial poverty and deprivation (Burger et al., 2017).

From these examples, we understand how quality education can shape a country's future and how low quality education can place pitfalls for a country's future generations. Education is crucial for individual growth and development, as well as for the social, economic, and political development of society. However, many topics related to educational inequality today have not been well-researched and understood by key stakeholders. At the same time, addressing these challenges requires a multi-pronged approach, including investment in technology to enhance access to teaching and learning in areas where traditional schools are not available. Because many online learning platforms and apps today have the potential to improve the quality of education in various aspects. This research project explores this topic further and discusses how technology can support education in remote areas to improve quality education for children and teachers who live in these areas.

1.4 Utilizing Technology as A Solution to Improve Education

UNSDG 4 places quality education at the forefront of the UN's global agenda, recognizing it as the foundation for sustainable development and a human right (UNDESA, 2018; UNESCO, 2019b). With its focus on "Education for All," SDG 4 seeks to ensure that every person, regardless of their background, has access to educational opportunities that equip them with the skills and knowledge necessary to reach their full potential. At its core, quality education is a beacon of hope and a means of uplifting entire communities, breaking down barriers of inequality, and creating a more equitable world. Every human being deserves a quality education in today's rapidly changing world, as it possesses the power to transform lives. Providing abundant resources and toolkits for people to thrive across their lifespans is more relevant to educators and researchers than ever. As such, technology can be a powerful tool for education in developing countries.

The diversity of technology can bolster the connection between educators and students, revolutionize our approaches to learning and collaboration, bridging long-standing bridge equity and accessibility gaps, and customize learning experiences to suit the needs of all learners (OECD, 2018a). From the primary level to higher education, educational institutions should embrace and be incubators of these explorations and innovations (Thomas, 2016). Previous studies have indicated that utilizing appropriate technology to build distinct learning experiences can re-kindle students' motivation and curiosity (Abumalloh et al., 2021). These cases of using Internet technology to improve educational practicability and diversity have been widely discussed. For example, Popenici and Kerr (2017) have argued that advances in cutting-edge technology open new possibilities and challenges for innovative education (Popenici & Kerr, 2017). These factors can fundamentally change governance and the internal architecture of institutions within all levels of education. Therefore, educators should be critical thinkers and users of integrating technology and education, seeking new knowledge and continually developing their skills alongside their students. As researchers, we should set a vision for utilizing cutting-edge technologies to craft inclusive and accessible resources and learning experiences to reduce inequalities and support all learners' lifelong development.

In response to SDG 4 (Quality Education) and SDG 10 (Reducing Inequalities), this research program explores the issue of global educational inequalities with a focus on individuals from an under-represented (non-WEIRD) background. Specifically, this research employs China's urban-rural educational inequities as an example, presenting a project of applying pedagogy of technology and utilizing immersive technology to deal with social competence education, classroom atmosphere, and stakeholders' views on immersive technology enhanced education. Immersive technology, such as virtual, augmented, and mixed reality,

has become increasingly adopted for teaching and learning purposes (Makransky & Mayer, 2022). Immersive technology is a computer-generated environment synthesizing multisensorial stimulation, immersive scenes, and simulated real-world contexts (Wedel, Bigné, & Zhang, 2020). Research has validated that it can contribute to understanding technology-mediated collaborations and offers new solutions for educational purposes (X. Wang, Young, Mc Guckin, & Smolic, 2021). Hence, this research employs immersive technology as a representative technology, developing extended reality (XR) mediated educational designs as a solution to present challenges in rural China's education.

The rationale behind selecting China as the research sample for this research is rooted in recognizing the persistent educational disparities within China's rural education system. The existence of the "two-track" education system clearly manifests such chronic inequality (Rozelle & Hell, 2020). Furthermore, this study also focuses on children's well-being in rural China, one of the largest populations of its kind in the world. This factor reinforces the significance of this choice. Therefore, China provides a compelling case study to explore the issue of educational inequality worldwide. This research project concerns global educational sustainability, aiming to apply the concept of Pedagogy of Technology (X. Wang, Young, Plechatá, Mc Guckin, & Makransky, 2023) to enhance under-represented rural children's education practices. It also tries to understand rural educators' perspectives on utilizing immersive technology for their future education.

1.5 Research Questions

In order to transfer these initial research ideas into practical applications, three empirical studies were devised to address the research questions at hand. While planning and executing the three research articles, **I was the Principal Investigator**, responsible for designing, implementing, analyzing, and drafting the work. As an emerging researcher, and noting what I have presented in my positionality statement about cross-cultural travel, experiences, and career development, I have actively sought international experiences in other countries, and work with researchers in various research teams. This was significant in developing my skills and language capabilities. However, what was the most beneficial was working and collaborating on other teams' non-Ph.D. projects concurrently with my Ph.D. work. In doing this, I was able to supplement and meaningfully expand upon the data and analysis for my own Ph.D. work with meaningful full contributions from these international collaborations. Importantly, these were invaluable extensions and contributions to the substantial conceptualization and operationalization of my three studies that were designed to answer these research questions. Thus, this thesis presents my own research, with acknowledgment clearly given of where my collaborators contributed.

As with all Ph.D. research, the request is to make meaningful contributions to knowledge. Traditionally, much of these works were completed after viva voce examination with required

amendments, where their Ph.D. work is re-drafted for manuscripts and submissions to peer-reviewed journals. However, as part of my development as a researcher throughout my Ph.D. study, opportunities for international travel and collaborations emerged and developed in a great way, hence, with the input from these collaborators, under my leadership, I have been fortunate to be able to simultaneously complete my Ph.D. research and translate my findings into a range of dissemination activities (e.g., journal articles, conference papers and presentations, and book chapters).

More importantly, there is the need to explicitly demonstrate how the three studies that represent this Ph.D. have been published or ready to submit to high impact peer-reviewed journals and acknowledge the contribution made by co-authors. In doing so, I am going to clearly state the three studies' main credits that are mine and represent this Ph.D. thesis, also, including meaningful contributions from others. These works have been partly used to develop my own work for the publications that would be developed after viva voce. Therefore, to provide impactful evidence for my claim, as noted previously, three research questions (RQ) were developed to examine the feasibility and efficacy of using XR to reduce inequities and benefit under-represented populations. These RQs are:

RQ1 – Can VR improve rural children's social competence and perceived social support?

RQ2 – Can VR facilitate quality education by improving the classroom atmosphere?

RQ3 – What are rural educators' perspectives on utilizing XR-enhanced teaching and learning?

To answer these research questions in a scientific manner, a series of fieldwork studies were conducted in rural China, designed and executed XR-assisted learning sessions and/or interventions with the rural cohorts, and collected data in a systematic and controlled way. Next, all data were analyzed using statistical techniques to determine if the results can or cannot answer the RQs. Meaningful and promising conclusions were drawn in the context of the problem being studied. Finally, three studies (listed below) were developed as three chapters to showcase the entire research project. All studies are peer-reviewed by experts in the field to ensure the validity of the methods and conclusions, as well as articles in-press before submission of the thesis.

Study 1 – Utilizing Virtual Reality to Assist Social Competence Education and Social Support for Children from Under-Represented Backgrounds (a quantitative study). This study investigates **the use of virtual reality to assist social competence education and social support for children from under-represented backgrounds**. Study One includes a 3*1*2 mixed design with repeated measures (Pre- and Post-test), analyzing the data to examine the 3 groups (VR, Lego, and Traditional Classroom as the control group) and 3 conditions, that is, three social competence educational approaches – (a) virtual reality

(VR) assisted social competence education, (b) Lego social competence education, and (c) traditional classroom learning, and their potential interactions or main effects of the three independent variables. I designed these three conditions based on three representative pedagogies in education - (i) Pedagogy of Technology, (ii) Play-based Learning, and (iii) Traditional Pedagogy). In doing this experiment, a total of 90 rural children participated the field trial. The results showed that VR and Lego social competence education prompted children's social competence and perceived social support with elementary school children. Furthermore, VR social competence education resulted in substantially greater social competencies and a subjective sense of social support than traditional classroom learning with middle school children. The results suggest that VR-assisted social competence education (Pedagogy of Technology) could potentially reduce educational inequalities in underdeveloped countries and regions.

Note. This study was published in *Computers & Education* (5-year impact factor 11.74) in May, 2023 (Wang, X., Young, G. W., Plechatá, A., Mc Guckin, C., & Makransky, G. (2023). Utilizing virtual reality to assist social competence education and social support for children from under-represented backgrounds. *Computers & Education*, 201, 104815.doi.org/10.1016/j.compedu.2023.104815). This publication drew heavily on the original data from this thesis' storage. The publication included additional contributions from the thesis supervisors - Prof. Mc Guckin and Prof. Young, and international collaborators from Copenhagen University, Denmark - Prof. Makransky and Dr. Plechatá. Adéla Plechatá was particularly guiding my work of data analysis. Guido Makransky was particularly guiding my work of drafting the methodology.

Whilst I am the first author and principal invigilator, contributions of each other are listed below:

Xining Wang: Conceptualization, Writing, Methodology, Field experiments with assistants, Data Analysis, Original draft preparation, Reviewing, and Editing;

Gareth W. Young: Reviewing, Editing, and Supervision;

Adéla Plechatá: Data Analysis, Editing, and Revision;

Conor Mc Guckin: Discussion and Supervision;

Guido Makransky: Methodology, Editing, and Lab Supervision.

Study 2 – Leveraging Virtual Reality to Enhance Quality Education (a mixed-methods study). In Study Two, I examined **the potential of using VR to enhance quality education for disadvantaged rural schools**. Specifically, the study investigates how virtual reality could improve classroom experiences and the learning atmosphere. This study includes a 2*1*2 mixed design with repeated measures (Pre- and Post-test), analyzing the data to examine the 2 groups (VR and Traditional Classroom) and 2 conditions (teaching & learning based in VR and teaching & learning based in a traditional classroom setting). In this study, a total of 70 students from urban and rural China were first recruited to participate in the field

trial. Secondly, students from the VR group were invited to take part in semi-structured interviews to obtain in-depth insights from rural students. In conclusion, the quantitative results revealed that VR education can enhance quality education and classroom atmosphere. The qualitative results reflected that students valued VR as an agent of their exploration in many aspects of education. However, students were worried that VR's novelty and entertainment might affect their performance within structured classroom education, which could further impede their success on future exams.

Note. This study is not published yet. All the content presented here was completed by myself. Therefore, different from the last two studies, no author credit statement is needed here.

Study 3 – The Potential of Extended Reality in Rural Education's Future – Perspectives From Rural Educators (a qualitative study). In Study Three, An identified gap is that the mainstream studies on XR-assisted education have often ignored the perspectives of an under-represented group – the rural educators. This study investigates **rural educators' perspectives on using XR technology to improve education quality in remote areas**. In this study, I provided XR Education Workshops for educators from rural China. These workshops provided hands-on XR teaching and learning experience. After the workshop, focus groups were used to elicit participants' feedback on this emergent education technology domain. The workshop and focus groups were designed and delivered by the principal investigator, qualitative data was collected from the discussion during the focus groups. As a result, rural educators offer a further depth of knowledge that XR education could be a promising solution to improve the teaching experience and bring transformative changes. They also pointed out XR education's limitations and challenges, and what can be used to expand the concept of rural education (e.g., XR education can raise public awareness, promote empathy and emotional engagement, and provide resources in vocational training for rural students).

Note. This study is under review in *Education and Information Technologies* (5 years impact factor 5.30) by June 2023. Similar to Study One, this publication drew heavily on original data from this thesis' storage. The publication included additional contributions from the thesis supervisors - Prof. Mc Guckin and Prof. Young, and international collaborators from Teesside University, the UK - Dr. Muhammad Zahid Iqbal. Muhammad Zahid Iqbal was particularly discussing the work of the XR continuum with me and helped with part of the editing work, and **I am the first author and principal invigilator**.

The contribution of each other is listed below:

Xining Wang: Conceptualization, Writing, Methodology, Fieldwork, Workshop, Data Analysis, Reviewing, and Editing;

Gareth W. Young: Reviewing, Editing, and Supervision;

Muhammad Zahid Iqbal: Reviewing and Editing;

1.6 Thesis Structure

As presented, **Chapter One is the *Introduction***. It introduced global educational inequalities that remain a significant challenge today. Disparities in educational opportunities and outcomes exist between countries, regions, as well as populations between WEIRD and non-WEIRD societies. It indicated that developing countries face severe social challenges due to educational inequalities, leading to long-term instability and stagnation. Students from underrepresented backgrounds in remote rural areas face serious challenges, including limited access to quality education and resources, which resulted in chronic inequality. In the meantime, Chapter One proposed that utilizing technology can be a solution to overcome these challenges; ensuring quality education for all through technological advancements can help reduce educational inequalities and contribute to economic growth, social justice, and political stability.

Chapter Two is the *Background & Theoretical Bedrock* of this thesis. It presents a theoretical framework to understand the evolution of fundamental inequality in China's educational system — “the “two-track” system” — through Bronfenbrenner's ecological systems theory. The chapter recognizes the complex interplay between China's education system, and how eco-environment shapes its development, which gives rise to the evolving inequalities in China's education. Using a systematic deductive approach, the factors creating these disparities from a macro to micro level perspective are investigated. This deductive approach emphasizes the importance of contextual factors in shaping educational policy and systems. It uses Bronfenbrenner's nested ecological systems model to exhibit China's rural education dynamics and dilemmas. This unique presentation can benefit readers' comprehension of how eco-environmental factors shape the national education system.

Chapter Three is the *Literature Review*. This chapter reviews the convergence of education with state-of-the-art technologies, e.g., extended reality (XR) technology, including virtual reality (VR), augmented reality (AR), and mixed reality (MR). The Use of XR in education is constantly evolving, from curriculum developments to new teaching, learning, and assessment approaches. The chapter highlights the applications of incorporating technology in education and the potential of XR to create innovative and engaging learning experiences for students. Three cases are presented to demonstrate the use of XR in different educational contexts, including XR-assisted social competence learning, XR-enhanced classroom learning, and XR application for reducing educational inequality. The chapter concludes by advocating for further research and evidence-based development of XR solutions in education to address the diverse needs of learners in our society.

Chapter Four is the *Quantitative Study (Study 1) - Utilizing Virtual Reality to Assist Social Competence Education and Social Support for Children from Under-Represented*

Backgrounds. An overview has been stated earlier in this chapter.

Chapter Five is the *Mixed-methods Study (Study 2)- The Potential of Extended Reality in Rural Education's Future – Perspectives From Rural Educators*. An overview has been presented earlier in this chapter.

Chapter Six is the *Qualitative Study (Study 3) - Leveraging Virtual Reality to Enhance Quality Education*. An overview has been shown earlier in this chapter.

Chapter Seven is the *Final Conclusion*. This chapter first presents the researcher's reflexivity on this Ph.D. project. Secondly, this chapter concludes the main findings and interprets the results with the eco-system framework (from micro-system to chrono-system). Next, it presents a discussion of this research project's limitations, and suggestions for future research. Lastly, this chapter shows a final conclusion from all studies. It suggests that XR can create innovative learning experiences, potentially reducing educational inequalities. However, limitations exist due to small sample sizes and pandemic restrictions, and future research should consider these factors. The study also underscores the need for evidence-based XR solutions in education. It highlights the transformative potential of XR, that is, XR can support quality education for groups and regions at disadvantages. Despite existing challenges, the project suggests that XR technology could revolutionize teaching and bring about significant change, especially for students in remote areas. Future research should focus on tech-enhanced education to ensure inclusivity, empowerment, and transformation in education. All in all, the research concludes with a call to embrace XR technology as a tool to create a more equitable educational landscape.

Chapter 2

An Analysis of China's Unequal Educational System Based on Ecological System Theory

2.1 Introduction

Having presented the project overview, the researcher's positionality, initial researcher questions, and a brief overview in the previous chapter, this Chapter examines China's educational system – the “two-track system” and rural education challenges through the lens of Bronfenbrenner's Ecological System Theory (eco-system). Using this theoretical framework to review the salient literature can support readers in understanding the intricate interplay between societal factors, cultural influences, policy decisions, and specific issues. Therefore, the aim of doing this is to understand how the ecological environment shapes rural education's development till today, and the Ecological System Theory is used as a theoretical guidance for this chapter only). Moreover, to find the potential answer to **“a priori” of research questions**, as previously stated, these are just initial questions at the start of the research process: (1.) What are the backgrounds of rural China and the “two-track system” in education and the “Hukou system”? (2.) What is the difference between China's urban education and rural education? and (3.) How does the related environment influence China's educational system? By addressing this fundamental issue, a comprehensive review is provided by following the ecology system theory from the macro-system level to the micro-system.

2.2 Ecological System Theory

Bronfenbrenner's Ecology Systems Theory (Bronfenbrenner, 1979b) presents a useful approach to analyzing the dynamic interaction between individuals and their environment. This theory provides a comprehensive understanding of human development by considering the

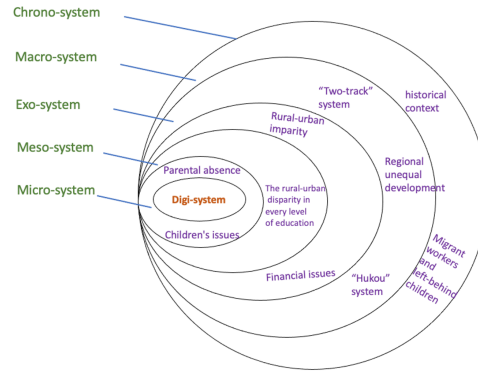


Figure 2.1: Keywords of China's educational system in the eco-system

various contexts and systems that influence an individual's growth and behavior. To be specific, Bronfenbrenner (1979, 1986) first proposed the theoretical framework of the “person in context” and conceptualized a model of human development as a multi-layered set of interconnected systems (i.e., ecological systems) to address the individual's lifespan development related to the relationship with his/her ecological environment.

According to this theory, the individual's development is not isolated and static, it is enmeshed in various ecosystems, from the most proximal system to the larger systems, and then to the macro system that includes society, group decisions, and culture. In this chapter, the ecology system theory is the rationale for the contextual review. The fundamental principle of the concept is the bi-directional interactions between individuals and their environment. Applying this approach to a macro level, we can gain insight into how the evolution of China's “two-track” education system – divided rural education and urban education has been shaped by a dynamic ecological framework. This framework encompasses the interactions and activities of individuals and their environment, spanning from historical influences to the present day. For example, the multi-layered nested figure below is a visualized graphic based on the concept of eco-system theory, presenting China's rural education as a confounding issue, its intangible interaction with the context at different levels (Figure 2.1).

2.3 Why Ecological System Theory?

Bronfenbrenner's ecological systems theory is a framework for understanding the complex influences on human development. This theory conceptualizes human development as occurring within a system of relationships affected by multiple levels of the surrounding environment, which is the reason why it can be useful for analyzing the divided educational system in urban and rural China. There, it can be a suitable bedrock for this chapter to provide a holistic view of a child's development, considering the interplay between various environmental systems. It underscores the role of context, valuing cultural, economic, and societal differences. Therefore, by employing Bronfenbrenner's ecological systems theory, I can bet-

ter address the complex, multi-faceted nature of educational disparities between urban and rural areas in China.

2.4 Defining Rural Education in China

Education in rural China refers to the educational system and practices in the rural areas of the country. Rural regions in China often face unique challenges compared to their urban counterparts, including limited resources, inadequate infrastructure, and a lack of qualified teachers. These factors contribute to significant disparities in educational opportunities and outcomes between rural and urban areas. In recent years, the Chinese government has strongly emphasized improving rural education to bridge this gap. Various initiatives have been implemented to enhance access to quality education in rural areas, such as providing better school facilities, and teacher training programs, and introducing modern teaching methods. Efforts have also been made to address high dropout rates and the urban-rural education divide. However, significant challenges persist (Rozelle & Hell, 2020).

Identifying the complexity of the issue, I employ a deductive way to understand the problem, that is, making use of a theoretical framework that integrates the systematic logic, from the macro level to the micro level, to analyze China's unequal educational system, including factors involved in shaping these inequalities. Given that the development of educational policy and procedures is inseparable from environmental influence, this study employs Bronfenbrenner's ecological system theory as the rational bedrock to present the chronic disparity in China's educational system (K. King, Palmer, & Hayman, 2005).

2.5 A Critical Aspect

How the ecological environment shapes rural education's development till today is a critical aspect to explore in the relevant literature. Because this critical inquiry is a step to glimpse the intricate relationship between the ecological context and the educational system. In order to provide a comprehensive response to this question, it is crucial to consider the multifaceted and context-specific factors that have played a role in shaping rural education. These factors encompass historical, practical, economic, intergenerational, and interregional aspects. To address this question comprehensively, the analysis proceeds through different levels of the ecological systems framework.

Beginning with the **chrono-system level**, it is a concept that elaborates on the role of time in shaping an individual's development. The chrono-system level is also the far-reaching level in Bronfenbrenner's ecological systems framework. This encompasses the dimension of time and the societal conditions during different periods (e.g., political changes, technological advances, and decisive events or experiences) (Bronfenbrenner, 1979b). This level

also recognizes how historical events, personal encounters, and significant life changes impact the progression of development (E. M. Rosa & Tudge, 2013).

The following level is the **macro-system level**, where a broad perspective is taken to examine the overarching societal and cultural influences on rural education, including national strategy for education, government policies, the development of rural, etc. Next, at the **exo-system level**, the focus is on the broader systems and institutions that surround and affect the individual's immediate context (E. M. Rosa & Tudge, 2013). This level includes factors such as the gap between urban and rural China, funding for education, and human resources in education. Further exploration is at the **meso-system level**, where these different micro-systems influence and impact each other (Bronfenbrenner, 1979b). It recognizes the dynamics, interactions, and interdependencies between these micro-systems. This includes the main disparity of each level's education in urban and rural China – i.e., early years, primary level, secondary level, and higher education. The **micro-system level** is the innermost circle, referring to the immediate and direct experiences of individuals within the rural education system. This level includes the individual's interaction with the proximal surroundings (Bronfenbrenner, 1979b).

Next, at the **exo-system level**, the focus is on the broader systems and institutions that surround and affect the individual's immediate context (Bronfenbrenner, 1979b). This level includes factors such as the gap between urban and rural China, funding for education, and human resources in education.

Further exploration is the **meso-system level**, where these different micro-systems influence and impact each other (Bronfenbrenner, 1979b). It recognizes the dynamics, interactions, and interdependencies between these micro-systems. This includes the main disparity of each level's education in urban and rural China – i.e., early years, primary level, secondary level, and higher education.

Finally, the **micro-system level** is the innermost circle, referring to the immediate and direct experiences of individuals within the rural education system. This level includes the individual's interaction with the proximal surroundings (Bronfenbrenner, 1979b).

2.6 Chrono-system: Historical Evolution of Educational Disparity between Rural and Urban China

Understanding the educational disparity between rural and urban China requires an examination of the historical evolution of educational policies, societal changes, and economic transitions that have shaped this divide. Hence, reviewing China's unequal two-track education system at the **chrono-system level** can elucidate the role of time in shaping this disparate two-track education system. It also delineates how historical epochs, transformative policy shifts, and pivotal societal transitions have sculpted the trajectory of educational develop-

ment (X. Wang, McGuckin, & Zhang, 2023). It emphasizes the pronounced impact of events, historical policy implementations, educational reforms, and socio-political upheavals on the evolution and divergence of educational pathways within rural and urban settings (E. M. Rosa & Tudge, 2013). This temporal lens illuminates the nuanced interplay between successive policy reforms, societal transitions, and their enduring imprint on the educational landscape, underscoring the imperative of temporal contextualization in comprehending the evolution and divergence of the two-track system (X. Wang, McGuckin, & Zhang, 2023).

2.6.1 Long-term Issues in China's Education System

Educational inequality in rural China represents a multifaceted and complex issue, which is entangled with the socio-economic status in rural China. Prior to economic reforms (since 1978), educational policies in China were largely urban-focused, resulting in significant disparities between urban and rural educational opportunities (Rozelle & Hell, 2020). The rural areas often received limited resources and attention compared to their urban counterparts. Due to the national policy prioritizing urban educational development over rural areas has not changed from history till today (Q. Wu, Lu, & Kang, 2015; Hannum, 1999), it leads to the widening of the gap in educational resources and opportunities between urban and rural regions (Johnstone, Arora, & Experton, 1998; Hayhoe, 2019). For example, advanced urban areas had better access to educational resources, including schools, qualified teachers, and educational materials. Remote rural areas lagged far behind due to limited infrastructure, a shortage of schools, and lower investment in education. This contrast presents drastic inequality in educational quality and opportunities among urban and rural student populations.

2.6.2 Migrate Workers and Left-behind Children

In addition, at the heart of this issue lies the phenomenon of “rural parents as migrant workers” and “left-behind children”. “Rural parents as migrant workers” refers to rural job seekers who migrate from one area to another, often from China’s Western rural areas to Eastern urban regions, due to the lack of employment opportunities in their hometowns (L. Shi et al., 2008). These workers rarely back home due to the work restrictions (e.g., economic status and employment terms, and this separation from home led to millions of their children staying in rural regions without parental guidance, so-called “left-behind children” (F. Wang, Zhou, & Hesketh, 2017). These can have a profound impact on the family dynamics, particularly affecting the development of their children (F. Wang et al., 2017). For instance, these left-behind children often cared for by their grandparents or relatives usually face emotional challenges during their childhood, such as feelings of abandonment and loneliness (Rozelle & Hell, 2020). Also, without adequate supervision, children may be at higher risk of neglect or engaging in risky behaviors during their development (Freisthler, Johnson-Motoyama, & Kepple, 2014). The consequences of these phenomena are pervasive. Research has indi-

cated that rural students often lag in critical areas such as literacy, numeracy, and scientific knowledge. This inequality impeded rural students' ability to gain equivalent opportunities (e.g., higher education admission), and further formed a cycle of educational marginalization (D. Wang, 2011).

2.6.3 Understand the Historical Context

Although efforts have been made by China's central government, international organizations (e.g., Unicef), and charity foundations to address these disparities, the historical effects of resource allocation, policy decisions, and societal categorizations are still ongoing. Reviewing such historical evidence based on the chrono-system can uncover how historical economic reforms, policy decisions, and societal structures have led to enduring disparities, hindering equal access to quality education between rural and urban areas. The chrono-system's historical influences on education have led to persistent disparities between rural and urban China. The historical trajectory of educational policies, economic reforms, and societal systems has contributed significantly to the existing gap in educational resources, opportunities, and quality between these regions. Understanding this historical context is crucial in addressing the enduring educational inequality in China.

2.6.4 A Priori Questions

Next, to answer the following questions

(Q1) What are the backgrounds of rural China and the "two-track system" in education and the "Hukou system"?

(Q2) What is the difference between China's urban education and rural education?

(Q3) How does the related environment influence China's educational system?

These questions explore how factors shape the educational systems, structures, and practices within society under the macro-system level of this framework.

2.7 Macro-system: Rural education's background and the fundamental inequalities (refer to Q1)

The macro-system is a larger cultural context level in Bronfenbrenner's ecological systems framework. It refers to the broad societal, cultural, and economic influences that shape individuals and their development. At this level, the focus is on the larger systems and structures that impact the individual's immediate environment (Bronfenbrenner, 1979b). At the macro level, the emphasis is on understanding the wider context in which individuals and their immediate settings exist. This includes examining the social norms, cultural values, economic policies, and political systems that influence the overall educational landscape in a given so-

ciety (Newman & Newman, 2020a). In education, a macro-system level analysis involves considering national or regional educational policies, governmental regulations, funding and resource allocation, cultural beliefs and values related to education, and broader social and economic factors that impact educational opportunities and outcomes (Mc Guckin & Minton, 2014a).

Therefore, to answer Q1, Q2, and Q3, this chapter first explored how factors shape the educational systems, structures, and practices within society under the macro-system level of this framework.

2.7.1 Socioeconomic Background of Rural Development in China (Q3)

According to Rozelle and Hell (2020)(Rozelle & Hell, 2020), China's dominant narrative has been constant development and an ever-developing economy. Nonetheless, there is an invisible side - rural China - a place of evident left-behind education, underrated issues, and chronic under-development villages (Rozelle & Hell, 2020). It is vast and uncompromising, demonstrating a deep chasm with urban China, and has been ignored by the well-educated urban throng as well as unacknowledged by the rapidly growing national economy (Rozelle & Hell, 2020).

At a macro-system level, inequality between China's rural and urban society is expanding (Rozelle & Hell, 2020; Y. Shi et al., 2015a; H. Wang et al., 2022). One of the primary obstacles to the sustainable development of China's rural regions is the lack of investment and general resource constraints among rural areas (K. Zhang, 2005). Research has indicated that most rural residents have lower incomes than their urban counterparts - the disposable income of urban households stands at 39,251 Chinese Yuan (5,465.27 US dollars) per capita per year and 16,617 Chinese Yuan (2,313.73 US dollars) for rural households (National Bureau of Statistics of China, 2019). In the meantime, urbanization progresses rapidly, resulting in further losses of cultivated land, and most rural adults, including parents, have to work far away from home for extended periods. The indirect result of this population movement has been a further reduction in educational resources in rural China (Rozelle & Hell, 2020).

2.7.2 Divided Urban-Rural Education: “Two-track” system and “Hukou” system (Q1)

The existence of the “two-track” system was asserted in the “Decision on the Reform of the Education System” (of the State Council, 2018) and in the “Directive Concerning the Reorganization and Enhancement of Primary Education” (the State Council, 1953) (? , ?). Since China was a country of limited capital but still expected to produce qualified experts for modernization, the government decided to support several key urban schools to develop first (i.e., Track 1). Once the economic situation was sufficiently improved, it was possible to fund the educational system on a large scale (i.e., Track 2). (Fu, 2005). As a result, A World

Bank – Chinese Ministry of Education joint report (Johnstone et al., 1998) confirmed that the disparity in educational opportunities was **5.8 times** between China’s rural and urban regions. Urban schools were usually sponsored with remarkably more significant investments than rural schools, and urban students with more and better educational opportunities (Hayhoe, 2019).

Moreover, another ever-existing system profoundly influenced rural residents – the “Hukou” system, a political institutional arrangement built on an unfair household registration system. A “Hukou” is the registered residency status of a particular individual in this system, which officially records a person as a permanent resident of an area and includes identifying information such as name, parents, spouse, and date of birth (T. Cheng & Selden, 1994). Under this system, all people are divided at birth into two categories - rural or urban. This status affects everyone’s life chances in ways, for example, education, health care, and retirement pension (Rozelle & Hell, 2020). Focusing on education, due to the “Hukou” restriction, rural students cannot move freely to urban areas where educational resources are more and better and have the same education as their urban counterparts.

In summary, at the macro-system level, China’s rural development is largely shaped by financial issues, natural conditions, and teacher shortages. Despite the nation’s economic growth, rural China suffers from educational inequalities, underdevelopment, and limited resources. The urban-rural income disparity is vast, and urbanization further depletes rural educational resources. A “two-track” system and the “Hukou” system exacerbate this educational divide. Moreover, the lack of investment and poor natural conditions in rural areas, particularly in Western China, impede educational progress and deter teachers from working in these regions. Therefore, the rural educational system lags behind the urban areas, leading to persistent educational disparities.

2.8 Exo-system: The Imparity between Urban Education and Rural Education (Q2)

According to Bronfenbrenner (1979), the exo-system is a system formed by one or more settings where the developing individual is not an active participant but in which events occur that influence or are influenced by what happens in that setting. It consists of the social structures and institutions that may not directly interact with the individual but have an impact on their development. These external systems can affect a person’s life indirectly through their influence on the micro-system. The exo-system level encompasses various social structures and institutions that surround individuals and shape their experiences. Examples of impact factors at this level include government agencies, religious organizations, local communities, healthcare systems, legal systems, and mass media. These structures and institutions provide the broader context within which individuals operate (Mc Guckin & Minton, 2014a).

When examining the connections to rural China, numerous external factors associated with the exo-system level have the potential to impact the country's rural educational development, such as financial issues, natural conditions, and teacher shortages (H. Wang et al., 2022). These factors can manifest in both direct and indirect ways, and they often include issues such as insufficient investments and unfavorable natural conditions (Ludlow, 2015). It is important to recognize that these external factors, including the lack of investment and poor natural conditions, interact with other levels of the ecological systems theory (P. Wang, Liu, & Zhao, 2014). These ever-existing hardships can influence the micro-system (immediate environment) of rural education, affecting their experiences within the family, school, and community. The negative consequences of these exo-system level factors can also trickle down to the micro-system, exacerbating the challenges faced by rural students and impeding their educational development (Townsend et al., 2020).

2.8.1 Under-investment

One significant challenge rural China faced was the lack of educational resources and infrastructure investment. Due to various economic and social factors, rural areas often receive fewer resources and funding than urban regions. This investment disparity hampers educational institutions' development and limits the opportunities available to rural students. Insufficient funding leads to a scarcity of qualified teachers, inadequate facilities, outdated teaching materials, and limited access to technology—all directly hindering educational progress (OECD, 2016; Rozelle & Hell, 2020).

The difficulty in providing quality rural education and retaining equality between the urban-rural educational model was caused by scarce financial investment. First, the reason is that the government's investment in education has always been insufficient, and it has only improved in recent years. For instance, in 2012, China's fiscal education budget as a percentage of Gross Domestic Product (GDP) was 4 percent, the first time the Chinese government had invested much money in education (OECD, 2016). However, it is still below the 5 percent of GDP that OECD countries spend on average on education (OECD, 2019).

Moreover, the Ministry of Education stipulates that funds for compulsory education shall be jointly provided by the central state government and the local council (Fan, 2008). However, this bill does not clearly define the proportion of funds the local council should offer, so each local council usually contributes a percentage from 20 percent to 80 percent, depending on each local government's financial situation (L. Shi et al., 2008). Hence, there is typically little budget for the rural educational system because Western rural regions' (Figure 2.2a) governments always have low fiscal revenue. In contrast, prosperous East coastal regions' (Figure 2.2b) governments can boost their educational resources in many ways. As a result, the educational investment from one urban council and the next varies dramatically because of their disparate financial situation.

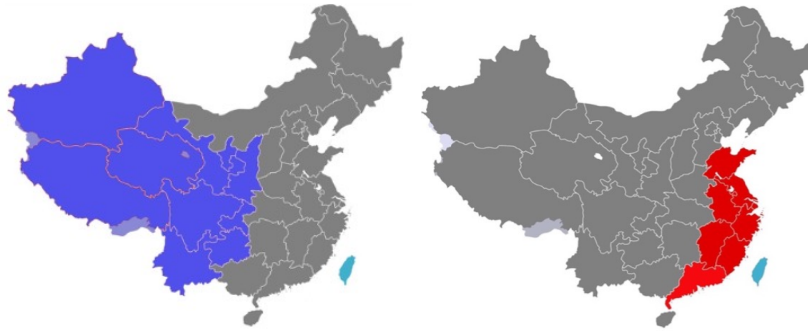


Figure 2.2: a. Western Regions (Blue) and b. Eastern Regions (Red) in China

2.8.2 Poor Natural Conditions and the Lack of Teachers (Q2 & Q3)

At the exo-system level, a systemic variable often overlooked in efforts to pinpoint impacts on development is the geographic locale (Iruka, DeKraai, Walther, Sheridan, & Abdel-Monem, 2019). The living environment for rural children in Western China has particular inequalities (Dürr, 1985; Lo, 1990). These areas experience structural and environmental problems, such as mountainous terrain, disadvantaged transportation, stagnating economics, and a lack of essential public services. These harsh natural and geographical conditions discourage teachers from working in rural areas. Because of the lack of (good) teachers, the rural education system is inherently far behind the urban areas (H. Wang et al., 2022).

In summary, the exo-system level in rural China unveils the significance of geographic locale as a frequently overlooked systemic variable impacting development. Western China's rural areas contend with unequal living environments characterized by structural and environmental issues such as mountainous terrain, limited transportation, stagnant economics, and a lack of essential public services. These formidable natural and geographical conditions deter teachers from working in rural areas, creating an inherent educational disparity between rural and urban regions.

2.9 Meso-system: The difference between urban and rural education at each level (Q2)

The meso-system of the ecological model is a set of inter-relations between two or more settings in which the developing person becomes an active participant (Bronfenbrenner, 1986). It consists of the interactions between two or more environments in which the developing person actively engages (Newman & Newman, 2020b). The meso-system recognizes that individuals experience transitions and changes as they move between different settings. For example, the transition from home to school, or from school to work, can have significant implications for development. The meso-system level highlights the importance of support and continuity during these transitions to facilitate successful adaptation. It also considers

the consistency or inconsistency of messages and practices between micro-systems. When the values, expectations, and behaviors across different settings are congruent, it promotes healthy development. However, inconsistencies or conflicts in messages, rules, or expectations between micro-systems can create stress or confusion for the individual (Anning & Edwards, 2006).

Examining education across these levels can provide a comprehensive understanding of the disparities between rural and urban contexts. The meso-system level highlights the interconnectedness and interactions between different micro-systems, such as family, school, and community. In the case of China's educational system, rural and urban environments constitute distinct micro-systems that influence an individual's development. To gain insight into the systemic inequalities in China's "two-track" system (Question 1), examine and compare the rural and urban educational systems at each level, including early childhood education, elementary education, secondary education, and higher education. This comparative analysis aligns with the meso-system level of Bronfenbrenner's ecological systems theory (Question 2).

2.9.1 Early Childhood Education (Q3)

Given that early childhood education (ECE) is not included in the national education system (Bullough & Palaiologou, 2020), kindergartens are usually run by local educational departments, with a number of them being private enterprises (Zhu, 2009). The allocation of early childhood education (ECE) resources in China is significantly unbalanced between urban and rural areas. Official statistics show that in 2012, there were 26,459,845 kindergartens in urban areas but only 10,397,779 in rural areas (See Table 1 below). The three-year ECE program gross enrolment rates of urban and rural kindergartens were 89.10 percent and 29.69 percent (Stokes, Holdsworth, & Stafford, 1999), which presents a disparity of 59.41 percent (see Table 2 below) (of Education of People's Republic of China, 2015).

Table 1. The Number of Urban and Rural Children in Kindergartens, 2006 to 2012

Year	National level	Urban areas		Rural areas	
		Total	Percent	Total	Percent
2006	22,638,509	12,160,090	53.71	10,478,419	46.29
2007	23,488,300	13,157,106	56.02	10,331,194	43.98
2008	24,749,600	14,076,041	56.87	10,673,559	43.13
2009	26,578,141	15,318,161	57.63	11,259,980	42.37
2010	29,766,695	17,626,405	59.22	12,140,290	40.78
2011	34,244,456	24,306,519	70.98	9,937,937	29.02
2012	36,857,624	26,459,845	71.79	10,397,779	28.21

Table 2. The Gross Enrollment Rate of Urban and Rural Kindergartens, 2006 to 2012 (Stokes et al., 1999)

Year	Three-year GER			One-year GER		
	Urban areas	Rural areas	Disparity	Urban areas	Rural areas	Disparity
2006	58.05	29.63	28.42	72.08	50.14	21.94
2007	62.11	29.86	32.25	74.85	49.51	25.34
2008	65.63	31.73	33.90	78.96	50.78	28.18
2009	67.72	33.13	34.59	77.05	49.03	28.02
2010	69.76	34.95	34.81	75.68	48.12	27.56
2011	87.72	28.59	59.13	76.37	29.64	46.73
2012	89.10	29.69	59.42	81.24	31.70	49.53

In urban areas, especially the Eastern coastal areas, participation in an ECE program is a crucial stage of an individual's lifelong education. Kindergartens in coastal areas are almost in line with (Zhou, 2011) international standards. By contrast, ECE is the weakest section in China's rural education system (Zhou, 2011), and the quantity and quality of kindergartens in China's poverty-stricken rural areas are low (see Table 2 above). Apart from the socio-economic reasons, the issue is compounded by the private and illegal rural ECE services across rural child play centers, as they are unlicensed and not quality assured by the government's accreditation and management system (Hong, Liu, Ma, & Luo, 2015), and the fact that ECE teachers are scarce in these areas. For example, the number of ECE teachers in urban areas (N=1,249,674) was 5.52 times higher than in rural areas in 2012, and many rural teachers did not meet the basic requirements in terms of quality and qualification (Hayhoe, 2019). Since research has shown that participation in ECE is vital for children's lifelong development, children without access to ECE could have lower levels of cognition, language, arithmetic, mental and physical fitness, as well as social skills (He et al., 2022; Parreñas, 2005).

2.9.2 Disparities in Elementary Education (Q3)

In China, the nine years of compulsory education start from elementary education. Both public and private primary schools in advanced urban areas have good reputations (Rozelle & Hell, 2020). Even so, in urban China, many education services provided by mainstream schools cannot meet urban parents' requirements; these parents invest heavily in their children's education and believe they need extra elementary curricula from the after-school market (X. Lin, 2019). By contrast, elementary education in rural areas is problematic. For instance, the number of rural school-age children continues to decline. Since the rural councils take administrative responsibilities for local education because of the "two-track" system, this has imposed a considerable financial burden on local rural residents, as well as several rural primary and secondary schools that were small in size since there are few qualified teachers could provide quality teaching (Rao & Ye, 2016).

Schooling at the primary level was not always universal in the rural region, particularly in terms of remote areas. Although both "The Compulsory Education Law" (1986) and "The Rule for the Implementation of the Compulsory Education Law of the People's Republic of

China” (1992) were introduced in an attempt to address this, still, rural elementary schools are facing dilemma such as insufficient teachers and students dropping off (Lu et al., 2016).

2.9.3 Inequalities in Secondary Education (Q2 & Q3)

Secondary education is considered one of the most essential driving forces for promoting a country’s economic development (Ozturk, 2008). Secondary education in China’s urban coastal cities has been valued as a more successful model than in other OECD countries. According to the OECD’s Programme for International Student Assessment (PISA) data for 2018 (15-year-old pupil’s scholastic comprehensive performance and capabilities concerning mathematics, science, and reading, China’s four regions - Beijing, Shanghai, Jiangsu, and Zhejiang were ranked first place among 77 countries (Peña-López, 2019). This result evidences that secondary education in these Chinese urban areas is at the forefront of the OECD level.

In stark contrast, secondary education in rural areas lags far behind that of its urban counterpart, with less than 40 percent of students in attendance at high school in China’s impoverished rural areas in comparison to urban areas, where the rate is 90 percent (Y. Shi et al., 2015a). Poorer rural students are more likely to drop out because they are disproportionately affected by the costs of continuing their education because high school education is not included in the nine-year compulsory education mechanism. The tuition fees for high school in China are the highest in the world, which is known to impose a significant burden on many rural families. On the other hand, and perhaps even more significantly, the rigorous academic requirements for academic high school admission set a severe barrier to rural students (Y. Shi et al., 2015a). The middle school dropout rate is higher than that of elementary education, which is approximately 25 percent of the population in disadvantaged rural areas. Research has indicated that apart from the economic factors, secondary school students often drop out of school as a result of five elements: (i) poor academic performance, (ii) higher prevalence among males than females, (iii) middle school students who are older, (iv) low-income family conditions, and (v) students with psychological issues or mental issues (Y. Shi et al., 2015a).

2.9.4 Rural-Urban Differences in Opportunities to Obtain Higher Education (Q2)

In China, rural-urban differences in the opportunities to obtain higher education qualifications reflect structural issues within the educational system (H. Cheng, 2009; Houxiong, 2011; L. Wang, 2011). The urban-rural inequalities in higher education are also a direct result of the “two-track” system and the “Hukou” system (see section 2.5.2) (M. Li & Yang, 2013). The central government has highly controlled higher education opportunities for decades. The distribution of these opportunities has been significantly uneven and imbalanced. In

particular, the higher education admission system has been segmented into different levels based on the administrative and geographical units of provinces and municipalities. Each institution designates discrepant admission quotas to other regions and municipalities (M. Li & Yang, 2013). For example, a student from the capital city or a financially-centered area would generally score less within the admission process than students from other regions. The planned enrolment figures for higher education institutions are preferentially distributed to metropolitan areas, such as Beijing and Shanghai (X. Zhang & Kanbur, 2009). These examples highlight the historical and geographical link between the province of birth and the unequal educational chances in higher education.

A World Bank – Chinese Ministry of Education joint report (Johnstone et al., 1998) confirmed that the differences in educational opportunities between rural and urban regions were 5.8 times nationwide. Li et al. (2015) (H. Li, Loyalka, Rozelle, Wu, & Xie, 2015) indicated that, in 2003, youth from poor counties in China were between 7 and 11 times less likely to access standard colleges and elite universities (Project 211 universities) than urban youth. Moreover, more significant gaps exist for rural female students and students from ethnic minorities from impoverished counties (H. Li et al., 2015). From the above statistics (1998 to 2003), the rural/urban gap in higher education admissions has expanded. Meanwhile, Zhang and Liu (2015) have pointed out that the most prestigious universities have the lowest percentage of students from rural areas (S. Zhan, 2005). Research has highlighted that any reduction in inequality concerning access to higher education is either small or negligible. Suppose rural students cannot gain fair access to quality higher education and achieve similar levels of socioeconomic status to their more advantaged peers. In that case, there will be an impact on social inequality and, ultimately, social cohesion (H. Li et al., 2015).

In summary, these findings highlight the systematic inequalities prevalent in China's education system. In the advanced coastal region, education resources such as teachers, funding, models, and facilities far surpass those available in rural areas across all levels of education. This disparity emphasizes the urgent need for targeted efforts to bridge the gap and provide equal educational opportunities for students in both urban and rural settings.

2.10 Micro-system: Human-environment interaction (Q3)

The micro-system includes the individual's immediate surroundings, such as the family, school, peer groups, neighborhood, and other immediate social contexts. These environments play a crucial role in shaping the individual's experiences, beliefs, values, and behaviors (Bronfenbrenner, 1986). The microsystem recognizes the significance of relationships within the immediate environment. The quality of interactions with parents, siblings, teachers, classmates, and friends within these settings can greatly impact the individual's development. Positive, supportive relationships can foster healthy development, while negative or dysfunctional relationships can have adverse effects. It highlights the influence of

relationships, immediate surroundings, and unique experiences within these settings on an individual's development. The microsystem level emphasizes the bidirectional influence between the individual and their immediate environment, recognizing the cumulative impact of experiences within this level (Lynam, McConnell, & McGuckin, 2018).

In rural China, the context of education is primarily influenced by the relationship between the person and the immediate environment. The quality of an individual's interactions with parents, siblings, teachers, classmates, and friends in these settings can greatly affect an individual's educational development. Positive, supportive relationships can promote healthy personal development, whereas relationships in an underdeveloped or dysfunctional education system can adversely affect personality development.

2.10.1 Individuals' Family and Home Environment in Rural China (Q3)

The family plays a crucial role in the micro-system of rural education. The family's interactions, support, and values influence a child's educational experiences. Parental involvement, educational aspirations, and economic conditions can significantly impact a child's access to resources and educational opportunities.

According to the 2018 Annual Report by UNICEF, around 69 million children in rural areas, which accounts for approximately thirty percent, have been separated from one or both of their parents due to migration (unicef, 2018). Left-behind children are children who remain in rural regions of the country while their parents leave to work in urban areas. In many cases, these children are taken care of by their extended families, usually by grandparents or family friends, who remain in the rural regions childcare is a way of accomplishing their family obligation to many kin caregivers (Spence, 2004). Most rural kin caregivers are confident in providing basic living conditions and meeting children's basic needs, such as food, housing, clothing, and personal hygiene. however, most of them do not have confidence in education and interaction. Kin caregivers who live in rural areas need to balance their farm work and childcare, which leads to a lack of essential communication between the child and the kin caregiver (Z. Wu, 2017), and less likely to invest in children's education as much as their parents.

2.10.2 Local Community Connections (Q3)

Traditionally, the neighborhood of China's rural villages is consolidated, supportive, and attached (Pianta, Hamre, & Allen, 2012). Villagers live, work, and socialize in an enclosed environment for most of their lives, which forms a naturally created community with a strong and close neighborhood (G. Liu & Yu, 2017). In such a neighborhood with dense and overlapping social ties, children can receive support and care from adults who are outside of their own families. Likewise, they may also benefit from a wider range of public interaction (Xie, Sandberg, Huang, & Uretsky, 2019). In some rural areas, there are care network sites named

“Children’s Family Education and Guidance Center”, which consist of towns, villages, and schools. Some rural villages have gradually established small libraries, parent cultural reading rooms, left-behind child center kindergartens; family activity rooms, and after-school activities (K. Lin, Yin, & Loubere, 2014; Z. Wang, Zhang, Zhang, Qiu, & Dai, 2017). Given that education in rural areas has lagged far behind urban education, these small community support centers can make up for this shortfall to a micro extent.

2.10.3 Healthy Issues (Q3)

Education is crucial in promoting health literacy, disease prevention, and healthy behaviors within communities. Access to quality education equips individuals with the knowledge and skills to make informed health decisions and adopt healthier lifestyles. Conversely, poor health, including physical and mental health issues, can hinder access to education and impede academic performance for individuals of all ages.

Because of the external limitations (e.g., rough geographical conditions, disadvantaged transportation system, and deficient public services), rural regions in China have more dilemmas, compromises, and deprivations, which are serious threats to rural children’s healthy development. According to a report from (unicef, 2014), rural children are severely deprived of access to basic infrastructures (e.g., safe drinking water, sanitation facilities, good health care, and education), especially rural children from low income families. It is estimated that over 75% of children from low income facilities are suffering from malnutrition, anemia, eyesight issues, and parasitic disease (Watkins & Thomas, 1991). For example, research demonstrated that the prevalence of stunting among 6 to 11 months of age infants in poor rural areas was 3.3 times the national average; in Yunnan province (Southwest China), children of the same age showed a stunting rate 5.7 times higher than the national average; in both Yunnan province and Qinghai province (Northwest China), rate of anemia of the children 12 to 23 months of age was respectively 3.9 and 3.2 times higher than the national average (Mai, 2012). Likewise, in rural areas, 13% of fourth to sixth-grade children had poor vision (Glewwe, Park, & Zhao, 2012). All these facts reflect that a great number of children in rural China experience diverse rural settings that may impact their development and educational well-being.

2.10.4 Cultural and Social Challenges (Q3)

Beyond the above challenges, children and youth in rural China are influenced by cultural and social factors. In some rural communities, parents may have a limited awareness of the full significance of education. This perspective can stem from various factors, including traditional views, the immediate necessity of physical labor for survival, and a lack of successful role models who have benefited from higher education. As a result, families might not fully understand or value the potential long-term benefits of digital education, which

can impact their investment in their children's education, both financially and motivationally (D. Zhang, Li, & Xue, 2015). Therefore, for some rural youth, their family may need them to contribute to the household economy, which often leads to higher dropout rates as students leave school to work (Y. Shi et al., 2015b). Additionally, rural parents may have less focus on the long-term benefits of education for their children. When education is not seen as a priority or a feasible path to a better life for the next generation, students may lack the intrinsic motivation to pursue their studies. This challenge is exacerbated by both economic pressures and cultural attitudes towards education. This cultural perspective can significantly impact the motivation and engagement of students in their educational pursuits.

2.11 Digi-system (Q2 & Q3)

As scholars and researchers continue to deepen and expand Bronfenbrenner's ecological system and bio-ecological system theory, the digi-system has been discussed to be embedded into this theory in recent years. This concept derives from the technology-enabled digitization and society that are ubiquitous and impact people's lives at all times (Plowman, 2016). Therefore, the newly developed digital system represents the virtual environments and online interactions that influence each level of an individual's life. For example, the impact of digital communication, social media, online communities, and virtual learning on personal development and social interactions, intersect with traditional micro-, meso-, exo-, and macro-systems. In this level of the system, the concepts of availability and publicness redefine interactions for individuals (Navarro & Tudge, 2023). Availability transcends physical and temporal constraints, enabling connections across distances anytime, a crucial aspect highlighted during the COVID-19 pandemic with the rise of online education, telehealth, and remote work. Publicness, unlike in physical settings, allows individuals to engage with a broader, geographically unrestricted audience through social media and interactive platforms. These networked publics facilitate wider social, cultural, and civic participation. However, the presence of an unseen, extensive audience influences how individuals present themselves in these virtual environments (Navarro & Tudge, 2023). In rural China, the education system grapples with a multitude of challenges that are distinct from those in urban areas. These challenges are complex, including technological disparities, socio-cultural differences, and policy-related issues, all of which contribute to a significant educational divide.

2.11.1 Technological and Digital Disparities (Q2 & Q3)

One of the most evident issues is the digital divide between urban China and rural China (Peng & Dan, 2023). Rural schools often lack access to basic digital infrastructure, such as high-speed internet and modern computers or tablets. This technological gap hinders the integration of digital tools and resources in the classroom, which are increasingly crucial for

modern education. The lack of such resources impairs students' ability to engage with digital learning platforms, access online resources, and develop essential digital literacy skills (Q. Wang, Zheng, & Zhang, 2023). This situation is further exacerbated by the rapid pace of technological advancement, which urban schools are more equipped to keep pace with, thereby widening the educational divide.

2.11.2 Unequal Educational Outcomes and Opportunities (Q2 & Q3)

The disparities in resources and teaching quality contribute to lower educational outcomes for students in rural areas (Rozelle & Hell, 2020). This is evident in the higher dropout rates, lower standardized test scores, and reduced access to higher education opportunities. Students in rural areas are less likely to attend college or pursue advanced degrees, limiting their future employment opportunities and perpetuating a cycle of poverty and educational disadvantage (X. Wang, Young, Iqbal, & Guckin, 2023).

2.11.3 Policy Implementation and Effectiveness (Q3)

Despite governmental efforts to improve rural education, including policies aimed at increasing digital integration in schools, there remains a considerable gap in effective implementation. Challenges include inadequate funding, lack of clear policy directives, and insufficient support for rural teachers and administrators. These issues hinder the effective adoption of digital technologies in education and the overall improvement of educational standards in rural areas (Y. Guo & Chen, 2011).

Addressing these challenges requires a holistic approach, like that offered by the digital system framework. This approach should include investment in digital infrastructure to bridge the technological divide, alongside targeted programs to train teachers in digital literacy and modern pedagogies. Policy interventions need to be tailored to address the specific needs of rural communities, considering cultural and social factors that influence educational engagement (Rieckmann, 2018). Data-driven strategies should be employed to track educational outcomes and adjust policies and practices accordingly. Moreover, engaging local communities in the dialogue about educational priorities and the role of digital technology is crucial for creating sustainable and effective educational ecosystems in rural China (X. Wang, McGuckin, & Zhang, 2023).

2.12 Chapter Summary

The ecology system theory pivots this analysis into a framework to explain how sociocultural elements and natural factors can influence rural education's evolution. Given that the society, culture, and geographic environment immersed within the objective may influence its developmental process direction, the presented factors from each level of the eco-system

can be seen as potential agents that directly and indirectly shaped the development of China's rural education. Under this frame, this chapter does not review individual-in-context issues, instead presents the divide between China's urban and rural areas as a stark existence (e.g., economy and education), which has led to a series of complex inequalities for rural education that may further catalyze a pernicious future crisis for the country. These disparities between rural and urban areas increased rural children's likelihood of being trapped in developmental issues. They reduced their opportunities to obtain the same educational resources as their urban counterparts, thus forming chronic and systematic inequality between China's rural education and urban education.

The consequences of this profound divide reverberate throughout rural communities, hindering countless children's educational prospects and life chances (Rozelle & Hell, 2020; X. Wang, Young, Plechatá, et al., 2023). The systemic and long-standing nature of these disparities underscores the urgent need for comprehensive interventions to bridge the gap and foster equitable educational opportunities for rural children. Therefore, the next chapter exhibits a literature review focused on the application of Extended Reality (XR) in education. This review explores the comprehensive utilization of XR technology in educational settings, including its application in rural and remote areas. By examining existing literature and related research and practice in this domain, valuable insights can be gained to inform and guide the current research project. Through a comprehensive analysis of the literature, the next chapter can contribute to a deeper understanding of the potential benefits, challenges, and best practices associated with the use of XR in educational contexts.

Chapter 3

The Application of Extended Reality in Education

3.1 Chapter Overview

In the previous chapter, an in-depth exploration was conducted utilizing Bronfenbrenner's ecological system theory to provide a comprehensive understanding of the background of rural China, and the unequal "two-track system" between rural and urban China. The disparities between urban and rural education in China were highlighted, underscoring the substantial lag experienced by rural education compared to its urban counterpart. The influence of the surrounding environment on China's educational system was also discussed, emphasizing the challenges faced by rural education despite significant government investments aimed at improving its quality. Recognizing the persistent gaps in rural education, this chapter shifts its focus to exploring the potential of technology, specifically Extended Reality (XR), to address this dilemma. By reviewing the application of XR in education, the chapter investigates how this innovative technology can potentially transform the educational landscape in rural China. The utilization of XR in education holds promise in bridging the educational divide by offering immersive and engaging learning experiences that transcend physical barriers. Through a comprehensive analysis of XR's application in educational contexts, this chapter provides insights into its related practices, potential impact, benefits, and challenges.

3.2 Introduction to Extended Reality

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) (Figure 3.1).

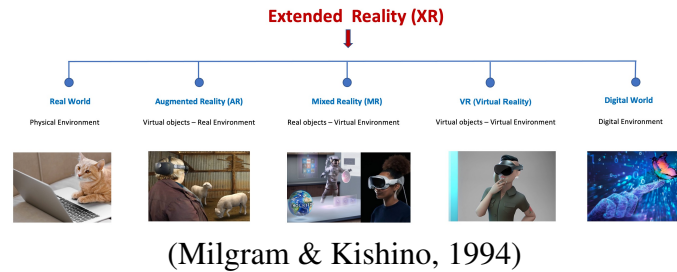


Figure 3.1: XR explained by the Virtuality Continuum

3.2.1 Virtual Reality

As a component of XR, virtual reality (VR) is a technology that integrates computer graphics, visual presentations, motion-taking, and sensor devices to serve users with a visual multi-sensory experience and a realistic simulated setting (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017). It is a highly immersive technology that disconnects users from the surrounding reality. With the continuous improvement of computer-generated graphic technology, the virtual environment has been created as a replacement or extension of the physical world, allowing users to look in any direction and content in a 360-degree space. Moreover, VR can generate a “sensation of being there” in remote places that are displayed by advanced immersive technology, i.e., self-location and action possibilities can be distinguished. In doing so, spatially presented VR can provide users with vivid experiences of being situated in a virtual space and being able to connect with the virtual environment (Hruby, 2019).

3.2.2 Augmented Reality

Another component is AR. AR is a newer technology than VR. It can be defined as a later technological system in which virtual objects are combined with the real world for users' real-time experience (D'zurilla & Goldfried, 1971a). It incorporates four systems: real environment, AR, augmented virtuality, and virtual environment (Milgram & Kishino, 1994). An AR system usually includes a combination of real and virtual objects in a real environment — a system running interactively and in real-time as well as the integration of the real and virtual objects. Technically speaking, although the AR system contains various elements, it usually exhibits three common components: a geospatial datum for the virtual object (e.g., a visual marker), the surface to project virtual elements to the user, and the process of merg-

ing graphics and animation (D'zurilla & Goldfried, 1971a). It is a technology that aims to enhance parts of users' physical world experience with computer-generated input.

3.2.3 Mixed Reality

Simply put, VR immerses users into a simulated real world, while AR enables virtual objects to be superposed in the real world. MR is an authentic setting that facilitates users' interaction with virtual experiences (Maas & Hughes, 2020). It has been recognized as one of the most promising technologies for next-generation mobile platforms (T. Zhan, Yin, Xiong, He, & Wu, 2020). The growing development of VR, AR, and MR technologies can be used simultaneously and contribute to an all-in-one reality framework; that is they can be used independently of each other or evolve into a mixture. MR simulates and interacts with the real world, empowering people to get the most realistic perception of reality in these different integrated systems.

3.3 The Use of XR in Education

Education is constantly evolving, from curriculum developments to new approaches to teaching, learning, and assessment. As Vockley (2007) noted “. . . today no organization can achieve results without incorporating technology into every aspect of its everyday practices. It's time for schools to maximize the impact of technology as well” (p. 2) (Vockley, 2007). Since then, technology has become a necessary part of students' learning experiences (Yoo, 2020) and is a powerful tool for students to engage in educational activities in a digital society (G. Young, Stehle, Yazgı, & Tiri, 2020).

The use of XR in education has gained popularity in recent decades, and it appears to be offering a new way to access the educational space. For example, there is a growing utilization of XR in remote education (X. Wang, Hodgers, McGuckin, & L, 2022), teaching training (Gandolfi, Kosko, & Ferdig, 2021), industrial manufacture (Fast-Berglund, Gong, & Li, 2018), medical practice (Andrews, Southworth, Silva, & Silva, 2019)(Andrews et al., 2019), special education (X. Wang, Young, et al., 2021), and soft skills training (X. Wang, Quirke, & McGuckin, 2022). 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). XR allows students to acquire both hard and soft skills in a safe, realistic simulated, controllable, and interactive setting and practice their acquisitions in real life.

Given that this phenomenal advancement is rapidly developing in many ways and increasingly links our educational reality to the digital world; by focusing on the opportunities the integration of VR, AR, and MR technologies offers learning, we can realize a broader opportunity XR-related pedagogy offers across all aspects of education (T. Zhan et al., 2020).

Therefore, the research journey is set out in three case studies that comprehensively present the utilization of XR in various educational aspects and its main limitations. To be specific, these case studies are XR-assisted **social competence learning**, XR-enhanced **classroom learning**, and XR-assisted **rural education for reducing educational inequality**.

3.4 Case 1- XR-assisted Social Competence Learning

3.4.1 What Should Innovative Education Look Like?

Whilst much of technology-based innovative work has been evident in the area of education, future developments may consider applying XR as a cutting-edge solution to a wider variety of educational and training issues, and, importantly, be developed for wider application to the diversity of learners that we encounter in our work. Therefore, I conclude by advocating that such work be conceptualized and operationalized with supporting evidence within the scope of prior studies.

3.4.2 Why Does Social Competence Education Matter?

Education systems are ongoing, being reflective of the changing society that they represent, and incorporating the latest knowledge from applied research. One issue that remains constant in education is the need for individuals to develop and hone their “soft skills”. Thus, it is necessary to review our understanding of soft skills and the social competencies that students need for success - both now and in the future (Kay & Greenhill, 2011).

In a busy school curriculum, the development of these skills can become less urgent in the traditional areas of literacy, numeracy, modern foreign language, and science. What is required is a recognition of the increasing demand for one’s social competence as we continue to learn and adapt to various novel situations in life. Such an approach is needed to help the individual to develop social abilities and to cope with new and evolving challenges.

In the meantime, what are the key competencies of 21st-century citizens? The summarized conclusion from the United Nations International Children’s Education Fund (UNICEF) is regarding how individual configures their world through the application of critical soft skills – social competence in collaboration, communication, critical thinking, interaction, creativity, emotional understanding, problem-solving, and decision making (Pešikan & Lalović, 2017).

3.5 The Concept Of Social Competence

Social competence includes the ability to analyze social situations and enact appropriate responses (American Psychological Association, 2022). It encapsulates the ability to get on

with others, to be able to have and maintain close relationships, and to be able to respond in adaptive ways on different social occasions (Orpinas, 2010). Social competence is a key determinant for success in life, in that it is our social (Orpinas, 2010) competence that frames our abilities and possibilities, helping us realize our true potential. Where social competence is a curricular outcome, particular skills are required - collaboration, communication, empathy, creativity, critical thinking, problem-solving, and decision-making (Rodriguez, 2018; Sanabria & Arámburo-Lizárraga, 2017; W.-C. V. Wu, Manabe, Marek, & Shu, 2021).

Thus, engaging the utility of recent development of state-of-art technologies to assist in developing important traits that lead students to personal success is indeed novel, and worthy of exploration and practice by educators (X. Wang, Quirke, & McGuckin, 2022). Moreover, emerging studies have highlighted that XR-assisted social competence education has been increasingly used with certain educational practices.

3.6 XR-assisted Social Competence Improvement

Research evidence has pointed out that when conducting social competence education, well-designed XR applications simulate real-life conventions and human interactions to support users to have a better understanding of emotional and behavioral patterns (Fagernäs et al., 2021; Pan & Hamilton, 2018), including collaboration and communication, critical thinking and creativity, emotional skills and understanding, problem-solving, and decision making.

3.6.1 Collaboration and Communication

Collaboration and communication are deeply human social competencies that are vital for forming effective communication and obtaining one's needs for normal community functioning (Meadan & Monda-Amaya, 2008). Even though collaboration and communication are currently integrated into our education processes, these competencies need to be practiced and adapted intentionally as we go about our daily lives. VR and AR have been valued as creative learning aids for twenty-first century education because these technologies enable users to access flexible learning through entertainment-based software and hardware, while also offering diverse support for personalized learning (S. Rogers, 2019; Sanabria & Arámburo-Lizárraga, 2017).

The learning tasks in VR and AR environments require learners to apply and synthesize multiple skills in collaboration, spatial navigation, technology manipulation, interactive capability, and immersion interfaces (Fromm et al., 2021). These collaborative activities through XR platforms can strengthen positive attitudes toward social engagement, social interaction, positive learning, and communication (Beach & Wendt, 2014). For example, a previous roleplay experiment illustrated that students were assigned identities to understand the working model of scientific investigations. These identities include social activists, sci-

entists, and environmental investigators. After a series of scene simulations and role-playing via the XR system, students learned how to use different thinking methods to access information relevant to their roles during the experimental sessions (Squire & Klopfer, 2007). XR-based collaborative learning, therefore, presents a further advantage to facilitate comprehensive learning and communication (Figure 3.2).



Figure 3.2: A student is playing VR

3.6.2 Critical Thinking and Creativity

Critical thinking is a capacity that refers to a complex process of evaluation and deliberation. It is also the ability to generate ideas and be imaginative while also applying new thinking so that one can efficiently solve problems (Kinga & István, 2012). Craciun and BunoIU (2016)(Craciun & BunoIU, 2016) have demonstrated social competence education in discovery learning and scientific learning activities by using location-aware AR technologies. In these educational activities, AR laboratories have become an innovative place to foster students' creativity and critical thinking. These social competence educational experiences develop learners' critical thinking while also providing scientific facts and concepts. Students have been encouraged to identify potential issues and find a solution through the AR system.

Another example of XR-assisted social competence education is an AR field trip in Romania. The AR platform is named Wikitude, which can be used to retrieve destination information through Wikipedia and automatically provides other sightseeing possibilities nearby. All attractions within Wikitude have visualized objects that are particularly designed for these field trips (Craciun & BunoIU, 2016). Having these virtual trips applied in social competence education provides students with options to discover attractions individually or travel as a group so that they can collaborate and communicate with their peers (Craciun & BunoIU, 2016).

Yang et al. (2018)(Yang, Zhu, & MacLeod, 2018) have indicated that VR can simulate physical settings and realistic experiences, reducing spatial constraints and facilitating creativity through imaginary and immersive settings. The fully immersive VR system has the advantage of “being there” and generating various scenarios that cannot be simply or safely completed in the real world (Figure 3.3). Likewise, AR combines the real world and the virtual world by following the idea of constructivist learning, which allows learners to make use of unreal objects in an enlarged environment to have critical thinking and learning (Faridi, Tuli, Mantri, Singh, & Gargish, 2021).



Figure 3.3: Students collaborate and Communicate with VR activities

3.6.3 Emotional Skills and Understanding

Emotional skills refer to the ability to regulate one’s emotions, thoughts, and behaviors. These skills determine how people manage their feelings, perceptions, as well as their surroundings and engagement (OECD, 2017). Perspectives from psychology demonstrated that understanding is one important aspect of emotional skills. It is related to “...the knowledge gained from inside the inter-subjective field formed by the intersection of two different subjectivities” (Orange, 1995).

XR-assisted social competence education makes emotional skills learning exciting for students and the technology makes it easy to generate various scenarios that imitate various social occasions, social activities, and social manners, all of which are key factors for students as they form their emotional understanding. In some cases, VR applications have been designed to generate body swap illusions. For example, by immersing in a safe virtual setting, users have reported that they experience less social embarrassment and increased motivation for learning perspective-taking, imagining one’s situation, empathic concern, and emotional understanding (Martingano, Hererra, & Konrath, 2021).

Huang et al.(2016) have developed an AR botanical garden to support students to immerse in floristic exploration and interaction with AR-enhanced ecological settings. Findings show that this AR application prompted students’ willingness to learn more about nature and the local ecological system. Furthermore, they developed a positive attachment to the virtual

plants and eco-setting and quickly understood the importance of environmental protection and climate change. As a result, the AR system aroused students' emotions for perspective-taking, interest, and happiness (T.-C. Huang, Chen, & Chou, 2016).

3.6.4 Problem-Solving and Decision-making

Problem-solving can be defined as a behavioral process that makes a range of responses to deal with a problematic situation and improves the probability of choosing the most effective response from alternatives (D'zurilla & Goldfried, 1971b). Decision-making is the process of identifying and selecting alternatives based on the decision maker's values and preferences. The process of decision-making refers to how choices are to be made, and in such a case people want to not only find options, but to choose the one that fits most with their goals, objectives, desires, and values (Harris, 1998).

Reviewing related studies, Mathews (2010) employed a mobile device in interdisciplinary studies of language arts. This XR-based design helped students to identify issues within their community, and then recommended relevant GPS-based games that would solve problems both individually and collaboratively. Finally, some games from mobile devices have the potential to teach students and community members to think about learning related issues.

Given that social competence education tasks in AR environments require students to exert multiple skills in social inferring, problem-solving, and spatial navigation, they can gain the capacity for problem-solving and decision-making. Similarly, Hoppenstedt et al. (2021) substantiated that AR can assist learners to solve problems effectively during collaborative working experiences (Hoppenstedt, Radu, Joy, & Schneider, 2021). The research team investigated different types of challenges encountered by collaborators as they interacted with a range of learning activities. The groups were divided into a non-AR group and an AR stimuli group, with the students from the AR group using AR features to address their learning difficulties. Results showed that educators believed AR might be useful for detecting potential learning issues in the classroom and could help students discuss solutions, thus preventing identified problems that negatively impact future learning.

In conclusion, XR can offer many possibilities for a wide variety of social competence education practices, allowing teachers and students to participate safely, supported by a virtual and augmented reality system before their learning can then be applied to life in the real world.

3.7 Case 2 – XR-enhanced Classroom Learning

3.7.1 VR-enhanced Learning Environment

With the rapid development of cutting-edge technologies, advances in VR open new possibilities for innovative education. It contributes to the understanding of technology-mediated collaborations and tech-based programs, as well as offering new solutions for educational purposes (X. Wang, Hodgers, McGuckin, & L, 2022). Existing VR technologies can further personalize the learning experience in a way that other educational technologies simply cannot (G. Young et al., 2020). For example, VR education supports students "learning by doing" instead of "learning by listening". Learning in a VR system allows students to touch and control objects, forming a greater understanding of learning tasks. Students can interact with datasets, complex calculations, and abstract concepts that are more difficult to understand through a teacher's verbal instructions (Dhar, Rocks, Samarasinghe, Stephenson, & Smith, 2021). At the same time, educational practitioners have also taken the major step of using MR technology to support a variety of educational activities.

VR has created new digital platforms that prompt educators to rethink the pros and cons of traditional pedagogies and, furthermore, take advantage of leading-edge technology to create a more inclusive, engaging, and creative environment for students' learning experience (Dhar et al., 2021). In many educational practices, VR facilitates embedding knowledge and social competence skills in the context of real life, reflecting daily life activities to virtual or augmented reality based scenarios. When compared to traditional contexts in education, it "feels more real" as students can flexibly transport themselves to a creative and effective learning experience within the VR system. The following cases are elaborations on how different VR technologies can positively support diverse learning experiences for mainstream education (Figure 3.3).

3.7.2 Interactive Learning with AR

As a superposition of virtual elements in the real environment, the use of AR in education allows virtual elements to be performed in the real environment, increasing more enrichment and diversification of learning experiences (Craciun & BunoIU, 2016). AR-assisted educational designs support students to interact with complex platforms and communicate with one another. For instance, AR learning software is compatible with different learning devices, such as smartphones, tablets, laptops, and smartwatches, which directly leads to the result of a more accessible and affordable solution for future education, and a possibility of generalized social competence education in mainstream education (H.-K. Wu, Lee, Chang, & Liang, 2013).

Mukkawar and Netak (2021) (Mukkawar & Netak, 2021) have indicated that applying AR

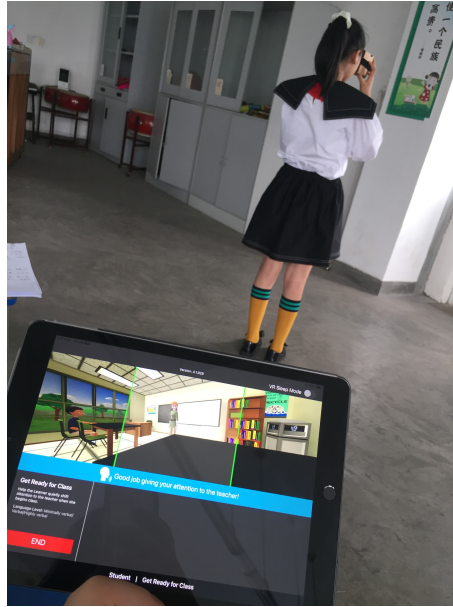


Figure 3.4: A student takes VR class by the teacher using a monitor

technology to education can improve student-teacher interaction and satisfaction. For example, AR-interfaced books provide a respite for students struggling with complicated or dull learning materials. It also can be used as an innovative learning toolkit to visualize and concretize learning resources with rich stereoscopic effects. Another example is that Mukkawar and Netak (2021)(Mukkawar & Netak, 2021) conducted an eye contact study and proved that AR-assisted classroom learning may improve abilities of communication and interaction, such as team group-based learning, real-life participation, and group communication.

Therefore, deducing from the above evidence, the authors believe that XR presents a real possibility to contribute to and enhance most conventional and modern educational methodologies and implementations. Although MR has been identified as an opportunity to revolutionize the way people perceive and interact with complex digital information (T. Zhan et al., 2020), the technology is not important since it does not cause or facilitate meaningful learning in and of itself. It is worth noting that when new technologies emerge in education, a majority of educators are usually excited about teaching and learning through technology-centered thinking, with little consideration as to “how” learners actually think and learn. Students may have a better sense of “being present” using AR-assisted learning systems, whereas AR cannot lead to better learning efficacy without a thoughtful and productive learning experience that has been well-designed in advance.

As a potent technology for future educational evolvement, XR-enhanced classroom learning can offer immersion, which refers to objective features of the instructional technology, is a system with a vivid virtual environment apart from the feeling of the physical reality; and presence, which refers to the learner’s subjective experience, is a psychological sense of “being there” in the virtual simulation (Makransky & Mayer, 2022). With the immersive nature of XR technology, having XR education in a classroom setting can strengthen learning

processes and deliver meaningful learning (Wang et al., 2022) by re-ensuring the appropriate operation, the learning design, and the classroom atmosphere (O'Connor & Worman, 2018).

3.8 Case 3 – XR Application For Reducing Educational Inequality

3.8.1 A Pilot Study of Quasi-VR Hygeian Education in Africa

Although little research has explored the application of using XR solutions to reduce educational inequality (X. Wang, Young, Plechatá, et al., 2023), some international education organizations have carried out XR-conceptualized pilot programs in under-represented countries/regions. Based on these significant experiences, it is not difficult for us to draw a conclusion, that is, VR has great potential in reducing educational inequality within and among countries.

The prior experience is that UNESCO (2004) conducted a pilot study using quasi-VR simulations (non-immersive visuals) for adult education in Uganda and South Africa with a total of 280 students and 32 teachers. The project's learning goal was to use interactive visual simulation to demonstrate basic hygiene to rural communities, with a focus on sanitation, water, and disease prevention (e.g., malaria, bilharzia, dysentery, and cholera). Results showed that with the aid of computer visuals, classes were more pleasant for students to learn, easier to recall, and more suited to different lessons with well-designed topics. Consequently, 50% of the students learned about more than one subject, 95% of students gave the VR lesson a rating as good to excellent, and 74% of students were satisfied and confident in the learning experience. At the same time, teachers were optimistic that virtual reality (VR) was an effective teaching tool that could be integrated into courses. All teachers considered that VR can be an effective method for teaching the topics in the near future (UNESCO, 2004).

What is more, there was a high correlation between teachers and students since both agreed that quasi-VR lessons were fun and interesting, simple to incorporate into coursework, and could have more educational usage. In addition, both groups agreed that the simulation could be used in more than one course. However, the expenses of software and hardware, and the need of technical knowledge for VR lesson preparation could be the issue, due to the shortage of computers in schools and community centers, as well as the lack of budget and technologists (UNESCO, 2004).

3.8.2 Creating Humanitarian Empathy by VR Film

Another case study is the United Nations' project to leverage VR to create humanitarian empathy (Nations, 2016). The initiative was based on Secretary-General Ban Ki-moon's



Figure 3.5: A Syrian Refugee in Lebanon - Clouds Over Sidra — 360° VR experience

advocacy to inspire global citizens and all governments to implement the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals that aim to address humanitarian crises, provide universal empathy education, alleviate poverty, and facilitate global development (Nations, 2016).

As a technology used to generate emotional reactions, VR can effectively produce a visceral, emulational, and immersive experience that arouses individuals' emotional responses more than other mediums (e.g., newspapers and flat-screen videos) (Gruenewald & Witteborn, 2022). This quality presence combines “physical being there” in a virtual safe setting with the natural sensation – feeling his/her body is placed within the circumstance of the humanitarian crisis (Gruenewald & Witteborn, 2022). Hence, there was the short 360 virtual reality film - *Clouds over Sidra* made by the UN, which illustrates a story about a 12-year Syrian girl named Sidra who lives with 130,000 other refugees in Za’atari camp in Jordan (Nations, 2016) (Figure 3.5). This short VR video included elements such as refugee camps, refugees’ lives, poor schooling conditions, and impoverished lifestyles; and implications such as wars, poverty, famine, and gender inequality.

Having a crucial range of emotional factors presented by XR, users are more likely to take another’s perspective, identify with fictional characters, and empathic concern (X. Wang, Hodgers, McGuckin, & L, 2022; X. Wang, Quirke, & McGuckin, 2022; X. Wang, Young, et al., 2021), and experience the act of going to understand the world as you think someone else does (Bloom, 2017). Therefore, more and more international organizations (e.g., United Nations High Commissioner for Refugees (UNHCR), and Unicef increasingly utilizing VR films as an “empathy machine” crisis (Gruenewald & Witteborn, 2022) to inspire global citizens to take action in humanitarian aid, sustainable developmental education, and reducing inequalities.

3.9 Limitations and Challenges

3.9.1 Challenges for Teachers and Learners

Prior to the rapid development of XR applications for mainstream education, Wu et al. (2013)(H.-K. Wu et al., 2013) indicated that AR environments could increase learners' cognitive load, and in fact, overload their thinking with a massive increase of information from the system. Also, learners had to learn how to engage with multiple AR devices in a short period of time, where the learning tasks were cumbersome. Meanwhile, in comparison to studies of other sophisticated technologies in education (e.g., information and communications technology-based education and multimedia platforms), XR applications in education are still in an early burgeoning stage. Although evidence shows that XR-assisted teaching and learning appears to show promise for future education approaches, many XR systems still focus mainly on technological updates and creating special effects, media, and graphics (Kobayashi, Zhang, Collins, Karim, & Merck, 2018; Poux, Valembois, Mattes, Kobbelt, & Billen, 2020), rather than concentrating on the actual objective and designing the system for educational and human developmental purposes. Furthermore, educators experienced inflexibility in XR systems with teachers unable to make changes to the system content, resulting in them being unable to accommodate individual students' learning interests, demotivation, and subsequently not accomplishing their teaching tasks (H.-K. Wu et al., 2013).

3.9.2 Limitations in Past Research

It must be appreciated that VR and AR are relatively new mediums for educational activities. Most research studies mainly focus on system design, case studies, and pilot studies. There was no research focused on long-term evaluations of MR-assisted knowledge and skills, and the transference of such learning from the virtual system to the students' practice in reality. Most research has been on a small scale, which is limited and as such affects the generalisability and relevance of the findings (Rodriguez, 2018). Furthermore, many studies reported that some students and educators are more likely to use this approach just to enjoy the virtual world without using it as an actual learning tool since the technology is novel, exciting, and rich in multi-sensory stimulations (Y.-C. Huang, Backman, Backman, McGuire, & Moore, 2019). Hence, there is a limited understanding of XR's efficacy, as reviewed studies have not presented any results about XR's long-term impact on a wide range of students' performance in both classroom education and/or online education.

3.9.3 Challenges for XR in and off Itself

Last but not least, when discussing the use of cutting-edge technology in education, it is easy to get carried away by the enthusiasm for new solutions but ignore the reality and real circum-

stances (Wójcik, 2016). Practically speaking, many studies pointed out that MR education brings students chaos and confusion with virtual environment controls - this unfamiliarity might cause fear and distraction that can weaken students' focus on the learning content. More seriously, users may have side effects from VR, which refers to cybersickness such as headache, nausea, motion sickness, eye strain, pallor, sweating, etc (Rodriguez, 2018). In addition, from a macro level, the biggest hurdle faced by XR education is how to make this technology equitable and accessible for all educators and students across the world. The cost of developing and purchasing XR platforms and devices is pricey, which makes this technology impossible for students who live in under-developed regions (Dhar et al., 2021). Therefore, paying more attention to the challenges of XR education and coming up with solutions is essential if we are to consider generalizing this technology to a mainstream level. More importantly, prejudging and diagnosing potential factors that may cause problems in XR education would protect the application from becoming impractical for teaching and learning, eventually assuring new XR platforms serve teachers and students on a daily basis (Wójcik, 2016).

Therefore, given the innovation and uniqueness of XR technology and its increasing implications in our twenty-first century digital society (G. Young et al., 2020)(Young et al., 2020), educational practitioners, stakeholders, and students need to engage with and harness these digital representations effectively (Niemi & Multisilta, 2016) since XR technology can present many opportunities for continuously changing learning environments. The integration of XR and education has the potential to develop the requisite soft skills for success in life, result in creative classroom learning, and reduce educational inequities.

3.10 Why Utilize (XR) Technology To Reduce Educational Inequalities?

As technology continues to advance at an exponential pace, the opportunities to use it to transform the way we learn and grow are limitless. However, in a world where education is still a luxury reserved for only a few, such as the WEIRD (western, educated, industrialized, rich, and democratic) group, the potential of technology to reduce educational inequalities is particularly thought-provoking. Consider the reality that even in the 21st century, access to quality education remains a privilege, often determined by socioeconomic status and geography, which means education is not for all yet. Creating a world where every student has an equal shot at success is a mission worth each educator strives for. Thus, with XR technology, the traditional limitations that have kept so many from reaching their full potential are no longer insurmountable.

Imagine that equal access to education is no longer defined by ethnicity, geography, socio-economic status, or culture, but instead by the extent of our imagination and the depth

of our curiosity and efforts. Evolving XR technology holds the potential to create immersive and interactive learning environments, accessible from anywhere across the world, and has the power to level the playing field for students from all backgrounds, especially the under-represented cohort. Students from any corner of the globe may have access to the same quality of education, resources, and opportunities.

3.11 Chapter Summary

This chapter presents the application of Extended Reality (XR) in Education. As an immersive technology, XR is an umbrella term, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). XR-enhanced education has become integral to student learning experiences, which can provide innovative ways to engage with educational activities. This chapter exhibits three cases of XR-assisted learning and its potential to reduce educational inequality. In these cases, XR was successfully been used to deal with social competence education, enhancement of quality education, and public engagement (e.g., public empathy awareness).

In the face of persistent global educational disparities, the advancement of Extended Reality (XR) technology offers transformative potential for equalizing access to quality education, transcending traditional barriers of geography and socioeconomic status, and empowering students worldwide with immersive and interactive learning experiences. Therefore, the following three chapters will be three detailed studies to showcase how to utilize XR to improve *Social Competence Education* and *Perceived Social Support, Quality Education and Classroom Atmosphere*, and *Educators' Insights on XR-enhanced Teaching & Learning*.

Chapter 4

Utilizing Virtual Reality to Assist Social Competence Education and Social Support for Children from Under-represented Backgrounds

4.1 Chapter Overview

As presented in Chapter 3, Extended Reality (XR) has brought together various immersive technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), to create blended immersive technology enhanced educational applications and experiences. Examples can be found as XR-assisted social competence learning is one area where XR is making an impact. Social competence encompasses skills such as collaboration, communication, critical thinking, creativity, emotional understanding, problem-solving, and decision-making. XR applications in this domain provide realistic simulations of social situations and interactions, helping students develop a better understanding of emotional and behavioral patterns. For example, XR-based collaborative learning activities foster positive attitudes toward social engagement, interaction, and communication. XR also enhances critical thinking and creativity by providing immersive and imaginative experiences. Additionally, XR facilitates the development of emotional skills and understanding by generating scenarios that imitate various social contexts and promoting empathy and perspective-taking. Moreover, XR supports problem-solving and decision-making skills through interactive experiences and the exploration of real-world issues. More importantly, XR is increasingly being used in remote education and has the potential to improve equality for teaching and learning in under-developed regions.

Again, the research questions (RQ) of this project are:

RQ1 – Can VR improve rural children’s social competence and perceived social support?

RQ2 – Can VR facilitate quality education by improving the classroom atmosphere?

RQ3 – What are rural educators' perspectives on utilizing XR-enhanced teaching and learning?

This Chapter is a quantitative study to answer RQ 1. It has also been published in **Computers & Education** (Wang, X., Young, G. W., Plechatá, A., Mc Guckin, C., & Makransky, G. (2023). Utilizing virtual reality to assist social competence education and social support for children from under-represented backgrounds. *Computers & Education*, 201, 104815.<https://doi.org/10.1016/j.compedu.2023.104815>). This study investigates the use of VR to increase social competence and perceived social support for children who live in remote areas of the world, reduce inequality, and improve the quality of education requires much attention to address the lacuna between urban and rural education systems. Based on three representative pedagogies (Pedagogy of Technology, Play-based Learning, and Traditional Pedagogy), three social competence educational approaches – virtual reality (VR) assisted social competence education, Lego social competence education, and traditional classroom learning, were designed and applied to interventions in two rural schools in Southwest China. The results showed that VR and Lego social competence education prompted children's social competence and perceived social support with elementary school children (Study 1). Furthermore, VR social competence education resulted in substantially greater social competencies and subjective sense of social support than traditional classroom learning with middle school children (Study 2). The results suggest that VR-assisted social competence education (Pedagogy of Technology) could be a potential tool to reduce educational inequalities in underdeveloped countries and regions.

4.2 Introduction

The challenge of inequality in education is a global issue that can be exemplified differently across countries. For instance, China's developmental resources are clustered in advanced urban areas rather than rural areas due to the imbalanced regional development of the economy (Rozelle & Hell, 2020). This unbalanced regional development includes the unequal distribution of educational resources in the state, directly leading to the educational chasm and inequality between urban and rural areas (Postiglione, 2015). For example, rural elementary pupils are more than two grade levels behind urban pupils in math, and this gap widens every year students are in school (Rozelle & Hell, 2020). Children who have been left behind at home are more likely to externalize lower social competence and consequently exhibit more problematic behaviors due to lower social support or less physical accompaniment ((Gaydos, 2015; Portner & Riggs, 2016). For instance, lower capacity in self-expression - delivering appropriate social messages and responses to families, peers, and teachers (Hosokawa & Katsura, 2017).

4.3 Literature Review

4.3.1 The Concept of Social Competence and Social Support

The concept of social competence refers to an individual's ability to appropriately engage in social occasions and develop meaningful interactions with others (Junge et al., 2020b). It usually incorporates additional components, such as social skills, social communication, social interaction, and social inference (Semrud-Clikeman & Semrud-Clikeman, 2007). Social competence manifests in a child's emotions, behaviors, and ability to interact with others (Junge, Valkenburg, Deković, & Branje, 2020). The development of social competence is essential for future functioning in society, emotional adjustment, and behavioral management (Junge et al., 2020). For example, children who get along with others are more likely to rate themselves as happier (Ryan & Deci, 2001) and have better academic performance (Denham, 2006). Socially competent children are also more likely to grow into adults with better health (Luthar, 2015), and adults with appropriate social skills gain more prosperous reciprocal interpersonal relationships and function better in society (Lopes, Gerolamo, Del Prette, Musetti, & Del Prette, 2015; Luthar, 2015).

Social support is the perception or experience that one is cared for, esteemed, and part of a mutually supportive social network that has beneficial effects on mental and physical health. Meanwhile, research has indicated that social support facilitates social competence and positive self-conceptions (Roohafza et al., 2014). External social support (e.g., parental support and school support) are substantial factors for social competence development, in which the family is the first and most important supportive resource (Roohafza et al., 2014).

4.3.2 Current Status of Rural Children and The Importance of Social Competence Education

The global rural population is now close to 3.4 billion (Profiroiu, Bodislav, Burlacu, & Rădulescu, 2020). Therefore, rural children's educational development is vital for global human sustainability. Growing evidence suggests that a higher quality of education positively influences children's social competence development (Curby, Rimm-Kaufman, & Ponitz, 2009; Demirci, 2020; Exenberger et al., 2021). For instance, research has indicated that children from disadvantaged rural regions who experience higher levels of classroom learning have better social skills and fewer behavior problems than children who have not been provided with the same (Broekhuizen, Mokrova, Burchinal, & Garrett-Peters, 2016). Thus, it is essential to ensure that as many children as possible can obtain quality social competence education, which can boost their chances for future success and reduce inequality in underdeveloped rural regions.

Social Competence Education (SCE) is the concept of teaching particular social skills for

students' development, future success, and social well-being (X. Wang, Quirke, & McGuckin, 2022). It has also been used in various pedagogies to train rural children's social skills at school. Here we review the most popular and widely used SCE pedagogies from previous and ongoing studies, categorizing them into three categories: the traditional pedagogy — traditional classroom learning; the student-centered pedagogy — play-based learning (i.e., Lego); and a novel pedagogy — the pedagogy of technology (i.e., virtual reality).

4.3.3 SCE-related Pedagogies

Traditional Classroom Learning is a highly teacher-centered activity. The classroom usually consists of rows of desks and chairs, allowing students to easily observe and listen to the teacher and watch PowerPoint slides or transparencies (H. Zhang, 2014). Many schools in rural areas are small and geographically isolated, with inadequate infrastructure, limited educational offerings, and continuous student absence (Echazarra & Radinger, 2019). Therefore, over the past decades, traditional classroom learning has been employed as the primary approach in many rural schools (Mahaye, 2020; Rana, Greenwood, Fox-Turnbull, & Wise, 2018). It can be effective despite being seen as rigorous and unprogressive. For example, research has demonstrated that students learning in a conventional setting may have higher social skills scores than those in an online environment (Shaw, 2015).

Compared to the traditional approach, Play-based Learning is a student-centered pedagogy that highlights learning through play as a valuable method for a child's development of social and emotional skills (Taylor & Boyer, 2020). As a representative of play-based learning, Lego playing has provided a practical approach to encouraging children's genuine interest in strategic play and motivating their socio-behavioral improvement by embedding social interactions through its construction activities (Huskens, Palmen, Van der Werff, Lourens, & Barakova, 2015; Kristiansen & Rasmussen, 2014; Simmons, 2019). Research has illustrated that Lego may have a powerful potential to engage children and young adults in interactive and collaborative activities (Kurkovsky, 2015; S. W. H. Lee & San Saw, 2021). Also, Lego has been harnessed globally to support many rural regions' educational sustainability and to help children's social skills education (The Lego Group, 2021). However, although many practitioners have endorsed that play-based learning is a practical pedagogy that benefits children's learning (Keung & Cheung, 2019), students might be distracted by it more than what they can gain from its learning activities (Dimitra, Konstantinos, Christina, & Katerina, 2020).

Pedagogy of Technology (e.g., information and communications technology) has been practiced as a novel and successful approach to establishing a quality system for education in under-developed countries/regions (Asongu & Odhiambo, 2019; Asongu, Orim, & Nting, 2019; Kurkovsky, 2015). It has significant potential to transform and improve teaching and learning activities in these remote areas when there is a real struggle to access external learn-

ing resources (C. OECD, n.d.) . While there has been some success in utilizing information and communication technology (ICT) to reduce educational inequality, little research has focused on further ambitions - using novel, cutting-edge technology (virtual reality, augmented reality, and artificial intelligence) to overcome educational inequality.

Well-designed virtual reality (VR) applications simulate real-life conventions and human interactions for users to understand social emotions and behavioral patterns better and display great potential in SCE (Fagnäs et al., 2021; Pan & Hamilton, 2018). The immersive function of VR can stimulate the individual's heightened emotional space and improve the user's attention and engagement in related VR activities (Johnson-Glenberg, 2018a). More specifically, VR can generate a sense of presence allowing the user to have an illusion of "being there" in the virtual environment while knowing that he/she is not there (Slater, 2009). Furthermore, users in VR can experience a sense of embodiment, a sensation linked to being inside, having, and controlling a body (Kilteni, Groten, & Slater, 2012). Users also can have a sense of agency, which is related to the subjective experience of control, intention, and actions in VR (Kilteni et al., 2012). Compared to traditional classroom learning and play-based learning (Lego), immersive VR, specifically, can be used to develop educational scenarios that feel real (referred to as presence), and are controllable (referred to as agency) while feeling like they are in a virtual body (referred to as "embodiment") but are too dangerous, expensive, or impossible in the real world (Bailey, Bailenson, Obradović, & Aguiar, 2019; Makransky & Petersen, 2021). Hence, the affordances of presence, embodiment, and agency can make VR an attractive tool for developing social competencies because students with low accessibility to social training can engage in fundamental social interactions, which they are unlikely to experience in the real world due to economic or social factors (Makransky & Petersen, 2021).

4.3.4 VR-assisted Social Competence Education

The main benefit of using VR as a social competence education tool is the possibility of displaying real-life social situations while maintaining control over what is happening. VR can provide simulated scenarios with the exact physical and behavioral mechanism as users' real-life environment, supporting increased standardizations of procedures (Howard & Gutworth, 2020). When conducting an intervention in a VR scenario, it is possible to create interactive social situations and manipulate all the presented variables simultaneously (Pan & Hamilton, 2018). Sophisticated VR technology offers a high level of interactivity with stimulating environments, which can motivate children to learn and practice social skills. For example, VR interventions can combine delivering social knowledge, emotional regulation, social interaction, and attention practice (X. Wang, Young, et al., 2021) while allowing students to practice social skills in a multi-sensorial, safe, realistic simulated, controllable, and interactive setting (Ip et al., 2018). Previous studies have illustrated that in many VR

interventions, the child has rich interactions with the virtual avatar (Howard & Gutworth, 2020). The child usually plays the first-person of the virtual avatar, or sometimes they also play a role as a third person behind the virtual avatar. In these situations, the child seemed to personify the avatar within the specific scenario and generate a sense of connection with the avatar (Howard & Gutworth, 2020).

With the rapid development of VR in education, VR- assisted SCE has emerged with related social support programs that may have the potential to enhance students' collaboration, communication, perspective-taking, creativity, and problem-solving, which is beneficial for a diversity of students who need to develop social competence traits for today's world (X. Wang, Quirke, & McGuckin, 2022). Research also indicates that VR-based social competence training is as effective for the general population as for special education samples (Howard & Gutworth, 2020), however, most studies related to VR-assisted SCE have focused on special education and clinical interventions. Thus, VR interventions can increase social competence more effectively than alternative training approaches for mainstream education (Howard & Gutworth, 2020).

4.3.5 VR-assisted SCE in mainstream education

Investigating VR-assisted SCE in mainstream education, Herbst et al. (2021) (Herbst et al., 2021) used VR as an educational training tool to enhance learners' competence in behavioral health and motivational interviewing skills (Young et al., 2021) (G. W. Young, O'Dwyer, & Smolic, 2021) used VR as an "empathy-making machine" to help individuals establish perspective-taking and emphasize another person's circumstances. Participants reported that they experienced empathy and oneness from VR sessions as VR delivered a sense of understanding that other technology-based training could not. Other VR-assisted SCE applications in mainstream education have been applied in engineer training for global collaboration and communication by desktop-based VR (T.-H. Wu et al., 2019); VR pottery making to formulate observation-doing-reflection processes in the class and foster students' practical and creative ability (Dhar et al., 2021); and VR games (e.g., river crossing game) for children to learn and practice problem-solving skills (Araiza-Alba, Keane, Chen, & Kaufman, 2021). VR has been increasingly used for SCE purposes yet has not been applied to the real-life classroom environment for teaching and learning in a rural educational context.

4.3.6 VR as a Social Support Intervention

Studies have investigated using VR to provide social support for people with aphasia (Marshall et al., 2020), for LGBTQs in social VR (Acena & Freeman, 2021), as well as psychology students (Collange & Guegan, 2020). Although some results have not found significant positive effects (Marshall et al., 2020), the majority have reported that VR has the potential to support individuals by affording a range of inclusive interactions (Acena & Freeman, 2021),

and these VR social support interventions led to a variety of benefits, such as the sense of peer support, benefaction, and gratitude (Marshall et al., 2020). Perceived social support has been established by offering students personal experience with positive aspects of VR (i.e., feeling safe and assured that they would be accepted and supported; learning more about themselves and interacting with others who may share their identity; and being the recipient of a virtual role's human action (Acena & Freeman, 2021). Hence, VR social support interventions can be compelling for generating complex emotions and enhancing individuals' hedonic experience, social connection, and reciprocity. More importantly, VR could be harnessed as a positive technology to stimulate the individual and group's function of social support (Collange & Guegan, 2020). Furthermore, a VR social support intervention has been used for educational purposes, and the interaction between students and virtual benefactors was effective in facilitating positive interpersonal and intergroup contact (Collange & Guegan, 2020).

4.3.7 Research Gaps

One issue that remains constant in current studies of VR education is that most relevant research is conducted with "WEIRD" samples (White, Educated, Industrialized, Rich, and Democratic), which represent only 12% of the world's population (Henrich et al., 2010). Given that few studies were conducted in an actual educational context in remote rural areas (Raja & Lakshmi Priya, 2022), this deficiency has been highlighted as a general limitation in current VR learning research (Di Natale, Repetto, Riva, & Villani, 2020; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020), as well as a crucial element for future VR research and disciplinary diversity (Henrich et al., 2010). Thus, to explore the potential of VR-assisted SCE for developing regions/countries, it is crucial to apply VR education research in non-WEIRD samples.

Furthermore, few field studies investigate VR education's applicability outside the laboratory setting (Y. Rogers, Marshall, & Carroll, 2017); therefore, most studies' external validity and impact on mainstream education are limited. On the other hand, although VR education is gaining popularity in schools, little research has compared VR SCE to other pedagogies in real-life classroom learning contexts.

4.3.8 Research Questions

To explore these topics further, two studies in rural schools in Southwest China were conducted to investigate the impact of three different SCE approaches on social competence and perceived social support. This approach was used to identify specific research gaps and examines the efficacy of using VR to facilitate SCE in rural classroom settings. Three eight-week SCE sessions were designed to reach this goal: VR-assisted SCE, Lego SCE, and traditional classroom learning.

In Study 1, we randomly assigned elementary school children ($n = 38$) to VR or Lego SCE. In Study 2, middle school students ($n = 50$) were randomly assigned to one of the three SCE approaches – VR, Lego, or traditional classroom learning. Thus, the following research questions (RQ) were explored:

RQ 1 – Can VR, Lego, and traditional classroom SCE improve children’s social competencies?

RQ 2 – Which pedagogy is the most effective for developing rural children’s social competence?

RQ 3 – Can VR, Lego, and traditional classroom SCE improve children’s perceived social support?

RQ 4 – Which pedagogy is the most effective for developing rural children’s perceived social support?

4.4 Study 1

Study 1 investigate whether VR and Lego SCE can improve children’s social competence and perceived social support. Children aged 9-13 years were recruited from an elementary school in a rural village located in Southwest China. The study was approved by the institute’s research ethics committee.

4.4.1 Participants

A total of 40 rural left-behind children from a rural elementary school were recruited to participate in Study 1 (Left-behind children in China are children left in rural areas while their parents migrate to urban centers for work). All children and guardians were provided with participation information and consent forms. After consent approval, participants were randomly divided into two groups with even numbers: VR Group ($n = 20$) and Lego Group ($n = 20$). However, during the SCE sessions, two children withdrew from the VR group, resulting in a final sample consisting of the VR Group ($n = 18$) and Lego Group ($n = 20$). See Table 1 for an overview of the characteristics of each group.

Table 1: Demographic characteristics for Study 1

Participants/Group	No. of Participants	Gender, female (%)	Mean Age (SD)
Total Participants	38	16 (42.1)	11.18 (0.56)
VR Group	18	6 (33.33)	11 (0.00)
Lego Group	20	10 (50)	11.35 (0.75)

Note. VR= virtual reality.

4.4.2 Procedure

The initial experiment consisted of eight-session interventions conducted over eight weeks, each with a different theme, such as meditation, communication skills, or body language, see Figure 4.1. All participants were invited to complete the assessment form to evaluate their multidimensional social competence and perceived social support before and after the SCE sessions. After each pre-test and post-test, participants were offered a gift bag equal to 20 Chinese Yuan.

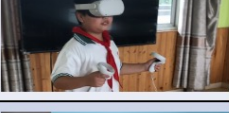
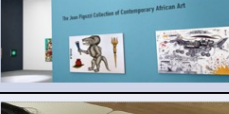
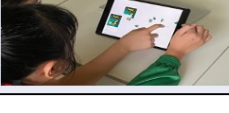
Sessions	VR	Example Figure (VR)	Lego	Example Figure (Lego)
1	Meditation & Class participation (Floreo VR)		Introduction and practice of teamwork	
2	Emotional regulation & Descriptive language (Floreo VR)		Communication skills	
3	Joining a conversation & Responding to classmates (Floreo VR)		Learning to share	
4	Body language training & School social events (Floreo VR)		Interpreting instructions	
5	Visiting Jonathan Yeo's large-scale 3D printed sculpture (Google Arts & Culture)		Puzzle, game, and play	
6	National History Museum (London) Tour		Problem-solving	
7	Art Gallery Visiting - The contemporary African art collection (Google Arts & Culture)		Emotional growth with teammates	
8	Science Tour - Inside the space (Google Arts & Culture)		Creativity & Thinking	

Figure 4.1: List of session themes for the VR and Lego groups

VR Group

Each child experienced eight 25-45 minutes VR sessions. Each session included 3-5 lessons per session, and each lesson lasted 5-10 minutes. There was a short break between each session to limit VR fatigue. We provided three types of VR devices (i.e., Cardboard VR,

Meta Quest 2, and Tablet VR) for children to experience different functions and effects in VR.

Floreo VR was used during the first four sessions (1-4). Floreo VR is a VR platform that teaches children social, behavioral, communication, and life skills through a range of simulations concerning children's daily life scenarios (Ravindran et al., 2019). However, as certain Floreo VR modules are designed for children with autism spectrum disorder (e.g., Communicative eye gaze and Focusing), the research team only selected relevant modules for inclusive learning in the study (e.g., Joining a conversation and School social events). We chose affordable VR gear (i.e., Cardboard VR) for children to access Floreo VR, and the instructor guided and interacted with the child while watching the same session on a tablet (Figure 4.2). Each VR session was designed with learning content consisting of several lessons, including learning cards to address specific subskills to develop children's social skills. The virtual scenarios occurred in school settings (i.e., classroom, playground, canteen, and library). The child was asked to proceed through each lesson's learning cards during the session to achieve the set SCE target.



Figure 4.2: A Floreo VR session with the instructor

During the second four sessions (5-8), students participated in VR tours and virtual public events at museums, galleries, and theatres using Google Arts & Culture with Meta Quest 2 and Tablet VR. Arts & Culture is an online platform using high-resolution images and videos, including virtual reality tours, 360-degree videos, virtual exhibitions, and virtual tours for artworks and cultural artifacts from partner cultural organizations worldwide. It offers rich arts and culture resources within various museums and galleries and powerful education functions for rural children to learn about arts and culture and acquire appropriate social knowledge from virtual public venues. In each session, children first used Meta Quest 2 to watch a 360-degree video individually, which aimed to enable children to experience immersive VR. Next, through Tablet VR, a non-immersive VR that supports multioperation with finger control, the child took virtual tours and played cooperative games with a peer.

During the process, the instructor explained relevant social manners and norms for rural children’s social competence learning during these sessions (Figure 4.3).

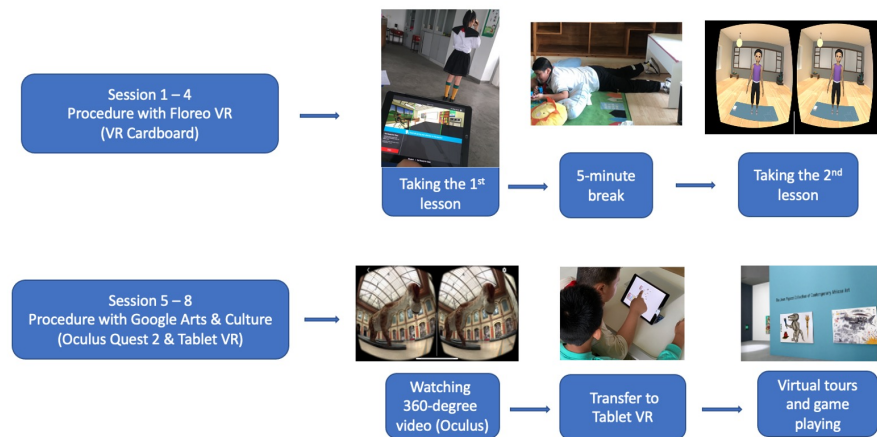


Figure 4.3: VR sessions procedure

Lego Group

Participants in the Lego group completed eight Lego collaborative play sessions with different themes. Each session was designed as teamwork with three children (Figure 4) and lasted 25-45 minutes. When the session started, the instructor assigned children to one of three roles – engineer, supplier, and builder. The engineer looked up manual instructions and instructed the supplier to gather the correct brick(s) and deliver them to the builder. The supplier was responsible for communicating with the other two roles and coordinating the project. The builder needed to pay attention, listen, and question teammates, using problem-solving skills to complete the project (Figure 4.4). The instructor’s job for the Lego session was to observe their teamwork and SCE processes, guide children to process the project, and mediate the group atmosphere when team members displayed friction with each other.

4.4.3 Outcome Measures

Multidimensional Social Competence Scale (MSCS)

MSCS (Rotatori, 1994) is a 77-item self-report questionnaire assessing the respondent’s social competence across seven domains: **social motivation** – one’s level of comfort, interest, and enjoyment in interactions; **social inferencing** – one’s ability to detect and interpret social cues; **demonstrating empathic concern** - the individual’s ability to recognize others’ negative emotions and to respond in an empathetic manner; **social knowledge** – the individual’s understanding of social norms; **emotion regulation** – one’s ability to modulate negative emotions, **verbal conversation skills** – one’s skills for having a conversation with others; and **nonverbal sending skills** – one’s proficiency in the “sending” of nonverbal social

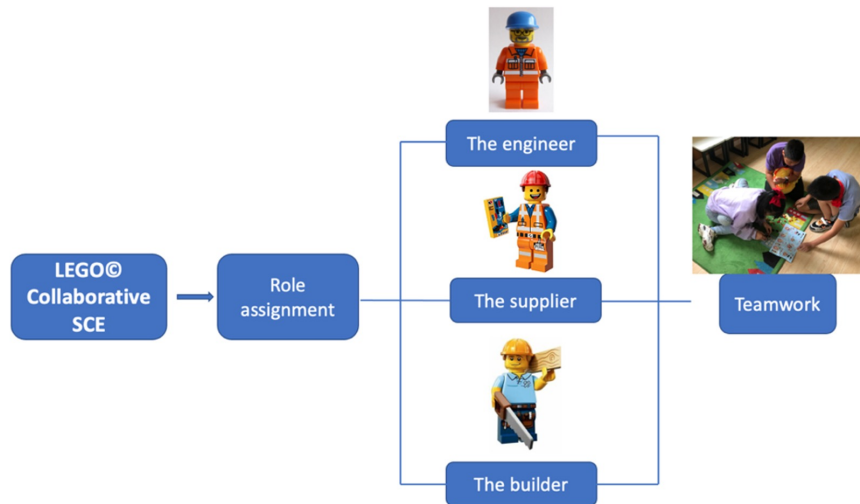


Figure 4.4: VR sessions procedure

communication cues, such as gestures/pointing (Trevisan, Tafreshi, Slaney, Yager, & Iarocci, 2018)(see Appendix A). MSCS precisely assesses aspects of social functioning that are fine-grained, multidimensional, and without disorder-specific purpose. The Chinese version of the MSCS has previously been validated by Leung et al. (2019)(Leung, Chan, Fan, Lam, & Yau, 2019).

Youth Social Support Questionnaire (YSSQ)

YSSQ (“Ye2008”, n.d.) is a 17-item Chinese self-report questionnaire to estimate children and adolescents’ perceived social support and adoption of existing social resources. It includes three dimensions: **subjective sense of social support** – personal feelings of own social support; **objective social support** – the essence of actual social support; and **utilization of social resources** – the individual’s active use of social resources (Appendix B). The school counselor recommended YSSQ as having particular utility in rural Chinese. YSSQ may allow us to understand if the SCE sessions can increase rural children’s perceived social support, especially for left-behind children who experience long-term parental absence.

4.4.4 Statistical Analysis

All data analyses were performed using IBM SPSS Statistics 27. With time as a within-subjects factor and condition as a between-subjects factor, mixed ANOVA was performed to determine the interactions and pre-post differences in each group. At the same time, Bonferroni correction was applied when making multiple comparisons to account for a type 1 error, $\alpha = .05/7 = .007$ in MSCS, and $\alpha = .05/3 = .017$ in YSSQ.

4.4.5 Results

Questionnaires Reliability

Before the primary analyses, we investigated the reliability of the MSCS and YSSQ using Cronbach's alpha. The analyses identified several items that did not have satisfactory psychometric qualities. These items were also evaluated qualitatively for linguistic and cultural content by a native speaker, which made it clear that cultural factors made it difficult for rural children to understand the items as intended. Thus, 21 items that decreased the scale's reliability and/or were identified as having linguistic or cultural issues were eliminated before conducting the analyses. The final MSCS used in Study 1 and Study 2 included 46 items. The reliability of the MSCS and the seven subscales, as well as a list of included and deleted items, are reported in Appendix C and D. In the case of YSSQ, 2 items that decreased the reliability were eliminated before conducting the analyses. The final YSSQ used in Study 1 and Study 2 included 15 items. The reliability of the final measure and subdimensions are reported in Appendix C and D.

VR and Lego's Impact on Social Competence (MSCS Results)

To investigate VR and Lego's impact on children's social competence, we applied mixed ANOVA (Table 2). The results indicate that there was a significant effect over time ($p < .001$). However, there was no significant interaction over time by group (VR/Lego). When looking at subscales, results show that four dimensions of the MSCS significantly increased from pre- to post-test. Specifically, social motivation ($p < .001$), social inferencing ($p < .001$), social knowledge, ($p < .001$), and verbal conversation skills ($p = .001$) increased significantly following the educational sessions after Bonferroni correction. It is worth noting that before Bonferroni correction ($p < .05$), the increase in demonstrating empathic concern was significant ($p = .014$) over time.

Impact of VR and Lego on Perceived Social Support (YSSQ Results)

We also investigated VR and Lego's impact on children's perceived social support using mixed ANOVA. Mixed ANOVA (Analysis of Variance) is a statistical technique used to analyze data with two or more independent variables, where at least one variable is a "between-subjects" factor (groups with different participants) and another variable is a "within-subjects" factor (repeated measures on the same participants). It allows researchers to examine the main effects and interaction effects of these factors on the dependent variable (Table 2). The results indicated that there was a significant effect of time on the overall score ($p < .001$). However, there was no interaction between time and group (VR/Lego). When looking at the subscales, Table 2 indicates that all three domains increased significantly following the educational session. Specifically, subjective sense of social support ($p < .001$), objective so-

cial support ($p < .001$), and utilization of social resources ($p < .001$) increased significantly following the intervention after the Bonferroni correction. Bonferroni correction is a method used to adjust the significance level (alpha) of statistical tests when multiple comparisons are conducted simultaneously. It helps reduce the risk of Type I errors (false positives) by dividing the original alpha level by the number of comparisons being made. This adjustment ensures that the overall familywise error rate remains at the desired level, making the results more stringent and conservative.

Table2: Results from mixed ANOVA (Study 1)

Scales Dimensions		M (SD)		M (SD)		Time Sig.	η^2	Time*Group Sig.	η^2
		VR (n=18)		Lego (n=20)					
		Pre-test	Post-test	Pre-test	Post-test				
MSCS	Total	188.44 (31.69)	211.56 (14.27)	187.75 (7.21)	211.65 (19.35)	.000	.478	.832	.001
(Bonferroni $\alpha = .007$)									
SM		33.44 (6.67)	37.83(4.45)	33.95 (3.68)	38.85 (5.27)	.000 ***	.386	.795	.002
SI		20.00 (4.45)	22.88 (3.14)	19.30 (2.05)	23.25 (3.87)	.000 ***	.327	.520	.012
DEC		35.83 (6.81)	37.61 (4.57)	36.15 (3.60)	40.55 (6.03)	.014	.156	.282	.032
SK		36.05 (5.59)	42.27 (3.19)	36.35 (3.95)	41.00 (5.49)	.000 ***	.423	.462	.015
VCS		20.83 (4.07)	25.44 (3.58)	22.20 (2.66)	24.65 (5.25)	.001 ***	.288	.250	.037
NSS		24.50 (13.55)	26.22 (2.57)	22.50 (2.50)	26.75 (3.94)	.071	.088	.436	.017
ER		17.77 (6.50)	19.27 (3.00)	17.30 (2.40)	17.60 (3.66)	.347	.025	.530	.011
YSSQ	Total	47.16 (10.51)	57.55 (8.17)	48.30 (9.06)	56.50 (8.84)	.000 ***	.394	.573	.009
(Bonferroni $\alpha = .017$)									
SSS		8.88 (2.69)	11.33 (1.94)	9.30 (2.07)	10.90 (2.40)	.000 ***	.320	.396	.020
OSS		19.50 (5.24)	23.61 (4.07)	19.65 (4.01)	23.75 (4.51)	.000 ***	.321	.996	.000
USR		18.77 (4.06)	22.61 (3.98)	19.35 (5.13)	21.85 (3.84)	.001**	.266	.452	.016

Note. MSCS = multidimensional social competence scale, SM = social motivation, SI = social inferencing, DEC = demonstrating empathic concern, SK = social knowledge, VCS = verbal conversation skills, and NSS = nonverbal sending skills, ER = emotion regulation; YSSQ = youth social support questionnaire, SSS = subjective sense of social support, OSS = objective social support, USR = utilization of social resources. VR= virtual reality. We applied Bonferroni correction for multiple comparisons, and MSCS alpha = .05/7 = .007; YSSQ alpha = .05/3 = .017.

4.5 Study 1 Discussion

The general findings in Study 1 showed that both SCE approaches (VR and Lego) led to an increase in social competence and perceived social support. In terms of domains of social competence, social motivation, social inferencing, social knowledge, and verbal conversation skills increased significantly after the intervention. Domains of nonverbal sending skills, and emotion regulation did not improve significantly from pre- to post-test. The increase in demonstrating empathetic concern was only significant before applying the Bonferonni correction. For example, students are told that they need to pay attention to their teacher; and raise their hand when they want to ask questions during class (Barry, Bodenhamer, & O'Brien Jr, 2011). That could be due to the low power of the study. Low power can stem from various factors, including small sample size, high variability, weak effect sizes, etc.

Furthermore, children's emotion regulation was not increased after the intervention. Previous study has indicated that the emotion regulation training conducted on youths with

emotion regulation difficulties led only to a small improvement (Moltrecht, Deighton, Patalay, & Edbrooke-Childs, 2021). Therefore, as the targeted sample did not suffer from any psychopathological symptoms, we can assume that a much larger sample size and more targeted training would be necessary to detect improvements in emotion regulation. Similarly, we did not find a significant increase in students' ability in nonverbal sending skills, which may relate to the fact that tested interventions did not provide students with more nonverbal skill training than they were receiving from their teacher controlling and instructing in the class (Neill, 2017).

The findings indicate that VR and Lego can improve children's perceived social support in all domains, specifically in subjective sense of social support, objective social support, and utilization of social resources. However, the current study's limitation was a missing control group, such as traditional classroom learning, which limited the possibility to draw firm conclusions about the effectiveness of the presented approaches. Therefore, we conducted a follow-up study (Study 2) with a different population of children from a rural middle school in the same region of China to assess if the designed VR and Lego SCE approaches could be successfully applied to an older group of students, and to investigate if the methods could be more effective in increasing social competence and perceived social support comparing to traditional classroom learning.

4.6 Study 2

Study 1 presented that both VR and Lego improved rural children's social competence and perceived social support. However, considering the lack of a control condition as a baseline to evaluate the experimental effectiveness, we executed a follow-up study (Study 2) with the Traditional Pedagogy - traditional classroom learning as a control condition. Children aged 12-15 years were recruited from a middle school in a rural town located in Southwest China. This study was also approved by the institute's research ethics committee.

4.6.1 Participants

A total of 50 middle school children were recruited to participate in this experiment (Table 3). Consequently, due to the limited number of VR devices, 10 children were randomly assigned to the VR group, 10 to the Lego group, and 30 to the traditional classroom (TC).

Table 3: Participants' demographics profile: divided by approaches (Study 2)

4.6.2 Procedure, Outcome measures, and Statistical Analysis

The experimental procedure, outcome measures, and rewards for participants (a gift bag equal to 20 Chinese Yuan) of Study 2 were identical to Study 1, except for the traditional

Participants/Group	No. of Participants	Gender, female %	Age mean (Years)
Total Participants	50	21(42)	13.06 (0.78)
VR Group	10	4 (40)	12.9 (0.74)
Lego Group	10	3 (30)	12.9 (0.74)
TC Group	30	14 (46.67)	13.17 (0.79)

Note. VR= virtual reality, TC= traditional classroom.

classroom condition. The process of traditional classroom learning was designed close to the original curriculum structure with a slightly altered lesson plan (e.g., group discussion was added) and executed in a structured format. This approach was built on traditional classroom learning concerning social skills training, which aimed to provide children with an open exchange of ideas and face-to-face interaction. To be specific, firstly, before each class, the teacher hosted a 5-minute meeting for children to discuss subjects based on their social experiences. Session topics included hobbies, sports, pop culture, video games, leisure time, friends, travel, and family. Secondly, children were taking the class with a local teacher for 20-25 minutes. Next, there was a learning content-based group discussion in the last 5-10 minutes in the classroom to spark children's self-expression. Figure 4.5 demonstrates an overview of the steps for the traditional classroom learning procedure.

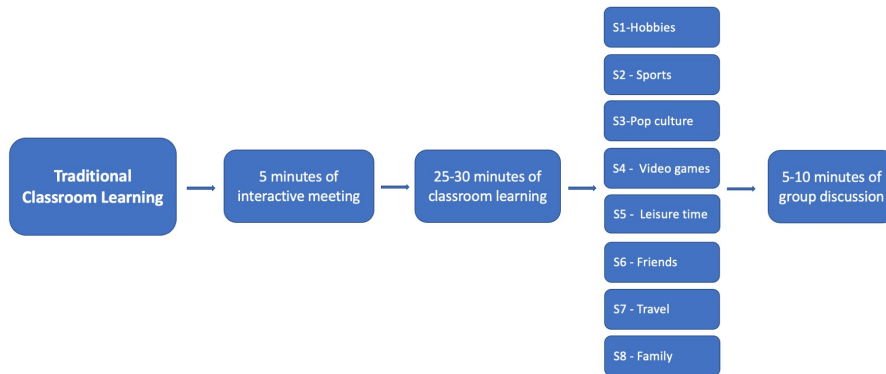


Figure 4.5: Traditional classroom learning sessions

All data analyses were performed using IBM SPSS Statistics 27. Mixed ANOVA was performed to determine the interactions and pre-post-test differences in the three groups. In the case of significant time by group interaction post hoc Bonferroni test was used to determine differences between groups. At the same time, Bonferroni correction was applied as $\alpha = .05/7 = .007$ in MSCS and $\alpha = .05/3 = .017$ in YSSQ.

4.6.3 Results

Impact on Social Competence (MSCS Results)

A mixed ANOVA was used to investigate if the three approaches (VR, Lego, and TC) influenced children's social competence (RQ 1). Results indicated that after Bonferroni correction, there was a significant effect over time on general social competence ($p < .001$). More specifically, social motivation ($p = .003$), social inferencing ($p < .001$), demonstrating empathic concern, ($p < .001$); and verbal conversation skills ($p < .001$) indicated a significant increase from pre- to post-test.

Moreover, there was also a significant interaction effect over time by group (VR, Lego, and TC) on general social competence ($p = .002$) and social knowledge ($p = .004$), verbal conversation skills ($p = .004$), and nonverbal sending skills ($p = .003$) (Table 4). The Post hoc Tukey test results showed that the VR group improved significantly more than the TC group in general social competence ($p = .005$). Moreover, VR group reported a significantly higher increase in nonverbal sending skills compared to TC group ($p = .048$). The results for the remaining subscales, i.e., social motivation ($p = .073$), social inferencing ($p = .082$), demonstrating empathic concern ($p = .025$), and emotion regulation ($p = .579$) were not significant.

Before Bonferroni correction ($p < .05$), social knowledge ($p = .014$) increased over time. Furthermore, the interaction between the time and group in demonstrating empathic concern ($p = .025$) was significant before the correction, but the post hoc test did not show any significant difference between groups (RQ2).

Impact on Perceived Social Support (YSSQ Results)

A mixed ANOVA (Table 4) was also used to investigate if the three approaches (VR, Lego, and TC) influenced different domains of children's perceived social support (RQ 3). It was found that an increase in general perceived social support ($p = .017$) was significant before applying Bonferroni correction. When looking at the subscales, there was a significant change over time in subjective sense of social support ($p < .0001$). However, there was no significant interaction between time and group.

Before Bonferroni correction ($p < .05$), the increase in general perceived social support ($p = .017$) and objective social support ($p = .033$) was significant. Similarly, the interaction between time and group was significant for the subjective sense of social support ($p = .031$). The Post hoc Tukey test showed that the VR group increased their subjective sense of social support significantly more than the TC group ($p = .007$) (RQ4).

Table 4: Results from mixed ANOVA (Study 2)

Scales & Dimensions	M (SD)						Time Sig.	np2	Time*G roup Sig.	np2
	VR (n=10)		Lego (n=10)		TC (n=30)					
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test				
MSCS Total (Bonferroni $\alpha = .007$)	188.10 (19.18)	224.20 (12.70)	187.80 (21.06)	211.50 (22.06)	190.46 (18.55)	192.06 (15.81)	.000 ***	.330	.002 **	.240
SM	33.60 (5.03)	38.30 (4.73)	32.30 (3.74)	37.50 (5.44)	32.76 (3.76)	33.13 (4.90)	.003 **	.173	.073	.105
SI	21.30 (2.90)	27.50 (2.50)	20.90 (1.92)	26.80 (4.21)	20.53 (3.43)	23.56 (3.31)	.000 ***	.502	.082	.101
DEC	37.90 (5.72)	46.20 (3.22)	38.30 (5.59)	41.10 (5.56)	38.00 (5.20)	39.33 (5.57)	.000 ***	.241	.025	.145
SK	34.40 (5.35)	42.00 (3.69)	35.00 (6.53)	39.10 (6.29)	36.96 (5.32)	35.03 (4.65)	.014	.123	.004 **	.212
VCS	20.80 (2.93)	25.20 (2.39)	20.90 (4.22)	25.00 (2.44)	22.93 (4.38)	22.66 (3.12)	.000 ***	.237	.004 **	.208
NSS	22.80 (2.89)	27.30 (2.58)	23.80 (3.88)	23.20 (3.22)	23.70 (3.59)	22.33 (2.74)	.246	.029	.003 **	.219
ER	17.30 (2.83)	17.70 (2.75)	16.60 (4.24)	18.80 (2.78)	15.63 (2.98)	16.00 (3.35)	.217	.032	.579	.023
YSSQ Total (Bonferroni $\alpha = .017$)	52.70 (11.09)	61.10 (8.73)	55.20 (8.62)	60.70 (8.30)	54.02 (9.58)	55.06 (8.48)	.017	.115	.233	.060
SSS	10.80 (2.52)	14.10 (0.87)	10.60 (2.27)	12.70 (1.76)	10.66 (2.12)	11.16 (1.94)	.000 ***	.268	.031	.138
OSS	20.80 (5.26)	24.70 (4.76)	22.20 (3.91)	24.20 (4.37)	22.06 (4.37)	22.26 (4.19)	.033	.093	.203	.066
USR	21.10 (3.813)	22.30 (5.18)	22.40 (3.16)	23.80 (3.79)	21.33 (4.11)	21.63 (3.49)	.275	.025	.814	.009

Note. MSCS = multidimensional social competence scale, SM = social motivation, SI = social inferencing, DEC = demonstrating empathic concern, SK = social knowledge, VCS = verbal conversation skills, and NSS = nonverbal sending skills, ER = emotion regulation; YSSQ = youth social support questionnaire, SSS = subjective sense of social support, OSS = objective social support, USR = utilization of social resources. VR= virtual reality, TC= traditional classroom. We applied Bonferroni correction for multiple comparisons, and MSCS alpha = .05/7 = .007; YSSQ alpha = .05/3 = .017.

4.6.4 Study 2 Discussion

Study 2 investigated the effectiveness of using VR, Lego, and TC to improve rural children's social competence and perceived social support. Results demonstrated that the three conditions led to increases in general social competence over time. Investigating MSCS and its subscales individually, the children in the VR group increased their general social competence and nonverbal sending skills significantly more than the children in the TC group. This finding supports the idea that VR users may get increased social skills and a feeling of connectedness with others in a virtual environment (Y.-C. Huang et al., 2019). During the experiment, there were three types of VR devices (Cardboard VR, Meta Quest 2, and Tablet VR) and two VR applications (Floreo VR and Arts & Culture) for children's SCE, which resulted in positive influences in different domains of children's social competence. This finding is consistent with Study 1 - children could gain improvement in social competence from VR (Dechsling et al., 2021; Parmaxi et al., 2017). Likewise, it is in line with findings that children are provided with nonverbal sending skills by manipulating virtual avatars, performing gestures, playing games, and making facial expressions in VR (Hasler & Friedman, 2012).

Furthermore, a higher sense of embodiment experienced in immersive VR (Kiltenei et al., 2012) can be beneficial for nonverbal communication skills and can provoke children to focus on the learning content, sometimes with body movement interactions, instead of verbal communication (Bailey & Bailenson, 2017). Nevertheless, consistent with the results from Study 1, we did not find any improvements in the emotion regulation domain.

In addition, across conditions, the students' general perceived social support only in-

creased significantly before applying the Bonferroni correction. We infer that the reason for this result ($p = .017$) could be the underpowered (e.g., small sample size) design of the study because both VR and Lego have caused significant increases in elementary school children's perceived social support in Study 1.

On the other hand, the VR group had significantly higher scores than the TC group in subjective sense of social support. This might be due to children's communication with the avatar, their peers, and the teacher during the VR sessions (Acena & Freeman, 2021; Y. Liu, Li, Chen, & Qu, 2015), and this kind of communication might be limited in a traditional classroom setting. Thus, given that many children are left behind in rural China, this finding suggests that making good use of technology and teachers' concerns could be beneficial for children who experience long-term parental absence.

Additionally, although previous research presents that Lego can enhance individuals' trust, communication practice, social support, and social conflict-solving skills (Bazoolnejad, Vakili, Kashani Vahid, & Yaripour, 2021), these findings from the Lego group did not exhibit significant differences from other groups. This may be because of the small sample size. At the same time, domains of general social support and objective social support were close to having a positive influence on rural children in Study 2, but not utilization of social resources. This indicates that neither VR, Lego, nor TC can comprehensively enhance children's perceived social support because these rural children are typically left-behind youth who experienced insufficient parental companionship and community support (Biao, 2007). It is difficult to greatly prompt their perceived social support in the short term by teaching and learning SCE.

4.7 General Discussion

4.7.1 Empirical Contribution

The presented studies examined the efficacy of Pedagogy of Technology (VR), Play-based Learning (Lego), and Traditional Pedagogy (TC) on rural children's social competence education and perceived social support. In terms of the research question **“Can VR, Lego, and traditional classroom SCE improve children's social competencies? (RQ1)”**, results across Study 1 and Study 2 demonstrated that rural children had increased their social competence during the eight SCE sessions. Pre-post changes were reported in all subdomains of the multi-social competence scale except for emotion regulation and nonverbal sending skills. As noted in a recent meta-analysis, the changes in emotion regulation following training can be subtle which might be especially true in a sample of healthy youths (Moltrecht et al., 2021). The interventions were not specifically designed for children's emotional regulation, which might give rise to no enhancement in children's emotional regulation in both studies especially considering the low sample size.

Concerning the research question **“Which pedagogy is the most effective means for developing rural children’s social competence? (RQ2)”**. In general, the results support the value of using Pedagogy of Technology (VR) and Play-based Learning (Lego) in developing social competence with a significant increase on available scales in elementary school children (Study 1); and Pedagogy of Technology showed a stronger increase in general social competence than Traditional Pedagogy with middle school children (Study 2). These findings support previous research that VR social training applications enable participants to apply learned skills to specific social knowledge effectively and to gain practical communicating skills with less cognitive load (Park et al., 2011). Moreover, VR allows students to embody virtual roles through visual, aural, and haptic feedback (G. W. Young et al., 2021).

Furthermore, when investigating the sub-dimensions of social competence, the results showed that VR-assisted SCE increased overall social competence and nonverbal sending skills significantly more compared to Traditional Pedagogy. This is in line with a meta-analysis by Howard and Gutowrth (2020) that concluded that VR training programs are more effective than traditional SCE approaches for social skills development (Howard & Gutworth, 2020). Compared to traditional classroom learning, VR offers more interaction, strengthened a range of children’s social knowledge and capacities, and forms comradery (Bailey & Bailenson, 2017). Hence, results indicated that VR-assisted SCE could be a more effective approach to prompt children’s social competence than traditional education in a rural context.

Lego SCE did not notably increase children’s social competence more than the other two groups in Study 2 with middle school children. Yet, Lego and VR prompted elementary school children’s social competence and perceived social support to a similar extent in Study 1.

In response to **“Can VR, Lego, and traditional classroom SCE improve children’s perceived social support? (RQ 3)”** and **“Which pedagogy is the most effective for developing rural children’s perceived social support? (RQ4)”**, we confirmed that both VR and Lego enhanced elementary school children’s perceived social support, including the subjective sense of social support, objective social support, and utilization of social resources in Study 1. Moreover, VR enhanced middle school children’s subjective sense of social support to a higher extent than traditional classroom learning in Study 2. However, no evidence was found for Lego to have an evident advantage in improving middle school children’s perceived social support compared to traditional classroom learning. This can refer to middle school children being less interested in using Lego (Kulkarni, 2019), as many of them collaboratively finished the session in a shorter time than the elementary school children. Nevertheless, children’s utilization of social resources and objective social support were not improved by any of the pedagogies in Study 2. This can be due to the social resources that already exist in the child’s living environment (e.g., family support and school support) are unlikely to be changed without environmental changes.

As VR and Lego led to a significant enhancement in perceived social support in Study 1, the missing effect in Study 2 might be due to the low sample size of VR and Lego groups. This suggests that apart from existing Traditional Pedagogy in rural education, Pedagogy of Technology and Play-based Learning could be investigated individually as potential approaches for developing actual social support in future studies. Likewise, all three approaches prompted children's general perceived social support in Study 2, which means school time is still meaningful to support these left-behind children when their parent(s) are working away.

4.7.2 Practical Implications

The presented results suggest that VR-assisted SCE and Lego SCE are feasible and valuable in rural mainstream education. Novel technologies, including VR, have great potential to facilitate under-developed countries/regions' social competence education by bringing immersive and interactive educational resources to settings where it is too expensive to engage in field trips (Makransky & Mayer, 2022; Petersen, Klingenberg, Mayer, & Makransky, 2020). For example, VR applications with affordable solutions, such as Floreo VR, Youtube VR, and Arts & Culture can be easily accessed by Cardboard VR. Although Cardboard VR education is a controller-free interaction method in teaching and learning (Yoo, 2020), and a few children reported discomfort, it is still a low-budget, easy assembly, and stereoscopic viewer that can be used with most smartphone devices. What is more, previous studies have found that Cardboard VR can trigger students' learning motivation and enjoyment better than flat-screen devices (S. H. Lee, Sergueeva, Catangui, & Kandaurova, 2017) and traditional teaching approaches (Oigara, 2019). Therefore, Cardboard VR holds potential for under-developed regions that need to reform and improve their educational systems, but have limited resources.

In both studies, children followed the instructor and the virtual avatar and practiced appropriate verbal (e.g., teamwork and communication) and body language (e.g., turning their head, looking around, bending their legs, reaching out and touching, etc) over the Floreo VR and Arts & Culture sessions. It was their process to construct the perception of reality through active movements and active engagement with VR (Steed, Pan, Watson, & Slater, 2018). Arts & Culture particularly took children to various public areas virtually, including educational venues, such as museums, galleries, and science labs. Children learned how to indirectly understand social information from public occasions and related comprehensive knowledge, which broadened their horizons on external resources and environments. This outcome is significant and advantageous for rural children with less travel experience and left-behind children with less family education than their peers. However, in most rural areas in underdeveloped countries, serious challenges make it difficult to adapt existing state-of-the-art technologies and apply them to the education system (Utoikamanu, 2019).

Hence, Lego can be a cost-effective and pragmatic strategy for schools in these regions since a) VR headsets and VR applications can be costly for most schools across the world, and b) systematic training for rural educators to use VR is difficult since rural teachers may be resistant to applying cutting-edge technology to their classroom activity. For example, some rural teachers exhibited their curiosity during the VR sessions, whereas when researchers invited them to join the process and observe how to give a VR lesson for students' social competence education, they showed uncertainty. It is, therefore, essential to identify and understand the relevant factors that play a role in rural teachers' behavioral intentions to use VR (Bower, DeWitt, & Lai, 2020). On the other hand, some rural educators showed existing knowledge of Lego play and actively observed and communicated with participants during their session observation.

As the availability of technology such as VR increases worldwide (Pimentel et al., 2022), some of these current challenges may decline. One crucial factor contributing to educational inequity is systematic differences in accessibility to high-quality education (OECD, 2012). VR could eventually help address this challenge by increasing the accessibility and affordability of extended reality (XR) devices (Plechata, Makransky, & Böhm, 2022). For example, through leveraging augmented and virtual reality technology, individuals worldwide including those in developing countries, could participate in the metaverse in the next decade and have access to high-quality educational programs, which will be similar to how many users in developing countries can currently access inclusive knowledge through videos from YouTube (ElKarmi, Hassona, Taimeh, & Scully, 2017; Lotto, Aguirre, Strieder, Cruvinel, & Cruvinel, 2019).

Regarding implementation in the classroom, the literature is quite clear about using VR for experiential learning and supplementing the VR experience with pre-training (Meyer et al., 2019), and including reflection activities following a VR- lesson (Makransky, Andreasen, Baceviciute, & Mayer, 2021; Makransky & Mayer, 2022). In the presented study, the Pedagogy of Technology (VR) was combined with other classroom activities (e.g., educational games) that were beneficial for learning. From a practical point of view, using immersive VR for an entire lesson can be problematic due to possible cybersickness symptoms, such as facial stiffness, eyestrain, and nausea (Wang, Young, Guckin, et al., 2021), and longer VR sessions can lead to cognitive load (Makransky et al., 2021). Similarly, not every rural educator appreciated Lego SCE as an unstructured program that might have lacked scientific learning content, concepts, and syllabus. Therefore, for educational interventions to be successful, it is crucial to understand the local context as well as the educators' values and priorities.

4.7.3 Limitations

This study was expected to collect data across provinces within China's most rural and disadvantaged areas for this research. However, I could only recruit participants from two rural schools – an elementary school and a middle school in Southwest China due to the local COVID-19 pandemic restrictions. Also, due to the lack of VR headsets, we only selected a small group of participants ($n = 10$) to participate in the VR and Lego groups in Study 2. Even though findings show that VR represented Pedagogy of technology and Lego represented Play-based Learning are promising approaches for rural children's SCE, the small sample size is a limitation that should be considered in future research.

4.8 Conclusion

In this chapter, two studies were conducted to investigate whether VR and Lego social competence education could increase rural children's social competence and perceived social support. In Study 1, performed with elementary school children, it was found that both VR and Lego social competence education prompted children's social competence and perceived social support, whereas, in Study 2, conducted with middle school children, VR social competence education presented substantially greater effectiveness in improving social competence and subjective sense of social support than the traditional classroom. As a novel educational approach, VR-assisted social competence education exhibits evident potential to be generalized to schools and populations in disadvantaged regions. Although there are still many challenges, based on our findings, educational practitioners may consider VR education as a potential tool that can be used in combination with other interventions to reduce educational inequalities in underdeveloped countries and regions. At the same time, Lego social competence education was a practical approach that got more rural educators' attention since it is easier to apply in classroom teaching. Therefore, it could be used as an alternative approach when it is impractical or impossible to implement VR education and related Pedagogy of Technology. Based on this prospect, we suggest that both VR and Lego could be applied to social competence education in under-represented rural areas.

Chapter 5

Leveraging Virtual Reality to Enhance Quality Education in Rural Area

5.1 Chapter Overview

The last chapter was a quantitative study investigating utilizing virtual reality to assist social competence education and social support for children from under-represented backgrounds (**RQ1**). As a limitation, the study did not present any students' perspectives on VR education. Hence, I designed another mixed-methods study in leveraging virtual reality to enhance quality education in rural areas to understand more about students' suggestions regarding VR education.

This Chapter reports upon a mixed-methods study that aims to explore the perspectives of rural students on the use of virtual reality (VR) technology in education, and answer **RQ2 – Can VR facilitate quality education by improving the classroom atmosphere?** This research investigated the impact of VR-enhanced learning on educational quality, classroom atmosphere, and students' learning experiences. Mixed methods were employed, including surveys and interviews, to gather data from rural students who participated in VR classes. A total of 70 students from rural China were recruited to participate in a randomized controlled trial and user experience investigation to test the efficacy of VR education. Next, semi-structured interviews to obtain in-depth insights from rural students. Results from students' evaluations revealed that virtual reality education can enhance quality education and classroom atmosphere. Qualitative results reflected that students were worried that VR's novelty and entertainment may affect their performance within structured classroom education, which could further impede their success on future exams. However, the majority of students actively participated in the process of VR education and valued VR as an agent of their own exploration in many aspects of education. Students appreciated the immersive and engaging learning experiences facilitated by VR, which allowed them to explore diverse subjects and concepts. The findings can contribute to understanding the implications and user

experiences of VR education in rural contexts. It also highlighted the importance of considering pedagogical approaches and ensuring a balance between engagement and academic outcomes.

5.2 Introduction

5.2.1 Quality Education

Quality education is a bedrock for individuals' development and a crucial factor in achieving the United Nations' Sustainable Development Goals (SDGs) (OECD, 2021; Nations, 2015). Specifically, quality education greatly contributes to individual and collective development - it provides individuals with knowledge, skills, and competencies (e.g., critical thinking, creativity, problem-solving, and emotional intelligence) to explore and grow in the world (OECD, 2018b; Willoughby, 2016); **social development** - quality education encourages social, cultural, and political participation (Quintelier, 2010; Weinberg, 2022), enabling individuals to foster understanding tolerance, empathy (Engbers, 2020), reducing conflicts (Miles & Singal, 2010), and prompting social cohesion (Ireland, 2016); **human health and well-being** - people with higher levels of education are more likely to have better health, longer life expectancy, and acquisition of health-related behaviors (Zajacova & Lawrence, 2018), this fact was reflected in studies related to the high levels of self-reported health and low levels of morbidity, mortality, and disability (Feinstein, Sabates, Anderson, Sorhaindo, & Hammond, 2021; Raghupathi & Raghupathi, 2020); **economic growth** – quality education is a significant contributor to economic growth (Grant, 2017), since well-educated population is more capable of creating, and using knowledge to increased productivity innovation, and adapt better to technological advances (Riddell & Song, 2017), which are crucial in today's economic growth (Berger & Fisher, 2013) and poverty reduction (F. Liu, Li, Zhang, Ngo, & Iqbal, 2021); **equity and social justice** –quality education for all, regardless of background or socioeconomic status, can help reduce social inequalities and promote social mobility and achieve social justice (OECD, 2012). Therefore, establishing a quality educational system for all is fair for individuals and efficient for achieving the SDGs. Nevertheless, while it is a desirable goal, chronic disparities in quality education persist among countries due to their chronic disparities in educational quality persist among countries due to their uneven development, factors such as conflicts (Diwakar, 2015), poverty, and lack of resources (Asaju & Adagba, 2014).

5.2.2 Fragmented Education System, Low Quality Education, and Their Far-reaching Implications

In low-income countries, a fragmented education system with low quality education can perpetuate a cycle of local poverty and result in inevitable disasters of future human resources and sustainable development (X. Wang, Young, Plechatá, et al., 2023). For example, in sub-Saharan Africa, ingrained domestic political circumstances and the lack of resources can be key reasons that deteriorate the next generation's opportunities in education (Lewin, 2009). According to (UNESCO, 2022a), sub-Saharan Africa has the highest rate of education exclusion in the world, more than 20% of children aged 6 to 11 are not attending school, approximately 33% are out of school for those aged 12 to 14, and approximately 60% of young people aged 15 to 17 are not enrolled in any level of education. Based on this fact, World Bank (2020) (Azevedo, 2020) reported that 87% of children in sub-Saharan Africa are classified as in "learning poverty", lacking the essential skills required for the 21st century and a competitive job market (CRAWFORD, BARRON, BERNAL, & DING, 2020). In a similar case in South Asia, UNICEF (2019) reported that 3.7 million children are out-of-school in Afghanistan – 60% of them are girls, and only 5% of children with disabilities are able to go to school (UNICEF, 2019). This dilemma increases Afghan children's risk of experiencing short and long-term injury, violence, and school absence (UNICEF, 2019). Also, in the Oceania region, the gross primary school enrolment rate was 116% in Papua New Guinea, but this number dropped to 46.97% for lower secondary schools. The literacy rate among those aged 15-24 was only 67.9% in 2010 (UNESCO, 2022b).

As one of the results of subpar education in Papua New Guinea, students are not adequately prepared for employment, leading to high unemployment rates among the youth – research shows that the unemployment rate in Papua New Guinea's urban centers is 29.3% (Levantis, 2019), with approximately 17% of individuals aged between 15-24 years are unemployed (Melpa, 2022). Thus, it is clear that individuals may suffer from economic stagnation (Rozelle & Hell, 2020), persistent poverty (H. Zhang, 2014), poor health (Buckley, Denton, Leslie Robb, & Spencer, 2004), and generation exclusion (Bhalla & Lapeyre, 2016) if the quality of education in all these countries cannot be improved for a long run.

5.2.3 Uneven Quality Education in China

Unlike low-income countries whose overall education quality is low, as a middle-income country, education in China presents a complex situation where high quality education and poor quality education coexist for a long term (Rao & Ye, 2016; Rozelle & Hell, 2020). This educational gap exhibits the most between urban and rural China. For example, in the latest OECD test of the Programme for International Student Assessment (PISA) in 2018, China's four advanced provinces/municipalities – Beijing, Shanghai, Jiangsu, and Zhejiang

– ranked first place, and their achieved scores exceeded their peers from the other 78 participating countries and regions by a large margin (Peña-López, 2019). Because of the lack of PISA attendance in the rest of regions in China (e.g., rural China), retrieving previous studies, it was found that in China’s Northwest rural areas, the average two-year dropout rate in grades 7 and 8 ranged from 7.2 percent to 27.1 percent (Wang et al., 2015). Another example can be found in Ningxia Province in Northwest China, where only 60% of students from poor counties take the high school entrance exam, yet 100% of students from non-poor counties did the same (Loyalka, Chu, Wei, Johnson, & Reniker, 2017). According to Gao et al. (2021), students from lower income provinces with under-developed rural areas have performed among the lowest in China’s student population (Gao, Wang, Chang, Yi, & Shi, 2021).

Rural youth from disadvantaged areas were seven times less likely to be admitted by higher education institutes and 11 times less likely to be admitted to the elite universities (i.e., Project 211- a project that China wants to build up world-class universities) than urban youth (H. Li et al., 2015). If a country with high quality education and low quality education coexist over the long run, it can lead to a divided society with few equal opportunities and a growing gap between the educated and the undereducated, which would eventually impact the overall progress of the country on a global scale (Rozelle & Hell, 2020).

5.2.4 Technology-enhanced Quality Education

Having realized the inadequacy of quality education in these underdeveloped countries and regions, governments and international organizations have already started looking for ways to alleviate these issues. A typical example is leveraging technology to enhance quality education in areas with limited resources and infrastructure (Blanchard, LePrevost, Tolin, & Gutierrez, 2016; Pruet, Ang, & Farzin, 2016). For example, the “hole-in-the-wall” experiments conducted in India tried to test whether unsupervised use of the Internet can lead to the accelerated learning of skills by children by providing Internet-connected computers embedded in a wall in remote rural areas (Mitra, 2005). Findings from this longitudinal project indicate that children exhibited self-direct learning when given access to the computers embedded in the wall (Mitra & Dangwal, 2022). Moreover, their academic performance was improved, their motivation in learning new things was enhanced, and the school dropout rate decreased significantly (Mitra & Dangwal, 2022). A similar instance is a large-scale evaluation project called “One Laptop per Child Program”, conducted by the Massachusetts Institute of Technology (MIT) Media Lab (Warschauer & Ames, 2010). This large field trial aimed to improve students’ learning by providing low-budget laptops and collaborative software to all children in schools across 40 low-income countries in the world. Results revealed that there were positive impacts on users’ cognitive skills, and a higher level of students’ improvement in learning (e.g., language and math) needs high quality instruction added in

(Cristia, Ibarrarán, Cueto, Santiago, & Severín, 2017). Furthermore, this affordable model stimulated innovation in the industry - more advanced technologies and human-computer interaction based approaches appeared in today's education (Kraemer, Dedrick, & Sharma, 2011), which finally led to more attempts in using state-of-art technology (e.g., virtual reality) to increase quality education opportunities in under-developed regions.

For example, UNESCO (2004) conducted a pilot study using quasi virtual reality (VR) simulations (non-immersive visuals) for adult education in Uganda and South Africa with a total of 280 students and 32 teachers. The project's learning goal was to use interactive visual simulation to demonstrate basic hygiene to rural communities, with a focus on sanitation, water, and disease prevention, e.g., malaria, bilharzia, dysentery, and cholera. Results show that with the aid of computer visuals, classes were more pleasant for students to learn, easier to recall, and more suited to different lessons with well-designed topics. Consequently, 50% of the students learned about more than one subject, 95% of students gave the VR lesson a rating as good to excellent, and 74% of students were satisfied and confident in the learning experience. At the same time, teachers were optimistic that VR was an effective teaching tool that could be integrated into courses, and they believed that VR could be an effective method of teaching for Africa's future education (R. Liu, Wang, Lei, Wang, & Ren, 2020).

Similar to UNESCO's study, the current research is the second phase of a longitudinal project of applying VR education in Rural China. The premier 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, and a total of 90 children from China's remote rural areas were involved in the first phase study (X. Wang, Young, Plechatá, et al., 2023). To further discuss the possibility of VR education benefiting individuals from under-focused remote regions, this study aims to leverage VR to improve quality education, specifically, classroom atmosphere for children in rural China, because as United Nations' (UN) Sustainable Development Goal 4 (SDG 4) noted, quality education is a beacon of hope and a means of uplifting entire communities as it can break down barriers of inequality and create a more equitable world (UNDESA, 2018). As a result, in response to the mission of Quality Education, Google Earth VR was employed as the VR education platform to conduct this mixed-method study. The first objective was to further examine VR education's efficacy in improving classroom atmosphere as a key factor of quality education by using validated questionnaires; secondly, we planned to understand students' perspectives on creative learning through VR classes by interviewing participants who have had the VR experience.

5.3 Literature Review

Virtual reality (VR) refers to a computer-generated, immersive, using 360 videos and images to simulate a three-dimensional (3D) environment with interactive experiences, which

can completely immerse the user in a 3D world that is totally disconnected from his or her real one (Aloqaily, Bouachir, & Karray, 2023). Users typically engage with VR through specialized devices, such as headsets (Angelov, Petkov, Shipkovenski, & Kalushkov, 2020), goggles and cardboards with smartphones (Kesselman, 2016), tablets (Moro, Štromberga, Raikos, & Stirling, 2017), and desktops (Makransky & Petersen, 2019) that provide a visual, auditory, and haptic experience, which can create a sense of presence and immersion in the virtual environment.

5.3.1 Applying VR in Classroom Teaching & Learning

Classroom teaching and learning are vital components of quality education as students acquire the knowledge and skills they need from effective learning within the classroom setting to achieve future success (Kasem & Pathak, 2015; Shirani Bidabadi, Nasr Isfahani, Rouholahi, & Khalili, 2016). With increased digitalization in the classroom setting, VR technology plays a novel role in the evolution of education (Di Natale et al., 2020; Shirani Bidabadi et al., 2016). For example, Souza et al. (2020) (Souza et al., 2020) noted that VR can be integrated into the classroom, leading to an increase in learning and also providing students with an engaging and stimulating learning experience. Hamilton et al. (2021) (Hamilton, McKechnie, Edgerton, & Wilson, 2021) suggested that VR education can be a novel teaching method that helps create engaging, memorable, and kinaesthetic educational materials that can be integrated into various instructional designs (Serin, 2020). Krajčovič et al. (2022) believed that implementing VR into the manufactory teaching process could help students experience simulations within their classrooms, transferring students' acquired manufactory training skills into their practice, which also assists students to develop problem-solving skills and prepare them for real-world challenges they may encounter in the future (Krajčovič, Gabajová, Matys, Furmannová, & Dulina, 2022).

So far, information and communications technology (ICT) based education still dominates the field of technology-enhanced education (Sarkar, 2012) and is consistently supporting education in low-income countries and areas (Bai, Mo, Zhang, Boswell, & Rozelle, 2016). This tendency encourages educators and VR scientists to look to the widespread VR adoption in education (Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017) since the cost of VR drops over time (Dozio et al., 2022), various feasible and affordable devices have emerged, such as learning with VR cardboard, VR compatible with smartphones, and cost-effective devices like PICO VR and Meta Quest VR. To be specific, there are unique advantages that VR can assist in teaching and learning. For example, one problem that constantly remains in education is that rote learning has been widely used to address recall more than deep understanding (Bhattacharya, 2022). Educational practitioners have been working on this issue (Rowe, Frantz, & Bozalek, 2013) (Rowe et al., 2013), and research shows that students reported that their understanding of course content improved more than when using

rote learning approaches by using virtual environments to engage with educational materials (Reeves, Crippen, & McCray, 2021). Moreover, VR has been used to create virtual tours for students who live in remote areas or have limited access to educational institutions and face long travel distances to reach museums, historical sites, or other learning destinations (X. Wang, Young, Plechatá, et al., 2023). VR field trips offer a cost-effective way for rural students to access diverse educational experiences from their classrooms (Hodgson et al., 2019). At the same time, for remote areas with limited resources (e.g., insufficient industries) for students' vocational education - VR provides a safe and controlled platform for teaching safety protocols and procedures (Patle, Manca, Nazir, & Sharma, 2019), and job skills training - VR could practice tasks and procedures in a virtual environment that close to real-world work settings (Levac, Huber, & Sternad, 2019).

More importantly, unlike the traditional learning mode that requires students to be based on learning styles mainly in auditory, reading, and writing (Alkhasawneh, Mrayyan, Docherty, Alashram, & Yousef, 2008; Arthurs, 2007) due to the teacher-cantered instructions, such as reading textbooks, and writing assignments (Regmi, 2021), whilst VR can present 360-degree stereoscopic content with haptic interactions that traditional textbooks and traditional media cannot present, which can greatly help visual learners (Nadan, Alexandrov, Jamieson, & Watson, 2011) and kinesthetic learners to have efficient learning (Borman et al., 2018). Based on this evidence, it is clear that traditional education models are constantly collaborating with and being improved by burgeoning technologies (i.e., immersive technologies and artificial intelligence) (Southgate et al., 2019), hence VR has great potential to be used to meet students' various needs, including helping underrepresented groups access to quality education that their peers already possessed (X. Wang, Young, Plechatá, et al., 2023).

5.3.2 VR-enhanced Classroom Atmosphere for Quality Education

Quality education in the classroom setting is influenced by factors such as competent teachers (Mundial & UNICEF, 2016), well-designed learning materials (Nathenson & Henderson, 2018), education approaches (Mok & Chan, 2001), and classroom atmosphere (Ofoghi, Sadeghi, & Babaei, 2016). Classroom atmosphere plays a crucial role in shaping quality education (Ofoghi et al., 2016). It can be defined as everything that takes place in the educational department, e.g., classroom setting, faculty, school, or university (Ofoghi et al., 2016). Students' perception of the classroom atmosphere can reflect the integrality of quality education in a classroom setting (Cerón, Garbarini, & Parro, 2016). The classroom atmosphere is also closely linked to classroom teaching and learning quality, characterized by teaching enthusiasm, course organization, student learning and engagement, group interaction, rapport with students, and effective evaluation practices within the classroom setting (Barr, 2016; T. OECD, 2009). Therefore, the teacher's ability to create a harmonious and engaging classroom atmosphere is a critical determinant of the quality of education that students receive

(Loughran, 2018). VR may help teachers create this classroom atmosphere by providing opportunities for active participation and collaboration (Jensen, 2017), as well as personalized and adaptive learning experiences (X. Wang, Hodgers, McGuckin, & Lv, 2021).

Research indicates that students who value the classroom atmosphere more positively achieve better academic performance and form a stronger sense of belonging in the school than those who evaluate it more negatively (Cerón et al., 2016; Hamid, Faroukh, & Mohammadhosein, 2013). When used correctly, using VR as part of the learning experience can lead to a positive classroom atmosphere (Mc Guckin & Minton, 2014a). For instance, previous studies have found that VR can assist teachers and students in building trust, understanding, and constructive interactions, improving multi-dimensional classroom climates (Santos Garduño, Esparza Martínez, & Portuguese Castro, 2021). By learning through VR, students can get access to various resources, get involved in the virtual setting, and learn through touch, space, and motion by physically interacting with the virtual system (Markowitz, Laha, Perone, Pea, & Bailenson, 2018). This system provides safety, interactivity, simulation, and multisensory interactions in the classroom (X. Wang, Young, et al., 2021), creating a learning-friendly atmosphere for classroom activities. Therefore, well-designed VR classes can lead to increased student motivation and self-regulation, creating a positive classroom atmosphere (Makransky, Petersen, & Klingenberg, 2020).

5.3.3 Research Gap

Having reviewed related studies, VR seems can be seen as a valuable tool that can potentially improve the quality of education and classroom atmosphere. However, despite the many benefits of VR education, certain groups and regions are chronically excluded from its advantages. Most studies related to VR education were conducted in developed countries and regions. For example, in the United States, more than 15% of schools will have VR classroom toolkits by 2021 (Molnar, 2019); in Denmark, many higher school students have the opportunity to try VR tutorials in different subjects (Makransky et al., 2021); in China's metropolitan areas, many schools have tried to enhance learning experience by providing online and offline teaching resources in VR (Barrett, Pack, Guo, & Wang, 2023; Ying, Jiong, Wei, Jingchun, & Xiaopeng, 2017), only little attention paid to cohorts who live in less developed regions. Furthermore, even though VR education has been adopted across all education levels (McGovern, Moreira, & Luna-Nevarez, 2020), it is most commonly used in higher education for research purposes or discipline studies (Radianti et al., 2020), rather than used in elementary and secondary schools' classrooms, though research has pointed out that VR might bring tailored learning content to different elementary and second school subjects (Fransson, Holmberg, & Westelius, 2020).

Thirdly, little research has explored VR's potential to improve the classroom atmosphere or probe how this technology can contribute to the learning environment, developing a better

climate for class engagement, collaboration, personalization, and communication. Recognizing these research gaps, this paper reports the results of a study introducing VR-enhanced education to remote rural areas in China and investigating the potential of VR-enhanced education in improving the quality of education in these regions. To achieve this goal, three research questions (RQ) were proposed:

RQ1. Can VR-enhanced education improve class quality in the context of rural education?

*(This research question will be investigated by comparing the VR group and the traditional classroom education group through the **Students' Evaluations of Educational Quality questionnaire** in a rural school context.)*

RQ2. Can VR-enhanced education improve the classroom atmosphere in the context of rural education?

*(This research question will be investigated by comparing the VR group and the traditional classroom education group through the **What Is Happening in This Class questionnaire** in a rural school context.)*

RQ3. What are rural students' perspectives on their experience of VR education?

*(This research question will be investigated by VR group answering both **User Experience Questionnaire** and questions from **semi-structured interviews** in a rural school context.)*

5.4 Methods

5.4.1 Research Aim

The rationale for conducting this experiment was to critically assess the feasibility and efficacy of using VR technology to enhance quality education, including classroom atmosphere. To achieve this goal, the researcher selected China's (rural) education and students as our research object and sample population, given that rural areas in China have one of the largest numbers of rural children in the world ($N \approx 100$ million), and the educational chasm between urban and rural China has been a long-standing topic of discussion among organizations and experts, such as OECD (2019), Unicef (2018a), Rapoza (2017) and Rozelle and Hell (2020). Thus, the aim is to contribute to a broader conversation about the role of VR technology in improving educational equity and augmenting learning experiences in rural China (unicef, 2018; OECD, 2019; Rozelle & Hell, 2020; Rapoza, 2017).

To do this, a quantitative study was executed to examine the feasibility and efficacy of VR education for rural schools' class quality (RQ1) and classroom atmosphere (RQ2). Thirdly, to answer RQ3, we carried out a user experience investigation to understand students' interaction with VR, moreover, a qualitative study to comprehensively understand a) students'

perspectives on their VR learning experience, and b) students' outlook on how VR education has changed and impacted their learning in this specific rural context. The study was approved by the institutional research ethics committee prior to the initiation of all field experiments.

5.4.2 Participants and Procedure

A total of 70 rural students (10-16 years old) were recruited from 2 schools located in two rural villages in Western China. All students, their class teachers, and their teachers and guardians were provided with participation information and consent forms before the experiment. After consent approval, participants were randomly divided into two groups - the experimental group and the control group with even numbers. The experimental group was assigned as the VR group (n=34), and the control group was assigned the traditional class (TC) group (n=36). Experimental demographic information is presented in Table 1.

Table1. Demographic characteristics

Participants	No. of Participants	Gender, female (%)	Mean Age (SD)
Total Participants	70	50 (44.6)	12.47 (1.53)
VR	34	28 (49.12)	12.35 (1.55)
TC	36	22 (40)	12.58 (1.52)

The study employed a 2×2 design. The 2 conditions were VR education and traditional education, each condition has 3 types of lessons. For example, similar to the phase 1 study - social competence education in rural China (Wang et al., 2023a), VR education included lessons supported by **360-degree VR, Google Earth VR, and Street View**. Traditional classroom education included **Teaching & Learning and Group Discussion**. Both groups were asked to complete pre-test and post-test on the Students' Evaluations of Educational Quality Questionnaire and What Is Happening in This Class Questionnaire before and after 8 educational sessions. In addition to this, the VR group was asked to complete a User Experience Questionnaire during the post-test, next, a semi-structured was conducted with the VR group for specific questions in relation to their VR educational experience (See Figure 5.1).

5.4.3 Procedure of VR Group

The experiment for the VR group consisted of 8 lessons in geography with Google Earth VR. Google Earth is a complex application that creates three-dimensional representations of the Earth using satellite imagery. Its program maps the Earth by superimposing satellite images, aerial photography, and geographic information system data on a 3D globe. With Google Earth's VR function (i.e., Google Earth VR), students can explore the world in virtual

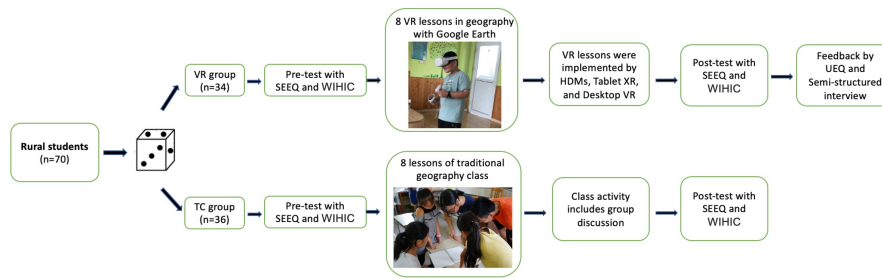


Figure 5.1: Experimental diagram

reality. It is worth mentioning that Google Earth is not limited to VR Head-mounted Displays (HMDs) to access, but is also open to desktop VR, smartphone VR, and tablet VR. Also, Google Earth has Street View for students to see streets, cities, and landscapes from various angles (Gartenberg, 2019). In this study, Google Earth and Street View were used as toolkits for geography education in VR.

To be specific, students were taught four themes, including a) planetary exploration on the Moon, b) planetary exploration on Mars, c) a glimpse of foreign communities, and d) visiting world famous attractions (Figure 5.2). Each theme was finished in two lessons, and a total of four topics were conducted in 8 lessons. Each lesson lasted 40 minutes, twice a week for four weeks. All lessons were implemented in VR with four means – Head-mounted Displays (HMDs), Desktop VR, and Tablet VR. To be specific, during the lessons, students first watched a 360-degree video related to their class theme by Meta Quest 2 in 5 -10 minutes (e.g., VR Spacewalk Experience and Inside Space Shuttle Discovery 360). Next, two students took a lesson together (e.g., Travel to Mars and Meet the Eiffel Tower by Desktop VR) with one instructor on Google Earth for 20 - 25 minutes. Thirdly, students were encouraged to discover the learned word famous sites (e.g., Angkor Wat and the Eiffel Tower) by Street View, and have a discussion with their instructor based on the learning content for 5-10 minutes (See Figure 5.2 as a VR education diagram).

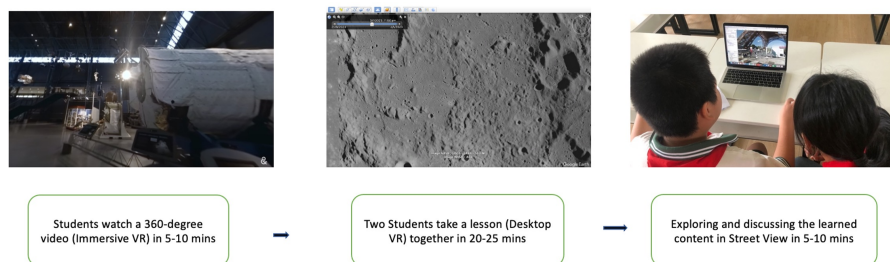


Figure 5.2: Diagram of VR Education

This educational design aimed to embody abstract concepts through these VR platforms, so that students may be able to connect what they learn in class to what they see from visualized images, 360-degree videos, and Google Earth provisions. This was an approach to allow students to have embodied visual views of prepared learning content, so that they

could have a better understanding of the knowledge from the textbook (Table 2).

Table 2: Experimental course plan for VR group and TC group

Topic	Approach		Learning Goals		Duration
	VR	TC	VR	TC	
Introduction of Astronomy	VR-based education	Traditional teaching & learning	Embody abstract astronomic concepts through VR and a virtual fieldtrip of space shuttle discovery.	Introduction of the universe and related basic knowledge	35 - 40 mins * 2
Moon & Mars Trip	VR-based education	Traditional teaching & learning	Watching 360-degree videos - Spacewalk in VR, and a trip to Moon & Mars.	Imparting necessary knowledge of Earth, Moon, and Mars	35 - 40 mins * 2
World Geography	VR-based education	Traditional teaching & learning	Learning geographic landscapes in VR and exploring learned content in Street View.	Observing local landforms and developing more geographic knowledge.	35 - 40 mins * 2
Life in Western Communities	VR-based education	Traditional teaching & learning	Virtual fieldtrip to world-famous sites and exploring learned content in Street View.	Acquiring more cultural knowledge	35 - 40 mins * 2

Note. This VR-based education in rural China aims to use VR and “student-centered” approach to create immersive learning environments and experiences for students’ education. Traditional teaching & learning in rural China is a “teacher-centered” approach where an instructor imparts knowledge through lessons to students. In doing this, students usually learn through listening, note-taking, and memorization.

The TC group was learning about similar topics to the VR group, but using the traditional teaching and learning approach in the classroom (Table 4). The topics for the TC group included the Introduction of Astronomy, the Moon & Mars, World Geography, and Life in Western Communities. The class aimed to help children develop their astronomic and geographical knowledge relating to understanding celestial bodies and local landforms. The lesson plans and classroom activities were designed as cross-subject learning in astronomy, culture, and geography. Each topic was covered in two lessons, with each lesson lasting 40 minutes. The main media used in the TC group was the smart whiteboard - a flat panel display that integrates a touchable surface, video projection, and computer interface usually mounted on a wall in the classroom. For the TC group, each topic was completed in two lessons.

The specific learning content for each topic was developed by local rural teachers who followed the guidance of the national syllabus (Figure 5.3). This syllabus was in accordance with the geography textbook for grades 6 and 7 (People’s Education Press Edition), which ensured that the students were taught the appropriate content for their age group. The class included teaching and group discussions. In the process of each lesson, the teacher gave a lecture for 25-30 minutes, covering the main topic of the lesson. After the lecture, the students had a group discussion for 10-15 minutes, allowing them to share their thoughts and ideas on the topic. The class was held twice a week for four weeks, allowing the students to develop their knowledge and skills over time.

All participants were invited to complete the assessment form to evaluate their class quality before and after completing all 8 lessons (Table 2). In addition, after the completion of



Figure 5.3: Diagram of the traditional classroom education

all the lessons, the VR group was particularly invited to give feedback on their VR experience by filling out the User Experience Questionnaire and taking part in semi-interviews individually.

5.4.4 Outcome Measurement

The Students' Evaluations of Educational Quality (SEEQ)

The Students' Evaluations of Educational Quality (SEEQ) questionnaire was used to investigate students' perception of their class quality from the school. The SEEQ is a questionnaire developed by Marsh (1982), and it is considered one of the most widely used and universally accepted instruments of students rated educational quality (Grammatikopoulos, Linardakis, Gregoriadis, & Oikonomidis, 2015). SEEQ has a total of 29 items in 8 subscales – Learning, Enthusiasm, Organization, Group Interaction, Individual Rapport, Breadth, Examinations, and Assignments. The SEEQ has successfully provided valid and reliable scores in various countries, e.g., Australia, USA, UK, Hong Kong, China, Spain, and India (Balam & Shannon, 2010; Coffey & Gibbs, 2001; Marsh, 1986; Marsh & Roche, 1997; Watkins & Thomas, 1991). The translated version can be seen in Appendix E.

What Is Happening in This Class Questionnaire

What Is Happening in This Class Questionnaire (WIHITC) is a widely applicable learning environment questionnaire to measure students' perceptions of the classroom atmosphere (Fisher, Aldridge, Fraser, & Wood, 2001). Previous studies have investigated the validity and reliability of the WIHIC, by testing its factor structure, internal consistency reliability, and associations between students' outcomes and the nature of the class environment (Skordi & Fraser, 2019). The initial questionnaire in English has been translated into Chinese for utilization with students in Taiwan and Singapore as their medium of instruction (Myint, 2001).

The newest version contains 56 items, with 8 questions in each of 7 subscales - Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity (Charalampous & Kokkinos, 2017). This version was used for the experiments (see Appendix F for a list of items).

User Experience Questionnaire

The UEQ (UEQ org, 2021) is an internationally recognized post-task questionnaire to measure the user experience of interactive activities and products (Schrepp, Hinderks, & Thomaschewski, 2014). The official Chinese version contains 30 questions that measure classical usability (i.e., efficiency, perspicuity, and dependability) and user experience aspects (i.e., originality, stimulation, and novelty). The UEQ is currently validated in more than 30 languages, including Chinese (see Appendix G).

5.4.5 Semi-structured Interview with VR Group

After the post-test, semi-structured interviews were conducted to gather qualitative, open-ended data from students following the post-test, in order to obtain their feedback on VR education. A set of 10 interview questions was designed to explore the VR group's in-depth thoughts, feelings, and beliefs in regard to VR-assisted teaching and learning in their rural context. The specific questions are listed in Table 5.

Table 3: The list of semi-structured interview questions

Number	Questions
1	<i>What do you think of the classroom atmosphere during the VR lessons?</i>
2	<i>How would you rate your overall VR experience as "liked it," "neutral," or "disliked it"?</i>
3	<i>Which lesson did you enjoy the most?</i>
4	<i>Have you learned something from the VR journey?</i>
5	<i>Do you enjoy interacting with the instructor when having VR lessons?</i>
6	<i>Do you think it helped your learning?</i>
7	<i>Would you be interested in more VR activities in the future?</i>
8	<i>Were there any limitations of your VR experiences?</i>
9	<i>Is there anything else you want to say that I didn't ask about?</i>

Procedure of Semi-structured Interview

The students were invited to participate in a semi-structured interview, which was conducted individually in an empty classroom. The duration of each interview ranged from 6 to 18 minutes. Prior to the interview, the students were informed that the interview was a two-way

communication process, where their responses and opinions were highly valued. They were encouraged to answer the questions, but were also informed that it was OK to not respond to specific questions and to withdraw from the interview at any time.

5.5 Data Analyzes

All quantitative data analyses were performed using IBM SPSS Statistics 27. Mixed ANOVA and paired t-tests were performed to determine the interactions and differences between the pre-test and post-test in each group. Time was used as a within-subjects factor and condition was used as a between-subjects factor. Meanwhile, a thematic qualitative analysis was performed for the qualitative data. Two people collaboratively analyzed the data, including original transcriptions in Chinese and translated transcriptions in English to identify related themes and subthemes from semi-structured interviews (See Appendix H for a brief description of the adapted procedure). Two investigators individually analyzed the bilingual transcriptions to review transcripts and identify emerging topics. During the data analysis process, the investigators developed a shared codebook to increase the methodological rigor of the analysis and create a more comparable analysis between themes. Each code had a label for its characteristics and a description of each subcategory and theme. In addition, specific dates, times, and themes were also noted for a more detailed analysis. The data analyses for both versions of transcriptions were performed through Quirkos (2.5.2).

5.6 Results

5.6.1 Quantitative Results

Questionnaires Reliability

Before the primary analysis, Cronbach's alpha was used to investigate the internal reliability of the SEEQ ($\alpha = 0.90$), WIHITC ($\alpha = 0.93$), and UEQ ($\alpha = 0.70$).

Impact on Rural Educational Quality (SEEQ Results refer to RQ1)

A mixed measures ANOVA was used to investigate the VR class and the traditional class's impact on astronomical and geography education for these rural students (Table 6). Results indicated that there was a significant effect of time ($p \leq 0.001$) from pre-test to post-test on SEEQ total score after accounting for Type 1 error ($\alpha = .05/8 = .006$). In terms of the subscales, there were significant differences in Enthusiasm ($p < .001$); Organization ($p < .001$); Group Interaction ($p < .001$); Breadth ($p < .001$), and Assignments ($p < .001$).

Meantime, there was a significant effect of time group interaction on the SEEQ total score ($p < .001$). In terms of the subscales, there were significant differences in Breadth

($p < .001$) and Assignments ($p < .001$).

Table 4: Results from mixed measures ANOVA of SEEQ

Dimensions	M (SD) M (SD)				Time Sig.	η^2	Time* Group Sig.	η^2
	VR (n=34)		TC (n=36)					
	Pretest	Post-test	Pretest	Post-test				
SEEQ Total	74.24 (7.17)	98.09 (9.71)	75.22 (8.47)	78.69 (7.31)	<.001	.791	<.001	.678
Learning	10.56 (1.80)	13.47 (1.78)	10.86 (1.68)	10.89 (1.65)	.024	.073	.506	.007
Enthusiasm	9.85 (1.52)	13.38 (2.22)	10.47 (2.16)	11.14 (1.72)	<.001	.466	.273	.018
Organization	10.24 (1.58)	13.47 (2.45)	10.61 (1.75)	11.25 (1.63)	<.001	.422	.238	.020
Group	8.53 (1.75)	13.26 (2.30)	8.33 (1.96)	9.42 (1.73)	<.001	.655	.115	.036
Interaction								
Individual	9.68 (1.61)	13.35 (2.36)	10.06 (1.93)	10.72 (1.88)	.731	.002	.473	.008
Rapport								
Breadth	12.06 (2.13)	13.44 (2.55)	11.75 (1.44)	11.86 (1.42)	<.001	.232	<.001	.161
Examinations	8.12 (1.86)	10.88 (1.30)	7.67 (1.67)	7.92 (1.36)	.039	.061	.076	.045
Assignments	5.21 (1.25)	6.82 (1.29)	5.47 (1.46)	5.50 (1.42)	<.001	.764	<.001	.172

To answer the **RQ1 – “Can VR-enhanced education improve class quality in the context of rural education?”**, investigating whether there were significant differences between the VR group and TC group from pre-test to post-test, we conducted a follow-up paired t test based on both groups’ significant effects from Time*Group interaction (Table 5). Regarding the VR group, after accounting for Type 1 error ($\alpha = .05/8 = .025$), results showed significant effects from the pretest to post-test on overall SEEQ ($p < .001$), and two subscales - Breadth ($p < .001$) and Assignments ($p < .001$). In terms of the TC group, the overall SEEQ result was significant ($p < .001$), but no significant effects related to any appeared subscale.

Table 5: Results from paired sample t test

Dimensions (posttest-pretest)	VR				TC			
	Mean Difference	SD	t	Sig.(2- tailed)	Mean Difference	SD	t	Sig.(2- tailed)
SEEQ Total	23.85	9.81	14.17	<.001	3.47	2.81	7.41	<.001
Breadth	1.38	1.74	4.63	<.001	0.11	0.52	1.23	.210
Assignments	1.62	2.08	4.55	<.001	0.03	0.17	1.00	.324

Impact on Rural Classroom Atmosphere (WIHITC Results refer to RQ 2)

To investigate Traditional Class and VR’s impact on rural educational quality, we applied a mixed measures ANOVA (Table 7). After accounting for Type 1 error ($\alpha = .05/7 =$

.007), results indicate that there were significant effects of time from pre-test to post-test on WIHITC total score ($p=.001$). In terms of the subscales, there were significant differences in Student Cohesiveness ($p < .001$), Teacher Support ($p < .001$), Investigation ($p < .001$), and Task Orientation, ($p=.001$).

Meantime, there was a significant effect of time group interaction on WIHITC total score, ($p=.005$). In terms of the subscales, there were significant differences in Teacher Support ($p=.001$), and Involvement ($p=.003$).

Table 6: Results from mixed measures ANOVA of WIHITC

Dimensions	M (SD) M (SD)				Time Sig.	η^2	Time* Group Sig.	η^2
	VR		TC					
	Pretest	Post-test	Pretest	Post-test				
WIHITC Total	193.47 (29.08)	205.06 (21.21)	194.14 (28.45)	196.28 (25.84)	<.001	.206	.005	.110
Student Cohesiveness	26.91 (4.38)	28.21 (4.30)	29.69 (4.65)	30.14 (4.95)	<.001	.149	.096	.040
Teacher Support	27.24 (4.31)	29.74 (4.43)	28.28 (4.97)	28.69 (5.07)	<.001	.254	.001	.148
Involvement	28.82 (4.83)	29.68 (4.78)	29.11 (5.98)	28.83 (5.56)	.128	.034	.003	.119
Investigation	28.44 (5.11)	30.26 (3.93)	27.44 (5.07)	27.67 (4.40)	<.001	.150	.008	.098
Task Orientation	25.26 (8.73)	28.53 (5.50)	26.31 (6.97)	26.83 (5.94)	.001	.141	.019	.078
Cooperation	29.62 (8.20)	31.24 (5.43)	26.97 (7.45)	27.78 (6.89)	.037	.062	.479	.007
Equity	25.79 (8.13)	27.41 (6.84)	25.44 (7.13)	26.33 (6.68)	.010	.094	.442	.009

Similarly, to answer **RQ 2 - “Can VR-enhanced education improve the classroom atmosphere in the context of rural education?”**, we conducted a follow-up paired samples t-test to investigate whether there were significant differences between the VR group and TC group from WIHIC’s pre-test to post-test, based on both groups’ significant effects from Time*Group interaction (Table 7). Regarding the VR group, after accounting for Type 1 error ($\alpha = .05/2 = .025$), results showed significant differences from the pre-test to post-test on the overall WIHIC score ($p < .001$) and two subscales. Specifically, these subscales were Teacher Support ($p < .001$) and Involvement ($p < .001$). In terms of the TC group, there was no significant difference from the pre-test to post-test.

Table 7: Results from paired sample t test

UEQ Results of the VR Group (refer to RQ3)

To answer **RQ 3 – “What are rural students’ perspectives on their experience of CE education?”**, interpreting students’ experience with VR and exploring the potential to deploy

Dimensions (posttest-pretest)	VR				TC			
	Mean Difference	SD	t	Sig.(2- tailed)	Mean Difference	SD	t	Sig.(2- tailed)
WIHIT Total	11.59	13.00	5.20	<.001	2.14	14.24	0.90	.374
Teacher Support	2.50	3.25	4.49	<.001	0.42	1.59	1.57	.125
Involvement	10.85	1.37	3.62	<.001	- 0.28	- 0.91	1.23	.338

VR education in rural areas, UEQ was carried out to get quantitative feedback from the VR group (n=34). According to UEQ's official statement "The range of the scales is between -3 (horribly bad) and +3 (extremely good). But in real applications, in general, only values in a restricted range will be observed. It is due to the calculation of means over a range of different persons with different opinions and answer tendencies (for example the avoidance of extreme answer categories) extremely unlikely to observe values above +2 or below -2." Moreover, according to Schrepp et al. (2014), "Excellent" is equivalent to the range of the 10% best results; "Good" is equivalent to 10% of the results in the benchmark data set are better and 75% of the results are worse. "Above average" is equivalent to 25% of the results in the benchmark are better than the result. "Below average" is equivalent to 50% of the results in the benchmark being better than the results, and 25% of the results being worse. "Bad" is equivalent to the range of 25% worst results.

The results presented that the Attractiveness M=1.96 (SD=1.05) and Stimulation M=1.74 (SD=1.16), which were valued as **Excellent**. Perspicuity M=1.59 (SD=1.13) and Efficiency M=1.50 (SD=0.90), which were valued **Above Average**. Dependability M=1.63 (SD=1.07) and Novelty M=1.43 (SD=1.15), which were valued as **Good**. The overall outcome is illustrated in Figure 5.4 and Table 8.

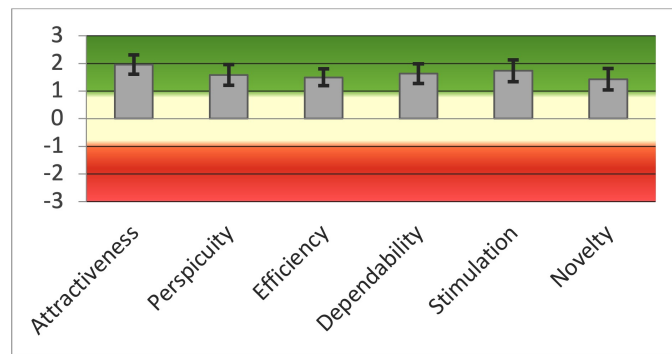


Figure 5.4: VR group's mean scores and standard distribution

Table 8: VR group UEQ test results

UEQ Dimensions	Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation	Novelty
Mean (SD)	1.96 (1.05)	1.59 (1.13)	1.50 (0.90)	1.63 (1.07)	1.74 (1.16)	1.43 (1.15)

5.6.2 Qualitative Results

The qualitative results show a thematic qualitative analysis of the interview responses from 34 students. Specifically, hierarchical classification was used as a method to categorize and organize living organisms into groups based on their evolutionary relationships and shared characteristics. Hierarchical classification refers to a method of classifying items or information in a hierarchical, or tiered, structure. This is often visualized as a tree-like structure or a "taxonomy" where each item or data point can be traced up to one or more higher levels of the hierarchy. Hierarchies can be "top-down" where large, general categories are subdivided into smaller, more specific categories, or "bottom-up" where small, specific items are grouped into larger, more general categories. In doing this, the analyses identified three overarching themes and 5 subthemes- **(a) Course Content**, including subthemes as *Impression* and *VR Technology*; **(b) Learning**, including subthemes as *Ease of learning*, *Classroom Atmosphere*, and *Learning Approach*; and **(c) Conflicts of Interest** (Table 9).

Table 9: Qualitative Results in Themes and Subthemes

Themes	Subthemes
Course Content	• Impression • VR Technology
Learning	• Ease of learning • Classroom Atmosphere • Learning Approach
Conflicts of Interest	

Theme 1 – Course Content

Students explore different parts of the world via VR and gain more knowledge of astronomy, geography, and culture in a novel way. Also, they had more chances to have a glimpse of Western street view and communities by Google Earth VR.

Subtheme 1 - Impression

A prominent topic of discussion was their impression of the technology-enhanced class. For many of the students, this was unfamiliar, but novel, it opened up a whole new perspective on learning and how to interact in the classroom, "it's all something we learned in geography class, but it's not the same feeling", Student (3) talked about this as a feeling of being immersed in the learning experience rather than just facing a book in class - "here it's this feeling of immersion, you feel like you're in it, which is different".

Many students praised the ability to delve into the material and explore it as a key reason for their positive experience with the VR class. They found it convenient to visit so many distinct places in VR while still being in the classroom, and found the immersive experience both surprising and motivating. However, some students were worried this type of learning would not directly benefit their exams – “VR learning didn’t really help my academic performance and final exams, but it helped me broaden my horizons and improve my understanding of the outside world (Student 33).” While there were some disagreements among students in relation to the course content in learning, the majority reported that it was a more relaxed and engaging way to learn, compared with the traditional pedagogy (Student 17).

Subtheme 2 - VR Technology

Students’ overall experience in VR learning was positive - “through this course, we can go where none of us can go. Not only foreign countries but also those planets, which are different from what we see in the textbooks. Textbooks are just photos, some in black and white, but what you see in VR is similar to real scenes and objects” (Student 1). This made some of the students wonder how this technology might help with accessing difficult-to-grasp knowledge. For instance, Student 32 speculated that VR technology could make STEM (Science, Technology, Engineering, and Math) subjects more intuitive by visualizing complex and abstract models.

Many students appreciated the unique and immersive learning experience provided by VR, but some faced challenges adapting to the new technology. They felt uncomfortable and embarrassed, especially when they needed to collaborate with their classmate to play the educational game (Student 19). At the same time, in some cases, students who initially felt out of their comfort zones using the technology expressed that they grew more familiar with VR classes during the course. As a result, “this kind of learning gradually became clear, and I learned more and more things” (Student 12). As the use of VR technology in the classroom becomes increasingly common, it is critical to consider how to support students in navigating these new learning environments.

Theme 2 – Learning

Subtheme 1 - Ease of learning

While some students found it challenging to interact with all these new technologies, students’ general sentiment was that this technology-enhanced course made learning easier. This could be attributed to that VR education made the learning goals more comprehensible by providing clear and illustrative concepts and examples. Some students described “Something could be very abstract, and it is not easy for us to understand, but if the teacher uses this virtual globe to show us, we can directly see what it looks like, and then VR can help us understand this abstract concept (Student 20)”, which indicates that VR has the capacity to embody (abstract) information, and “there were so many interesting things in it, so we did not see every theme. If the teacher continues to teach us this lesson, we can learn all of them

slowly (Student 13)".

Therefore, students believe that they were imparted more flexible and multi-faced knowledge, allowing them to have a deeper understanding of the context and background of what they were learning. For example, Student 14 suggested that the VR experience helped her/him to "physically" be on Mars and the Moon, which would not have been realized through traditional means. Similarly, Student 7 mentioned that the VR experience enabled them to form a more vivid memory of the content, making it easier for them to recall their experience, because it was now represented as a visualized environment rather than just text in a book. However, some students (e.g., Student 7) also expressed that the learning goals of VR-enhanced learning environments were clearly aligned with their ordinary classes, making them worry whether this kind of studying would be suited for preparing them for their exams.

Subtheme 2 – Classroom Atmosphere

Students valued VR education as a better way to enhance the atmosphere in the classroom since it fostered a more dynamic and collaborative classroom atmosphere. They experienced greater engagement with the learning environment, including VR classroom environment that was different from the traditional teacher-centered method with rules and disciplines. The VR-enhanced classroom atmosphere was more inquiry-based, combined with games and adventures, which was different from the classroom atmosphere students were used to, where the focus was on studying and exams, often accompanied by limited interactions and teaching methods that generated tension in the classroom atmosphere. However, some students felt that the VR classroom was less disciplined than their usual classroom since some of the other students became too excited or shouted during the class, which disrupted their peaceful atmosphere. This change in atmosphere might refer to different teaching styles between the VR class and the traditional class.

Subtheme 3 - Learning approach

VR-enhanced teaching and learning were creative and led students to believe that they have had various learning experiences. Given that VR-enhanced education reduced the didactic teaching load in the classroom, students enjoyed the classroom atmosphere more – "the atmosphere of this VR class was quite special because we have time to study with classmates, by ourselves, and to study and discuss with the teacher. These three forms all made the class very short, and you felt like time passed quickly (Student 20)." At the same time, some of the students preferred the gamified elements, which made the classes "not boring at all" (Student 7). However, there was no homework. Students indicated that "if we keep studying in VR without any homework and continue to do this in the future, we may not get good grades (Student 7)". Students valued that VR classes were closer to extracurricular activities - "the content in the VR class cannot improve our academic performance too much because the design is based on interests (Student 31)", while the content in the traditional class was mainly designed for competitions (M. Liu, 2021).

Theme 3 - Conflicts of Pedagogy

We found that students developed a mental divide between stress free learning and structured learning, that is, they had conflicts between their traditional learning experiences and VR learning experiences. Students appreciated the use of different teaching methods and multiple technologies, which enabled them to learn in different ways and rely less on traditional teaching styles. Student 20, for instance, noted that the VR classroom environment was unique, with diverse combinations for experiencing different VR formats with individual study, group study, and teacher-led discussion. This varied approach made the class feel more dynamic and engaging than in traditional classrooms. On the other hand, some students felt that this VR-enhanced learning was too different from traditional classes. It has a perceived focus on games and fun rather than exam preparation, whereas lacks homework and related practices. Students expressed concern that without the structure of traditional classes, they might not perform well on future exams. The students actively compared structured learning (rote learning) to learning for fun (exploration) during the interview, and addressed the importance of having good exam outcomes in their education. These perceptions reflect students' understanding of what "real learning" is in the remote rural context, and it appears to be a distinct understanding from the international mainstream education advocacy – "Inclusive and quality education for all and promote lifelong learning (OECD, 2021; Nations, 2015)", and "Education gives people the knowledge and skills they need to stay healthy, get jobs and foster tolerance" (UNESCO, 2019a).

5.7 Discussion

5.7.1 Implications of Quantitative Studies

The presented study used mixed methods studies to investigate whether VR education could improve educational quality for students who live in remote rural areas. The given literature review suggested that educational inequality between China's rural and urban areas, even though the government has given substantial financial support to all rural schools (C. Liu et al., 2020). Facing a shortage of qualified teachers in rural areas (H. Wang et al., 2022), leveraging VR technology could be an effective way to give teachers easily accessible classroom materials that may enhance the quality of teaching and learning within the classroom.

Results from the SEEQ indicated that after both conditions (i.e., VR and TC), students evaluated that perceived educational quality, in general, has been significantly enhanced ($P < .001$). Moreover, students' perceived educational quality enhanced significantly in Breadth, referring to the diversity of subjects, topics, and experiences that students were exposed to (Dutta, Li, & Merenda, 2011); and Assignments, which provided students with the opportunity to reflect on what they learned in the classroom (Lynch, Sage, Hitchcock,

& Sage, 2021). Reviewing the VR group and the TC group, the TC group, the VR group's scores increased more over time in general Quality Education, Breadth, and Assignments than the TC group. This could indicate that VR enabled rural students to access a wider range of environments that were not available to them in their usual classroom (Marks & Thomas, 2022), because of the disadvantaged conditions connected to rural teaching and learning, such as taking place in a remote location, using outdated educational facilities, and having a higher proportion of parents with low socioeconomic status and, connected to this, lower incomes. The VR technology might have increased the breadth of the course by expanding the number of things it was possible for the students to experience, such as visiting Mars and the Moon, different countries, and famous sites, all without needing to leave their classroom. Additionally, the classroom employed multiple different pedagogies, all of which were more student-centered, which might have increased the time and opportunities for reflection, increasing scores of Assignments. Compared to following the script within a traditional classroom, VR classes then integrated design features involving creativity and interactivity to kindle students' motivation in active learning (Freire, 1970).

Results from the WIHITC reflected that students perceived general classroom atmosphere was significantly enhanced by both conditions (VR and TC), at the meantime, results show that students' perceived Teacher Support (for students) is an essential component of promoting student learning and well-being (Lei, Cui, & Chiu, 2018); and Involvement, referring to engagement of students, teachers, and other stakeholders in the learning process (Könings, Mordang, Smeenk, Stassen, & Ramani, 2021). The follow-up t-test findings showed that the VR group's impression of the general classroom atmosphere increased more over time than the TC cohort, also, specifically in Teacher Support and Involvement. The results regarding Teacher Support could be attributed to a lower student-teacher ratio (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014) (the teacher was responsible for fewer students at a time). However, it could also be connected to the VR-enhanced classroom having a more active classroom atmosphere, which might lead to an enhanced experience in learning (Merchant et al., 2014; Pellas, Mystakidis, & Kazanidis, 2021) as well as an increased feeling of engagement due to increased interactivity between all stakeholders in the classroom, which can be seen in the increased feeling of Involvement (Calvert & Abadia, 2020).

Within the VR classroom, due to the small teacher-student ratio (1:2 or 1:3), the instructor was able to recognize and respond to each student's needs and provide timely and tailored support for personalized learning. Given that the teacher-student classroom ratio in participating rural schools varies from 1:30 to 1:65, it is often challenging for teachers to provide individualized attention and support to students and therefore reduced the quality of education directly. Furthermore, VR-supported classroom environments have been shown to provide multiple things to the learning experience, such as increased immersion (Makransky & Mayer, 2022), active participation (Checa & Bustillo, 2020), hands-on experience, as well

as a sense of safety and maneuverability (X. Wang, Young, et al., 2021), which might all help teachers create atmosphere with positivity and diversity.

5.7.2 User Experience Reflection

The UEQ results showed that students evaluated that VR education holds a good level of perspicuity ($M=1.59$, $SD=1.13$) and efficiency ($M=1.50$, $SD=0.90$). This might be partially explained by Google Earth's clear and intuitive user interface that makes it easy for rural students to navigate and access information. Additionally, clear and concise instructions were presented to the students before they were given access to the VR headsets, which might have helped the students more easily understand what they were expected to do and how to use the technology. Students also reported that the VR technology was attractive, stimulating, and novel to them. This is in line with prior research. Many studies have noted that immersive VR is more likely to provide students with a sense of novelty, recreational stimulation, and excitement (Makransky & Mayer, 2022). However, we wonder if this can last only for a short period of time, rather than greatly enhance students' learning motivation and help them maintain this momentum. The ideal situation would be that technology, including VR, is used strategically to support teaching and learning (X. Wang, Quirke, & McGuckin, 2022). Many rural schools even have access to some basic technological equipment already, such as whiteboards and computers (Bajpai, Biberman, & Ye, 2019). However, many teachers are not willing to adopt these new technologies and integrate them into their classes. Hence, even with the literature indicating that VR may be an effective educational technology (B. Wu, Yu, & Gu, 2020), and the current study finding support for the technology also has a positive effect in underdeveloped, rural areas, this might not be enough for the technology to be accepted and used by school environments. Previous research has suggested that teachers' technology acceptance and self-efficacy toward using new technologies may also be important predictors of how willing they are to adopt new technologies in their teaching (Smarkola, 2007). However, some studies also suggest that, when teachers use technologies in their teaching, they choose these technologies based on the evidence available to them only (Pierce & Ball, 2009), making the current study an important piece of the puzzle that is increasing effective technology use in classrooms.

5.7.3 Rural Students' Perspectives on VR Education

In comparison to the TC group, the VR group mainly valued that they experienced extra intriguing learning and human-computer interaction through VR education. The ease of learning via VR increased the enjoyment of students' classroom time, which directly led to a livelier and more positive atmosphere in the rural classroom. The students highlighted how their learning in the technology-enhanced environment seemed to be more driven by interest, which might lead to increased learning, but also increased interest in school subjects outside

of school, according to interest theories such as the Four-phase model of interest development (Hidi & Renninger, 2006). Nevertheless, a key topic of discussion among students was whether their exam results, which they have always prioritized in their studies, will be affected by the innovative VR learning, because without an excellent test result, rural students are more likely to be eliminated by future entrance examinations (Rozelle & Hell, 2020). In fact, evidence from meta-analyses shows that the VR environment is effective for teaching in K-12 and higher education (Coban, Bolat, & Goksu, 2022; Merchant et al., 2014). This relates to whether educational freedom and reform can still be developed and improved under an exam-oriented system like this, because traditional education often infiltrates competition and compliance (refer to oppression) to students' minds, maintaining power structures and hidden inequalities (Freire, 1970). This also seems to reflect the two distinct pedagogies of student-centered and teacher-centered learning, where traditional education seems to be closer to the teacher-centered pedagogy of learning. When the students are presented with student-centered learning, they thus do not recognize it as learning, because it seems more akin to extracurricular activities. This could be attributed to a) most research, including VR-education studies, are from Western contexts (Henrich et al., 2010), education models can be remarkably different under Western and Eastern cultural backgrounds; b) the fact that the subjects in the VR class were chosen by the researchers, and as such may have been less clearly connected to students' learning goals in their traditional classroom. We suggest further studies can consider these two relevant aspects (i.e., culture and educational subjects) when applying their research plans in the wild.

Another significant observation is related to student critical reflection. Even though after the students had reflected on both the pros (e.g., learning materials, learning approach, and virtual field trips) and cons (e.g., broad learning content, noisy classroom, and over-entertainment) of the VR-enhanced classroom, the majority of them still stated that they would like to explore more in VR education, and some of them also showed signs of individual interests being developed, wanting to go to the places they visited in VR in the future. The positionalities expressed by the students could thus be mirroring that these learners actively participated in the process of VR-enhanced education and became agents of their own exploration through this. In this way, technology-enhanced education can be seen as a useful toolkit to improve educational quality, and also for increasing students' ability to engage themselves in their learning not only during, but also outside of the school context. This also shows how technology-enhanced education could be an important step forward for education in underdeveloped countries and regions.

5.8 Conclusion

This study employed a mixed approach to conduct VR-based experiments for quality education and classroom atmosphere enhancement in rural China. The results illustrate that

implementing VR technology in remote, rural classrooms can enhance education quality by providing students with immersive learning and positive classroom environments. However, students' concerns about exam performance reveal a tension between innovative VR learning and traditional exam-focused systems. The novelty of VR education may also impact long-term student engagement, emphasizing the need for strategic technology use in education. Schools' acceptance of VR technology is another key to be considered for effective classroom integration. Furthermore, the cultural context of VR content requires scrutiny to ensure its feasibility and relevance in different countries and regions.

Chapter 6

The Potential of Extended Reality in Rural Education's Future – Perspectives from Rural Educators

6.1 Chapter Overview

The last chapter was a mixed-methods study that aims to explore the perspectives of rural students on the use of Extended reality (XR) technology in education (**RQ2**). However, that study focused on rural students without any insights from rural educators. To better understand stakeholders' insights into using XR to improve rural education, I designed another qualitative study with a workshop offering hands-on VR education experience for rural educators to understand more about their reflections regarding using VR education in their future classes.

This Chapter is a quantitative study to answer **RQ 3 - What are rural educators' perspectives on utilizing XR-enhanced teaching and learning?**. It is also under review in **Education and Information Technologies** (2. Wang, X., Young, G. MZ, Iqbal., & Mc Guckin, C. (2023). The Potential of Extended Reality in Rural Education's Future – Perspectives From Rural Educators [Under Review]. Education and Information Technologies).

The current chapter indicates that technology-enhanced education can potentially enhance teaching and learning outcomes for rural educators since they face dilemmas such as 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 Chapter presents that 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 included a lack of school infrastructure to apply XR and a structured curriculum design to use it in the classroom setting. Future studies could explore bringing good XR practice into primary and elementary education in those areas with limited educational resources.

Note. This study is under review in *Education and Information Technologies* (5 years impact factor 5.30) by June 2023. This work was a collaboration between Trinity College Dublin and Teesside University. I am the first author and credit of the co-author statement listed below:

6.2 Introduction

6.2.1 The Importance of Rural Educators and Their Under-appreciated Situations

Educators play one of the most important roles in student learning, and rural educators represent a special group of educators who often have a more critical impact on rural students' lives (Starrett, Yow, Lotter, Irvin, & Adams, 2021). Rural educators work in schools in rural or remote areas, typically 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, Hardie, Gause, Moyi, & Ylimaki, 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 multiple 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 a lot to rural education as they are familiar with local resources, communities, and the environment (Starrett et al., 2021). They have been seen as the group of people who can address the specific needs of rural students (Brenner, 2016), foster parents' and students' 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 experienced (D. 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, Ezeuduji, Iwu, Ikebuaku, & Tengeh, 2018). On the other hand, research has shown that rural schools often receive fewer resources and face more significant challenges than their urban counterparts (H. Wang et al., 2022). Many rural schools have limited access to technology and advanced course resources (Bower et al., 2020) and are only able to offer lower salary levels for educators (H. Wang et al., 2022), 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 (H. Wang et al., 2022), and students in these areas may receive lower quality education compared to their peers in better-resourced areas.

To address these dilemmas, research suggested that investing in technology-enhanced educational training for rural educators can potentially enhance teaching and learning outcomes (Kasem & Pathak, 2015; D. Wu, Yang, Yang, Lu, & Li, 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 (D. 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, Greenwood, & Henderson, 2022) indicated that after the series of ICT-based training, teachers reported that they did a better job in their classroom teaching. Kalonde (2017) (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 lacking 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; J. Li, Shi, & Xue, 2020). For example, teachers from advanced regions can deliver online classes to students in rural areas (Yang et al., 2018), and rural teachers can collaborate online with urban teachers to share the teaching materials and deliver classes jointly (Zuo, Wang, & Yang, 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, Quirke, & McGuckin, 2022; Yu, 2021).

6.2.2 Defining XR Technology

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) (Figure. 6.1).

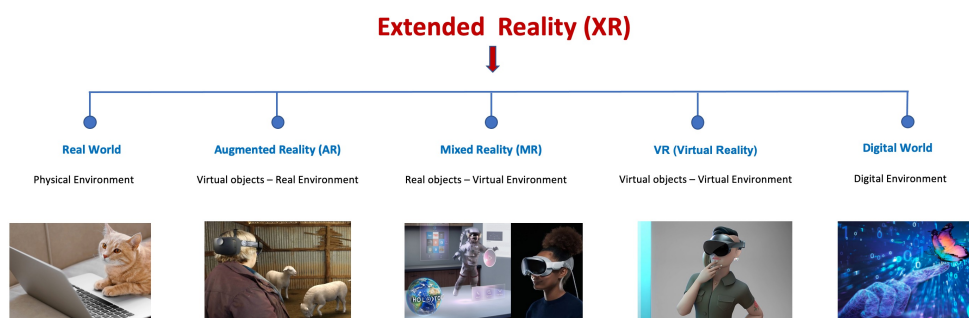


Figure 6.1: XR explained by the Virtuality Continuum, (Milgram & Kishino, 1994)

Using XR for learning, also called immersive learning, continues to provide immersive and interactive learning experiences with the latest technology developments (Dengel, Iqbal, Grafe, & Mangina, 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. 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, Panopoulos, Angelopoulos, Wang, & Wang, 2022). With its immersive nature and adaptable capabilities, XR represents a valuable asset in the educational realm, revolutionizing teaching and learning methodologies (Kluge et al., 2022).

6.3 Related Work

In education, the use of XR for learning is gaining popularity in teaching and training activities. For example, there is a growing utilization of XR in remote education (G. W. Young, O'Dwyer, & Smolic, 2023), teaching training (Gandolfi et al., 2021), industrial manufacturing (Fast-Berglund et al., 2018), medical practice (Andrews et al., 2019), special education (X. Wang, Young, et al., 2021), and soft skills training (X. Wang, Quirke, & McGuckin, 2022). 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, Dietrich, Prash, & Schneider, 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, 2018b), 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 for 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 a total of 280 students and 32 teachers. The project's learning goal was to use interactive visual simulation to demonstrate basic hygiene to rural communities, with a focus on sanitation, water, and disease prevention, e.g., malaria, bilharzia, dysentery, and cholera. The outcome showed that with the aid of 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 the topics in the near future (UNESCO, 2004). Another case study is Liao et al. (2023) (F. Huang, 2006) tried to use an XR Learning application called "StemUp" to improve rural students' English learning performance and motivation, results show that this application can help participant language gain more knowledge in English vocabulary, speaking, and listening, students also commented that the course became more engaging and less boring. In addition, Rasheed et al. (2015) (Rasheed, Onkar, & Narula, 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 it was presented through traditional teaching methods. However, there was a notable increase in learning in color perception, orientation, and size estimation through the use of 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 percent 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 both regional and global sustainable development of quality education.

6.3.1 Research Gap and Questions

Having reviewed the presented evidence, it can be identified that, firstly, 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, the following research questions (RQs) are proposed and aimed to investigate the interaction between educators from rural areas 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 research 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, and a total of 90 children from China’s remote rural areas were involved in the first phase study (X. Wang, Young, Plechatá, et al., 2023). 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 results demonstrated that 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 their future teaching activities.

However, unlike urban schools in China with certain opportunities to access XR education (Chen & Chan, 2019; Wei, Weng, Liu, & Wang, 2015), few pilot studies have allowed rural students to have such experiences (X. Wang, Young, Plechatá, 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 can allow educators to understand the advancement of XR technology and how it can be 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.

6.4 Methodology

6.4.1 Study Procedure

In this study, a workshop called “Extended Reality and the Future of Rural Education” was designed and delivered 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, Hill, Holland, & Pool, 2015). Converting this concept to a research methodology, the “workshop” was used to explore domain-based issues, present relevant literature, provide background knowledge, and deliver real-world demonstrations (Ørngreen & Levinsen, 2017). After the workshop, a focus group with the educators was held 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.

6.4.2 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 percent 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?

6.4.3 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 presented below (Figure. 6.2). The workshop devices consist of 2 Meta Quest 2, 2 iPads, 2 iPhones, and 3 Cardboards, and all the equipment was sustainably used to support various studies under the project of Applying XR Education in Rural China.

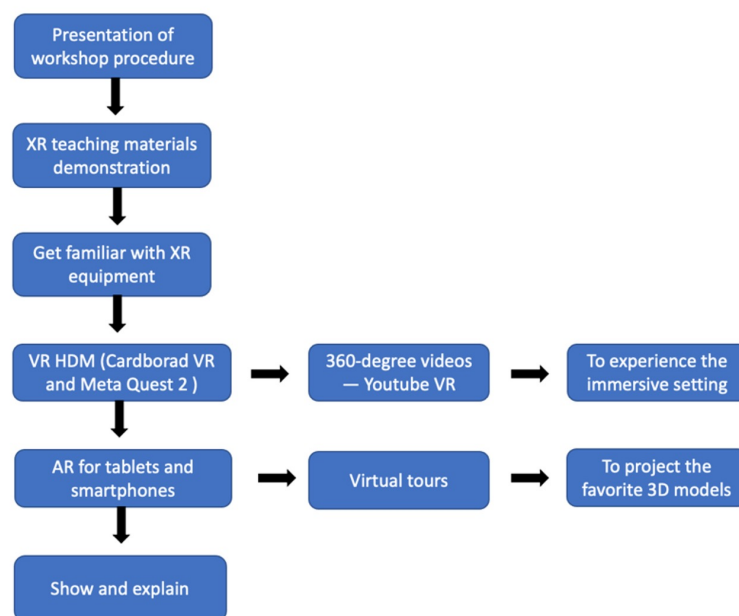


Figure 6.2: The workshop procedure

A total of 13 rural educators from 6 rural villages in Western China were invited to participate to experience two VR HMDs (Cardboard VR and Meta Quest 2) and watch 360-degree videos through YouTube 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 minutes and was limited to four or five participants maximum to allow for a suitable demonstration time and open discussion. After each workshop, a follow-up focus group was conducted to understand rural educators' perspectives on using XR applications in future teaching activities.



Figure 6.3: Using VR with Meta Quest

These groups consisted of two groups of four and one of five educators. As a result, the educators comprehensively experienced using VR headsets, tablet-rendered AR, various XR educational applications, and XR-led teaching activities. For instance, as presented in Figure. 6.3 and Figure. 6.4, a rural teacher was trying a VR headset and successfully projecting a 3D model by tablet AR.



Figure 6.4: A 3D model projected by tablet AR

6.4.4 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. In order 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 were able to 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?

6.4.5 Focus Groups 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, there were three rounds of focus on rural educators, with four participants in each round. These focus groups were recorded with the participant's consent for post-task data analysis. To ensure anonymity, all identifying information of individuals or schools was removed during transcription. Additionally, all participants were encouraged to ask further questions and share their opinions openly to provide valuable insights for the study.

6.5 Data Analyses

A thematic analysis was performed on the transcriptions to identify related themes and sub-themes 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 ($Kappa = 0.8$).

6.5.1 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 a longer period of teaching experience in rural areas than fixed-term educators. Each focus group session ranged from 38 to 57 minutes in duration (Table 1).

Table 1: Participants' Information

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.

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). Quirkos is a qualitative data analysis software that helps researchers, analysts, and individuals explore, organize, and gain insights from textual data. It is designed to assist in the analysis of unstructured text, such as interview transcripts, survey responses, open-ended questions, and other forms of qualitative data.

6.5.2 Qualitative Coding

A hierarchical framework was employed to code the focus groups' transcripts (Saldaña, 2021) (Figure. 6.5). The first level involved gathering all useful information from focus groups. The second level presented two primary categories — discussions focused 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.

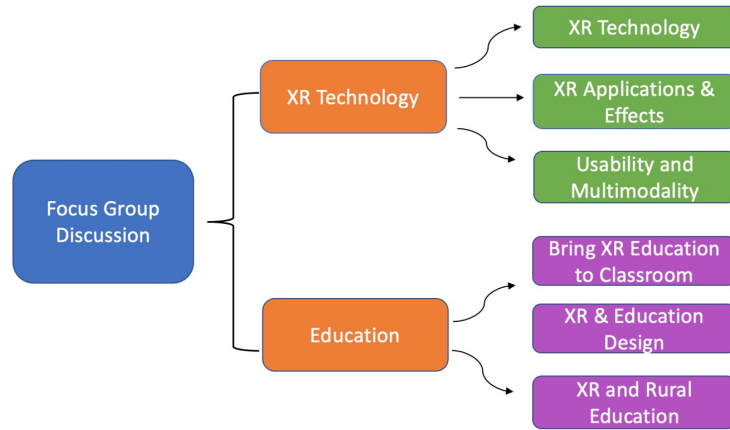


Figure 6.5: The hierarchical framework for the coding process

6.6 Results

6.6.1 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. Theme 2 is accompanied by four subthemes. Subtheme 1- Learning Content Design and Subtheme 2 - Learning Motivation & Vocational Training suggest 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. 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. To visualize the key information, we use Table 2 to show an overview of these core themes and subthemes.

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.	<i>Subtheme 1: Learning Content Design</i> <i>Subtheme 2: Learning Motivation & Vocational Training</i> <i>Subtheme 3: A Toolkit to Support Multiple Discipline</i> <i>Subtheme 4: The Suitable Device for Rural Education</i>	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.		

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 and 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)

Theme 2 – Inspiration for Education Design (RQ2)

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 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 be used to 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 that students can closely observe the given 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 use Extended Reality technology to present them to us.” — (QP11)

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.

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.

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 and 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 not be able 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.

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 found to be particularly noteworthy due to its responsive controllers (C2V9). Educators found that the controllers provided detailed and timely responses to their movements, while the haptic feedback function created a sense of immersion that allowed them to feel like they were interacting with the virtual world. This 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)

Theme 4 – Leveraging XR for Future Rural Education (RQ 3)

In investigating the possibilities of using XR technology and applications in rural educational settings, both traditional classroom education and the macro level of education need to be considered. The complexity of unequal education in urban and rural China, and the specialty of educators’ roles provoked rural educators’ thinking that XR-assisted teaching and learning can be developed to a larger 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 not only good for educational purposes but also 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 useful for 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. As 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 have the impression that the countryside is underdeveloped and not conducive to career develop-

ment; 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).

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 minutes. 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 experience 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 rural classrooms in the future, students may become addicted to the technology with exaggerated effects, which may impact their studies (FM66 and NR38).

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 the continuation of 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 a lot of pressure on students and provides few interesting classes. So, I do not think it will improve the rural schools’ educational quality.” — (C2V6)

6.7 Discussion

6.7.1 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 (Dwivedi et al., 2022). 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 (X. Wang, Rodgers, et al., 2021). 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, Can, Pindrik, Rocque, & Johnston, 2016) and that students have gained significant oral communication competence (Tai, Chen, & Todd, 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.

6.7.2 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 (G. W. 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 useful resources, forming a sense of connection to engage citizens through emotional means (Gruenewald & Witteborn, 2022).

6.7.3 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 percent of the local population in disadvantaged rural areas (Y. Shi et al., 2015a). Many of these dropout students from mainstream schools either choose to continue their education with vocational schools in urban China (D. Guo & Wang, 2020) or directly migrate to prosperous cities and become labor-intensive workers

without any vocational training (Rozelle & Hell, 2020). Based on this fact, XR simulations allow students to visualize and interact with complex concepts (X. Wang, Hodgers, et al., 2021), 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 prosperous areas.

6.7.4 Limitations

Although this study was an XR-related educational experiment that was 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, there is a clear demarcation 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 are not equipped with 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. There are no existing applications that are tailored for curriculum-based teaching and learning for elementary and secondary education. We hope the evolving XR industry will develop more structured learning applications for the emerging need.

6.7.5 Conclusion & Future Work

The emergence of XR as a learning technology is transforming traditional educational practices, creating new opportunities for engaging and effective 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 continues to advance, educators expect more innovative applications and content tailored to different educational levels and subjects, further enriching the education experience in rural schools and developing rurality. XR developers may believe the product can be easily applied to schools and used by educators from different backgrounds. 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 educational standards for mainstream schools. Therefore, future studies may 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.

Chapter 7

Final Conclusion

This chapter presents a section on Reflexivity to illuminate the author's positionality, biases, and influence on the research process and outcomes. It involves a reflection on the critical self-examination undertaken throughout the research process. It is a recognition of how the four years of Ph.D. study experiences, beliefs, and social identities shaped every aspect of this research project. Informed by Bronfenbrenner's ecological system theory (eco-system) (Bronfenbrenner, 1979a, 1986, 1989), this research investigates the complex interactions within the environments affecting China's education system, particularly through the lens of educational inequity between rural and urban China. The following section presents the main findings of this research project. The main findings generate moderate contributions to the body of knowledge in the disciplines of Education and Human-Computer Interaction, discovering what is known and understood in the context that the majority may not be familiar with (e.g., how immersive technology can facilitate educational equality for rural regions). This understanding is fundamental to the researcher's academic pursuit of learning and discovery. Reflecting on the eco-system framework, the findings prompt an updated interpretation that incorporates the insights gained from this study, which enriches the presented eco-system framework (in the theory chapter) with relevant research outcomes. For instance, the main findings may enrich the content, provide stakeholders with up-to-date information and perspectives, and open further study and support opportunities. Finally, due to the nature of this project's interdisciplinary research, the main findings may lead to the development of new practices, technologies-based solutions, and further innovations in the future. Next, the Implication, Limitation, and Future Studies sections indicate how the findings can be applied in practical settings, e.g., technology development in educational contexts. It addresses the study's limitations, acknowledging the inherent constraints and areas where further clarification or exploration is needed. Lastly, it casts a forward-looking gaze toward future research avenues, suggesting how subsequent studies can build upon the current project's findings to explore uncharted areas, refine existing knowledge, and continue the pursuit of innovation in education and human-computer interaction.

7.1 Reflexivity

As an early-career researcher conducting my Ph.D. study on utilizing XR to improve quality education and reduce inequalities in rural China, I have critically and constantly examined my positionality, motivations, and biases, reflecting on how they might have impacted various stages of my research during the four years of study.

Being a researcher with a Chinese background but an outsider to rural China, my previous work experience and complex overseas journey have played a crucial role in shaping my perspective on the challenges rural communities and residents face. I have been aware that my views could have been influenced by preconceptions and assumptions when I decided to conduct this research topic. Thus, I have made efforts to guard against any ethnocentric attitudes. To counterbalance these thoughts, I have remained open-minded, conducted thorough literature reviews, and engaged in continuous dialogue with various people. For example, I have supervisors from both the Department of Education and the Department of Computer Science and Statistics; I have read many papers from Rural Education Action Program (Stanford University); I have collaborated with many Western scholars and universities; I have been working and talking with a large group of computer scientists on the topic of XR; I have physically been to rural China and conducted numerous field experiences with the community members; and I have used a mixed-methods approach as a primary methodology to develop this research project, aiming to provide the readers with in-depth understanding of the context and findings.

Certainly, there were difficulties and challenges across the project span. The most influential challenge to this research project was the COVID-19 pandemic. Due to the school and public areas' short and long-term closure, it suddenly addressed that immersive technology (VR, AR, MR) can play an even more significant role in education and people's lives during the pandemic era and in the future. This unforeseen circumstance led to a major change in my research trajectory. Initially, I was interested in utilizing XR to assist children with special needs, but because of this global crisis, I decided to design to study how to use XR to help children from under-represented backgrounds. The reason for this change is the potential to leverage XR to benefit a larger population. This motivation boosted my enthusiasm for XR as a potential solution that could have influenced my approach to the research. In addition, I have been mindful of this potential bias and have critically assessed whether XR is genuinely suitable and accessible for education in rural China.

My reflexivity has prompted me to explore alternative perspectives and consider the implications of relying solely on technological solutions, ensuring that I do not overlook other scientific methods. Engaging with rural communities and participants, my role as a researcher has positively and negatively impacted the data collection process. My position has granted me authority and access to resources, but it could have also led to power imbalances and participants providing socially desirable responses. To address this, I have fostered

an open and respectful environment during the questionnaire tests, surveys, workshops, interviews, and focus groups, encouraging participants to freely share their experiences and opinions and ask me questions anytime. Throughout the analysis phase, I have been vigilant about how my beliefs and values could have shaped the interpretation of the data. I have also been conscious of confirmation bias, the tendency to favor information that supports my initial hypotheses, which could have led to skewed conclusions. To mitigate this, I have been reminding myself that I am a scientist and doing scientific research. I should always seek diverse data sources and perspectives to validate my findings. I did it.

Moreover, peer debriefing and engaging in discussions with my supervisors and colleagues have further helped me to question and challenge my interpretations. Hence, the following section reviews the main findings of this research project. At the same time, all main findings are categorized into micro to macro levels based on the ecosystem framework to facilitate a nuanced understanding of how XR interfaces with educational processes at various systemic levels in this research project.

7.2 Review of Research Questions

In reviewing the research question, this section is to provide a synopsis of each research question and its background, since this research crafts evolving issues of societal and educational challenges in rural China, particularly in rural and under-represented communities, and how XR can be used to facilitate educational equality. Hence, this research project was designed to answer and it answered the following research questions (RQ):

RQ1 – Can VR improve rural children’s social competence and perceived social support? (Study 1 was designed to answer this question) The context of RQ1 was that rural children often face unique challenges, including limited access to social and educational resources, which can impede their social development and support networks. VR technology presents an innovative solution by simulating social scenarios and environments that foster social skills and competence. The immersive nature of VR could provide rural children with experiences and interactions otherwise inaccessible in their immediate environments, potentially bridging the gap in social exposure and competence. This fact led to the first research question that looked for answers about the capability of VR to improve rural children’s social competence and perceived social support.

RQ2 – Can VR facilitate quality education by improving the classroom atmosphere? (Study 2 was designed to answer this question) The background of RQ2 was that the quality of education in rural areas can be compromised by factors such as resource limitations, teacher shortages, and less engaging learning environments. VR technology offers a dynamic and interactive platform that could transform the classroom atmosphere, making learning more engaging and accessible. Educators can create immersive and interactive learning ex-

periences that transcend traditional teaching methods by integrating VR into educational settings. The second research question explored how VR can facilitate this transformation in education, specifically through improving the classroom atmosphere. It also aimed to seek answers in the enhancement of education quality and foster a more inclusive and stimulating learning environment.

RQ3 – What are rural educators’ perspectives on utilizing XR-enhanced teaching and learning? (Study 3 was designed to answer this question) The rationale of RQ3 was the adoption and integration of XR technologies in educational practices require the support and insight of educators, especially those in rural settings who may face unique challenges and opportunities with these technologies. Understanding rural educators’ perspectives on using XR in teaching and learning is crucial for identifying barriers to implementation, potential benefits, and strategies for effective use. Their insights can guide the development of XR-enhanced pedagogical methods tailored to the needs and constraints of rural educational contexts. The third research question, therefore, sought answers that gather and analyze rural educators’ views on utilizing XR to enhance teaching and learning processes.

7.3 Main Findings

Following the background of three research questions, the main findings are presented to reflect the potential contributions of this research project and provide a reference for future studies. Specifically, in this final chapter, the main findings are listed to answer research questions but also re-synthesized to align with the ecosystem framework (Bronfenbrenner, 1986, 1989; Guy-Evans, 2020), i.e., from the ecosystem, meso-system, exo-system, macro-system to chrono-system to reveal the entangled and complex relationships within the context of the potential of utilizing XR technology to enhance education in rural China. Employing this approach addresses the specific research questions but also situates the contributions of this research within a broader, interconnected framework, such as the multifaceted impact of XR technologies on educational and social systems in rural China.

To do this, the main findings summarize this research project’s three empirical results and present the findings from the micro to chronic level: (a) How VR and XR technologies enhance direct interactions within classrooms, improving social competence and educational quality; (b) The connections between rural students, educators, and school environments through technology, including potential benefits and challenges; (c) Discuss the broader educational issues (e.g., education inequalities), access to technology, and how these external factors influence the adoption of XR in rural education; (d) Cultural and societal attitudes towards technology in education, and their impact on XR technology adoption; and (e) Reflect on the temporal aspect, considering how changes in technology and societal attitudes towards education over time affect the potential and challenges of integrating XR into rural education.

7.3.1 Micro-system

The micro-system is the innermost level in Urie Bronfenbrenner's Ecological Systems Theory, which describes the immediate environment in which an individual lives and interacts. This concept is foundational in understanding human development from an ecological perspective. A micro-system encompasses the direct relationships and interactions an individual has with other people and settings in their immediate surroundings (Bronfenbrenner, 1979a, 1986; Mc Guckin & Minton, 2014b). In this research, Study 1 examined the effectiveness of VR-assisted learning in developing social competence and perceived social support among rural children, contrasting these outcomes with those from traditional pedagogies and play-based learning approaches like Lego. It was found that VR and Lego positively impact enhancing social skills and support, with VR demonstrating marked advantages over conventional methods (RQ1). This finding suggests that VR's immersive and interactive nature may offer unique benefits in fostering social interactions and support networks among students, potentially counteracting the effects of social isolation or marginalization experienced in underprivileged settings (RQ1). Study 2 discussed VR's potential to uplift educational quality and atmosphere, albeit with caveats concerning its novelty and potential to distract from exam preparation. In this study, students reported high engagement and interest in immersive VR experiences (RQ2). The highlight is VR's capacity to make rural students' disciplinary learning interactive and enjoyable. However, students' concerns were raised about the balance between technological engagement and academic focus, given the immersive nature of VR potentially leading to distractions (RQ2). Study 3 highlights rural educators' positive attitude about XR's ability to enhance educational quality despite notable challenges like infrastructural limitations and integrating XR into existing curricula (RQ3). Educators highlighted accessibility and cost as significant barriers to XR's widespread adoption in underprivileged areas (RQ3). These findings demonstrated the role of technology in strengthening the foundational layer of the ecological model—the microsystem—where individual development is significantly shaped.

7.3.2 Meso-system

The meso-system is a concept from Urie Bronfenbrenner's Ecological Systems Theory, which emphasizes the complex layers of environments and their influence on an individual's development. Specifically, the meso-system refers to the interconnections between the various microsystems in a person's life. Microsystems are the immediate environments with which an individual directly interacts, such as family, school, peer groups, and the workplace (Bronfenbrenner, 1989; Guy-Evans, 2020; Mc Guckin & Minton, 2014b). In this research, Study 1 shows that integrating VR in educational settings bridges various elements of children's microsystems (e.g., home and school), potentially providing a cohesive support network that positively influences their social development (RQ1). In Study 2, VR encouraged

collaboration between educators, students, and parents. Hence, a more integrated learning approach can enhance the educational experience (RQ 2). Moreover, Study 3 presents that XR can simulate complex social scenarios in a controlled environment (RQ3). This function may help educators and students to practice and develop social skills in ways that traditional learning environments may not support (RQ3). However, in Study 3, findings reveal the importance of using nuanced approaches to integrate XR in educational contexts, emphasizing the need to maintain a delicate balance between leveraging VR's immersive benefits and safeguarding academic rigor (RQ3). At the meso-system level, educators voice a hopeful yet cautious outlook, recognizing XR's potential to bridge educational gaps while acknowledging the hurdles that must be overcome (RQ3). Results also exhibit a forward-looking agenda for integrating cutting-edge technologies into education, emphasizing the need for continued research and innovation to make XR a practical and impactful tool in rural educational settings. The discussion extends to strategic recommendations for surmounting these challenges, including investments in infrastructure, professional development for teachers, and collaborative efforts to develop XR-compatible curricula (RQ3).

7.3.3 Exo-system

The exo-system expands the framework for understanding human development within the context of increasingly complex layers of the environment. It also highlights how indirect influences can play a substantial role in an individual's development. For instance, a change in educational policy might alter the curriculum or resources available in schools, affecting a child's learning environment without the child having direct contact with policymakers (Bronfenbrenner, 1989; Newman & Newman, 2020a; Mc Guckin & Minton, 2014b). The core findings of this research project were tightly connected to the ecosystem theoretical frameworks and context in rural China. These fundamental elements facilitated experimental design that leveraged case studies from XR studies in educational psychology (e.g., learning motivation and engagement) and theories related to XR technology-enhanced learning (e.g., pedagogy of technology). Therefore, the research design drew upon these disciplines to showcase the mechanisms through which XR technology fosters deeply engaging and immersive learning environments (RQ 1, 2, & 3). At an exo-system level, findings demonstrate how VR's immersive attributes stimulate cognitive and emotional engagement among learners (RQ 1), thereby facilitating a more profound understanding and retention of the material and a more creative "learning for fun" experience (RQ 2). Furthermore, it explored the role of XR in fostering empathy and understanding through simulated social interactions, illustrating the potential for XR to transcend traditional educational methodologies by offering experiences that are both richly interactive and highly personalized (RQ1 & 3). This synthesis of educational psychology with technology-enhanced learning theories provides a robust framework for understanding the transformative potential of XR in educational settings. It

suggests that when effectively integrated, XR can be a powerful tool for enhancing learning outcomes and improving social competencies. Further, results shed light on XR's capability to enhance educational experiences in a way that significantly augments social outcomes (RQ 1, 2, & 3). Thus, this research project advocates for scientists, educators, and scholars to use an interdisciplinary approach to utilize external resources and craft more accessible, innovative, and minority-group-friendly learning environments.

7.3.4 Macro-system

The macro-system represents the broader socio-cultural context in which an individual lives. This layer encompasses the overarching patterns and characteristics of a culture or society, including its laws, values, customs, and resources (Bronfenbrenner, 1989, 1979a; Mc Guckin & Minton, 2014b)). At the macro-system level, the findings related to rural educators' perspectives underscore the importance of external factors such as policy, infrastructure, and community resources in the successful adoption and integration of XR technologies in educational settings (RQ 3). These elements are crucial for creating an enabling environment that supports the effective use of XR for educational advancement (RQ 3). The broader implications of the study's findings shed light on how XR technology can play a useful role in reducing educational inequalities (RQ 1 & 2). This research project presented various immersive learning experiences, which were instrumental in enhancing social competencies vital for the holistic development of rural children and rural education (RQ1). By drawing on detailed experiments, the integration of VR into educational settings can enhance the learning experience, leveling the playing field for children from under-represented backgrounds, thereby contributing to a more equitable educational landscape (RQ 1 & 2). Therefore, there is a critical need for these stakeholders to thoughtfully consider the cases introduced by this research in the context of immersive technology enhanced education. There could be a balanced approach in the future, wherein XR tools are deployed to complement traditional teaching methodologies to enhance these tools align with and enhance educational objectives. Careful planning and implementation of VR can transform it from a novel innovation into a potent educational tool that enriches the learning environment without overshadowing the fundamental goals of education (RQ 1 & 2). Moreover, results also implicated a collaborative approach to overcoming the educational challenges prevalent in rural communities through the use of XR technologies (RQ3). One of the potential contributions of this research project is a call for a united front of educators, policymakers, and technology developers to work together in seeing barriers these under-represented communities face, such as limited access to advanced educational resources and infrastructure (RQ 1, 2 & 3). These challenges significantly impede the efforts of rural educators and hinder the prospects of younger generations from under-represented backgrounds. A distinct disadvantage can be seen compared to their urban counterparts (RQ 1, 2 & 3). Thus, national strategic in-

vestments in technology, training, and curriculum development are worth considering. This project may also contribute to showing hope that we can mediate the persistent educational disparities by integrating XR technologies into the academic sectors.

7.3.5 Chrono-system

The chrono-system recognizes that personal and environmental characteristics change over time and that these changes can significantly impact development. The chrono-system includes life transitions, significant events, and historical contexts that occur throughout an individual's life, as well as broader changes that take place over historical time and affect entire societies (Bronfenbrenner, 1989; Newman & Newman, 2020a; Guy-Evans, 2020). This research project shows that XR technologies, encompassing both VR and AR, can serve as cornerstone tools for educational enrichment across various contexts, particularly in remote rural communities (RQ1, 2 & 3). The disadvantages of traditional educational resources traditionally characterize these areas. For example, from textbooks to laboratory equipment, these under-represented areas have limited resources and quality of educational experiences available to rural educators and students. Although rural educators and students exhibited strong enthusiasm for VR and XR more broadly, it depends on how it can be critically practiced at a broad level (RQ1, 2 & 3). Unlike conventional teaching methods that rely heavily on passive forms of learning, XR technologies immerse students in their learning experiences, making education more engaging and interactive. At a chrono-system level, this immersive quality is precious in rural education, where XR can transcend geographical and socio-economic barriers, bringing world-class educational content to remote areas. For example, students can explore historical events, scientific phenomena, and complex mathematical concepts in a virtual space, making learning not only accessible but also captivating (RQ 2). Therefore, another moderate contribution of this research project is that by integrating VR, AR, and XR into educational settings, the research posits a powerful case for how these technologies can bridge such gaps, offering rich, interactive learning environments that foster social development and mitigate educational disparities. The potential contribution to the ecosystem's extension is that this research facilitated a modern application of Bronfenbrenner's ecological systems theory by highlighting how XR technology. It also can profoundly influence the micro-system through enhanced social competencies and support networks for rural children. By bridging disparate micro-system elements such as home and school, XR technology could foster a robust meso-system that supports integrated learning experiences, while addressing the exo-system through its ability to offer solutions despite infrastructural challenges. At the macro-system level, these findings illustrated how the cultural and societal embrace of XR can support educational equality, leveraging technology to level the playing field for under-represented communities. Lastly, from the chrono-system perspective, this research helped present the timely significance of XR in education, where historical and lo-

gistical barriers are mitigated through immersive, engaging learning experiences that adapt over time to meet the evolving needs of rural educational settings.

7.4 Contribution, Limitation, and Future Studies

This research project addresses educational inequalities in rural China by integrating XR and education as a potential solution. It highlights the hardship and challenges faced by schools, educators, and children from remote rural areas - long story short, it was challenging for them to access quality education. Therefore, the studies of this research project show that XR technology can create meaningful and creative learning experiences for the under-presented rural residents. Findings reveal that there is potential between XR technologies and educational activities to be adaptable for various environments, including contemporary learning environments. Findings also implicated the importance of evidence-based development of XR solutions in education to address the diverse needs of learners in our society. Finally, the project presents the potential that XR technology can revolutionize the traditional teaching experience. It can also bring transformative changes to rural education, especially for children lacking equal access to formal learning opportunities. Findings indicated that XR holds the potential to meet the needs of a diverse student population in developing social competence traits essential for navigating the complexities of today's world. This development meant leveraging XR technology to reduce educational inequalities is not just a pipe dream. XR technology could potentially reduce educational disparities in underdeveloped regions, and it is promising to turn this vision into a reality. However, certain limitations within the scope of this project must be acknowledged.

Study 1 - Utilizing virtual reality to assist social competence education and social support for children from under-represented backgrounds focused on educational inequality and children from under-represented backgrounds. This research primarily explored rural children's experience of social competence education in VR, Lego, and traditional classroom learning. Thus, it did not include rural educators' perspectives on the VR application in the rural classroom. Yet, results show noticeable possibilities that XR is a constructive and beneficial technology for future rural education. Further studies may extend the research sample and increase the utilization of VR or Lego for rural educators. Further, the curriculum design regarding VR-based teaching and learning should be considered a crucial factor for rural schools' systematic enhancement and sustainable development. Future studies may also consider employing VR to conduct comprehensive programs for all educational levels, enabling engagement on a large scale to improve quality education and reduce inequalities across a diverse student population.

Study 2 named Leveraging Virtual Reality to enhance quality education in rural areas. One limitation of this study was that the focus was mainly on students' perceptions and experiences with VR education, without considering the perspectives of teachers and

parents. By not including the viewpoints of these critical stakeholders, the study may provide an incomplete understanding of the overall impact and effectiveness of VR technology in the classroom. Teachers and parents play crucial roles in shaping the educational environment and supporting students' learning, and their perspectives could provide valuable insights into the benefits and challenges of VR education. Additionally, the study primarily relied on self-reported data from students, which may be subject to biases and inaccuracies. Students' perceptions and experiences may be influenced by various factors, such as their preconceived notions, social desirability bias, or the novelty effect of VR technology. Hence, without objective measures or triangulation of data from different sources, the study's findings may be limited to subjective interpretations and may not fully capture the actual impact of VR education on learning outcomes or academic performance.

Furthermore, the study focused on a specific rural context. Factors such as cultural differences, educational disparities, and technological infrastructure could significantly influence the implementation and effectiveness of VR education in different contexts. Also, the rural context should be considered when interpreting the findings and considering the broader implications of VR technology in education. Future studies may incorporate the viewpoints of researchers and scholars in the same field. For example, examining how teachers perceive and support VR education can shed light on the benefits and challenges of its implementation, enriching the analysis of its outcomes. Future studies can also explore the implementation and effectiveness of VR education in diverse settings, accounting for factors such as cultural differences, educational disparities, and technological infrastructure. By doing so, a more holistic understanding of the impact and effectiveness of VR technology in the classroom can be obtained.

Study -3 The potential of extended reality in rural education's future – perspectives from rural educators provided in-depth exploration using XR as an educational resource by educators working in rural areas. Challenges and opportunities existed for educators in rural areas to take XR-assisted learning into formal classrooms. As XR advances, rural educators expected more innovative applications and content tailored to different educational levels and subjects. They were also unsure, yet anticipated that this technology could enrich the education experience in rural schools and develop rurality. However, a lack of necessary structured design and academic thinking could lead to XR apps that are not well-suited for the classroom setting or do not align with current educational standards for mainstream schools. Therefore, future studies are suggested to 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.

7.5 Summary

Through a series of literature reviews, empirical studies, and suggestions for future studies, these chapters in this research project collectively advocate for a nuanced, strategic, and collaborative approach to harnessing the transformative potential of VR and XR in education, aiming to foster an inclusive and dynamic educational ecosystem. In conclusion, in reflecting on the potential benefits of XR-enhanced education, it is vital to acknowledge the opportunities it presents for underrepresented areas and groups in the 21st century. At the same time, it is true that schools currently lack a specific strategy for implementing XR-enhanced education at various levels of teaching and learning (e.g., social competence education, classroom atmosphere enhancement, and XR training for school educators), the demand for skills cultivated through such innovative methods continues to grow. In this research, XR shows the possibility of being a promising solution to offer a comprehensive educational experience to establish quality education - social skills education, high-quality instruction, a nurturing classroom atmosphere, and diverse creative activities in many educational aspects. Further, leveraging XR technology, we can prompt the development of sustainable educational environments that empower those chronically underrepresented in education, fostering a supportive and engaging learning environment for all.

The potential of XR-enhanced education reaches beyond the conventional boundaries of traditional classrooms, opening doors to new possibilities for learners from diverse backgrounds. It can bridge the educational gap and provide equal access to quality learning experiences, regardless of geographical location or socio-economic status. By embracing XR in education, we pave the way for more inclusive and forward-thinking learning spaces that cater to all students' diverse needs and strengths, which can become a foundation for a more sustainable educational landscape. Likewise, by utilizing the technology, respecting the imperative of inclusion, and recognizing the necessity to redesign our approaches to learning, we can proactively shape a more equitable education system that aligns with the United Nations Sustainable Development Goals. Therefore, XR holds promising possibilities in fostering essential competencies for future education and empowering under-represented individuals (e.g., minority communities, low-income populations, individuals with disabilities, and rural residents) to excel as outstanding citizens in the modern world.

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Appendix A

Appendix: Questionnaire items and reliability

Appendix A. A Multidimensional Social Competence Scale

The full scale can be viewed here:

Trevisan, D. A., Tafreshi, D., Slaney, K. L., Yager, J., & Iarocci, G. (2018). A psychometric evaluation of the Multidimensional Social Competence Scale (MSCS) for young adults. PLoS One, 13(11), e0206800.
<https://doi.org/10.1371/journal.pone.0206800>

Appendix B. Youth Social Support Questionnaire

The full scale can be viewed here:

Dai, X., & Ye, Y. (2017). The Development of Social Support Scale for College Students. Chinese Journal of Clinical Psychology, 15, 456 - 458.

Appendix C. The reliability and items included and deleted in MSCS and YSSQ (Elementary School)

Dimensions	Pre-test α	Post-test α	Items deleted	Pre-test α	Post-test α	Items left
MSCS	0.83	0.83	21	0.86	0.88	56
SM	0.43	7.6	42	0.67	0.7	10
SK	0.72	0.84	73	0.6	0.72	11
DEC	0.37	0.87	NA	0.75	0.87	11
SI	0.38	0.57	59, 13, 40, 52, 67	0.65	0.67	6
ER	0.37	0.26	46, 25, 41, 15, 68, 4	0.53	0.58	5
NSS	0.37	0.33	70, 29, 51, 62	0.67	0.68	7
VCS	0.7*	0.748	56, 63, 61, 50	0.5	0.71	7
YSSQ	0.84	0.89	2	0.88	0.93	15
SSS	0.83	0.9	4, 7	0.58	0.68	5
OSS	0.86	0.89	N/A	0.86	0.89	6
USR	0.84	0.88	N/A	0.84	0.88	6

Note. N/A= not applicable

Appendix D. The reliability and items included and deleted in MSCS and YSSQ (Middle School)

Dimensions	Pre-test α	Post-test α	Items deleted	Pre-test α	Post-test α	Items left
MSCS	0.79	0.85	21	0.86	0.88	56
SM	0.43	7.6	42	0.67	0.7	10
SK	0.72	0.84	73	0.6	0.72	11
DEC	0.37	0.87	NA	0.75	0.87	11
SI	0.38	0.57	59, 13, 40, 52, 67	0.65	0.67	6
ER	0.37	0.26	46, 25, 41, 15, 68, 4	0.53	0.58	5
NSS	0.37	0.33	70, 29, 51, 62	0.67	0.68	7
VCS	0.7	0.748	56, 63, 61, 50	0.5	0.71	7
YSSQ	0.92	0.87	2	0.93	0.88	15
SSS	0.83	0.9	4, 7	0.58	0.68	5
OSS	0.86	0.89	N/A	0.86	0.89	6
USR	0.84	0.88	N/A	0.84	0.88	6

Note. N/A= not applicable

Appendix E. SEEQ Chinese Version

Find it here -

<https://docs.google.com/document/d/1suDwxwldwJYUAQoE3gPPzqCzL.Fh6PU7/edit>

Appendix F. WIHITC Chinese Version

Find it here -

<https://docs.google.com/document/d/1suDwxwldwJYUAQoE3gPPzqCzL.Fh6PU7/edit>

Appendix G. UEQ Questionnaire Chinese Version

Find it here - <https://www.ueq-online.org>

Appendix H. The collaborative analyses process between 2 researchers, which is adapted from Braun and Clarke (2006)

Process of Collaborative Analyses	Description
1. Familiarising yourself with your data	• Reading through the interviews • Noting down initial ideas. • Meeting to discuss and plan the analysis.
2. Generating initial codes	• Coded 5 interviews. • Met and discussed these. • Created a shared codebook, consisting of 17 codes. • Coded through all 34 interviews, one of us in Chinese and one of us in English.
3. Searching for themes	• Re-discussed and calibrated our codes. • Started discussing initial themes and their relation to codes.
4. Reviewing themes	• Re-visiting our codes. • Starting to gather central quotes, based on the discussion of themes. • Beginning to draw the thematic map. • Meeting to discuss and calibrate this.
5. Defining and naming themes	• Working with the themes and thematic map separately. • Considering how this connects to the original research question and could be presented in the written report. • Meeting to discuss this and plan the structure of the written report. • Considering the theoretical, empirical and practical relevance of our analysis.
6. Producing the report	• Writing the report based on the discussions. • Revising based on feedback from co-authors.