MetaACES 2024

JUNE 19 - 21 2024

The 2nd International Conference on Metaverse and Artificial Companions in Education and Society

THEMED-BASED INTERNATIONAL CONFERENCE SERIES TBICS

國立中央大學 National Central University

Hosted by

國立中央大學
National Central University

網路學習科技研究所
Network Learning Technology

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MetaACES 2024

Publisher
National Central University
Graduate Institute of Network Learning Technology

The 2nd International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2024)

Conference Proceedings

Editors:

Chee-Kit LOOI, The Education University of Hong Kong, Hong Kong

Tanja MITROVIC, University of Canterbury, New Zealand

Yu-Ju LAN, Taiwan Normal University, Taiwan

Sridhar IYER, Taiwan Normal University, Taiwan

Sheng-Yi WU, National Pingtung University

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Yu-Pei HSU, National Central University, Taiwan

Yi-Hong ZENG, National Central University, Taiwan

Yen-Che SHU, National Central University, Taiwan

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Conference Chair
Maria Mercedes T. RODRIGO
Ateneo de Manila University, Philippines

The 2nd International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2024) aims to provide an interactive platform for academics, researchers, practitioners, and professionals in the education sector to share and exchange research agenda, innovative ideas as well as practices of promoting and exploring metaverse, artificial companions, and related technologies. MetaACES 2024 comprises keynote speech, panels, teacher forum, and parallel sessions delivered by internationally renowned scholars, researchers, and practitioners. Catalysed and facilitated by emerging technologies, the metaverse and related artificial companions will affect us in every aspect of our lives. MetaACES is one of the APSCE Theme-based International Conference Series.

MetaACES 2024 focuses on the themes related to education and society and has three tracks, namely, Educational Practice and Assessment, Technology Design and Social and Ethics Issues.

The main themes of MetaACES 2024 include but not limit to the followings (in alphabetical order):

Program Track1: AI and Artificial Learning Companions (ALCs) in Education

Artificial Companion in Education
Artificial Companion in Society
Artificial Intelligence (AI) in Education
Artificial Intelligence (AI) in Society
Automated Feedback for AI and ALCs in Education
Avatars or Player Characters for ALCs
Behaviour and/or Interaction Modeling, Detection and Visualization for AI and ALCs in Education
Big Data Analysis and Processing for AI and ALCs in Education
Chatbot in Education
Computational Models of Knowledge and Expertise

Computer-Supported Discussion Analysis and Assessment for AI and ALCs in Education
Educational Robots and Toys in Education
Emotion (Affective State) Modeling, Recognition and Detection
Emotive Agents in Education
Enhancing Grading, Scoring and Feedback for AI and ALCs in Education
Human-Computer Interaction (HCI) design for AI and ALCs in Education
Human-robot interaction (HRI) design for AI and ALCs in Education
Intelligent Agents in Education
Intelligent Tutors and Mentors in Education
Internet of Things (IoT), Internet of Everything (IoE), and/or Sensors in Education
Learning Companion Robots (Robotic Learning Companions)
Learning Companions
Motivational and Affective Factors on Learning with AI and ALCs
Natural Language Processing supported AI and ALCs in Education
Personal Learning Environments (PLE) for AI and ALCs in Education
Sentiment Analysis for AI and ALCs in Education
Simulation and Training (Skill, Competence, Vocational Learning)
Social Network Analysis (SNA) for AI and ALCs in Education
Speech Recognition and Synthesis for AI and ALCs in Education
Stealth Assessment for AI and ALCs in Education
Unstructured and Semi-structured Data for Computers to Read and Learn
User Experience (UX) Evaluation for AI and ALCs in Education
Virtual Animal Learning Companions
Virtual Characters in Learning and Life
Virtual Companions in Learning and Life

Program Track 2: Metaverse in Education

Assessment in Games and Virtual Worlds for Education
Authentic Environments and Worlds for Education
Big Data Analysis and Processing for Education
Bridging Informal and Formal Learning Outcomes
Computational Models of Knowledge and Expertise for Education
Computer-Supported Discussion Analysis and Assessment for Education
Educational Applications of Metaverses
Enhancing Grading, Scoring and Feedback for Education
Game Analytics
Internet of Things (IoT), Internet of Everything (IoE), and/or Sensors in Education

Languages, Thinking Skills, Meta-cognitive Skills, Cognitive Skills, and STE(A)M
Learning Analytics in Educational Games
Metaverse in Education
Metaverse in Society
Roles of Artificial Companions in Metaverse
Virtual and Augmented Learning Environments
VR, AR and Simulation Technology in Education
User Experience (UX) Evaluation for Metaverse in Education

Program Track 3: Social Issues
Deployment of AI and ALCs in Education
Ethical Considerations for AI and ALCs in Education
Impact of using AI and ALCs on student autonomy and agency
Security and Privacy Issues
Sentiment Analysis for AI and ALCs in Education
Using AI and ALCs in promoting diversity and inclusivity in Education
Understanding ethical intersections, trade-offs, and social cost-benefits in the deployment of AI and ALCs in Education

Teacher Forum
With the advancement of AI applications and 5G transmission technology, the Metaverse has expanded the potential of traditional Virtual Reality (VR), especially in K-12 education. K-12 teachers, as front-line designers and implementers in education, possess vital experience in transforming classroom teaching both inside and outside through the use of AI, AR, VR, XR, and the Metaverse. The Teacher Forum of MetaACES 2024 provides K-12 teachers and administrators around the world a platform for publishing papers and exchanging experiences in practical integration of Metaverse in education in order to enhance their professional development. The valuable teaching experiences of the practitioners would not only constitute crucial inspirations and resources for academic researchers, but also offer mutual learning opportunities among peer teachers. We would like to invite K-12 teachers and education administrators around the world to submit their papers to the Teacher Forum and join in the conference community to share their works.
The topics in the Teacher Forum include, but are not limited to, the following:
- Professional Development for Teachers in Metaverse and AI Applications
- Teaching Strategies Integrating Metaverse or AI Applications
- Curriculum Design for Metaverse or AI Applications
- Learning Assessment in Metaverse or AI Applications
- Development of Educational Materials for AR, VR, XR, and Metaverse
- Experience in XR Live Broadcasting and Remote Co-Teaching with the Metaverse
- Policies for Education in the Metaverse or AI Application Education

Warm congratulations to the MetaACES organizing team! My thanks also to all our guests, speakers, and conference participants for contributing your time and expertise to making this event a success!

Maria Mercedes T. RODRIGO
MetaACES 2024 Conference Chair

Ateneo de Manila University, Philippines

MESSAGE FROM THE INTERNATIONAL PROGRAM CHAIR

International Program Chair
Chee-Kit LOOI
The Education University of Hong Kong

The 2nd International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2024), hosted by the Asia-Pacific Society for Computers in Education (APSCE) and organized by National Central University, will be held from June 19 to 21, 2024. I am honored to serve as the International Program Chair for this esteemed event. The International Program Committee is led by a dedicated team, including the Conference Chair, Prof. Maria Mercedes T. RODRIGO, myself as the International Program Chair, and three International Program Track Chairs: Prof. Tanja MITROVIC, Prof. Yu-Ju LAN, and Prof. Sridhar IYER. Additionally, the Local Organizing Chair, Prof. Ying-Tien WU, and Co-Chair Prof. Li-Jen WANG (executive), along with 72 Senior PC members and PC members, and the staff from National Central University have contributed significantly to the success of this conference. MetaACES 2024 calls for full papers, work-in-progress submissions, extended summaries, and extended abstracts from scholars around the world. This year, the conference received a total of 27 submissions from five countries/economies: Singapore, Hong Kong, Croatia, Japan, and Taiwan. The submissions were distributed as follows:

Table 1: Author Statistics by Country or Economy for MetaACES 2024

- Taiwan: 19 submissions
- Singapore: 2 submissions
- Hong Kong: 2 submissions
- Croatia: 1 submission
- Japan: 2 submissions
- Pakistan: 1 submission
- **Total**: 27 submissions

Out of these 27 submissions, 23 were accepted, resulting in a high acceptance rate of 85.19%.

Table 2: Statistics of Paper Acceptance in MetaACES 2024

- Submissions: 27
- Accepted: 23
- Rejected: 4
- **Acceptance Rate**: 85.19%

The accepted manuscripts were categorized into three types: long papers, short papers, and posters. The distribution is as follows:

Table 3: Categories of Accepted Manuscripts in MetaACES 2024

- Long Papers: 5
- Short Papers: 11
- Posters: 7
- **Total**: 23

We are grateful to everyone who contributed to the success of MetaACES 2024. We extend our heartfelt thanks to all the authors for choosing MetaACES 2024 as the venue to present their research. We also thank the Program Committee chairs and members, who meticulously reviewed and selected high-quality abstracts. Our appreciation goes to the local organizing committee from National Central University for their hard work in making this event possible. Special thanks to our keynote speakers, panelists, and session chairs for accepting our invitations and sharing their invaluable insights in the world of MetaACES.

Thank you for your participation and your unwavering support!

Chee-Kit LOOI
International Program Chair

The Education University of Hong Kong

MESSAGE FROM THE LOCAL ORGANIZATION COMMITTEE CHAIR

Local Organization Committee Chair
Ying-Tien WU
National Central University, Taiwan

Dear Esteemed Colleagues, Scholars, and Practitioners,

On behalf of the local organizing committee, I am delighted to welcome you to the 2nd International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2024). We are excited to host this event, providing a platform for sharing innovative ideas and practical experiences in the rapidly evolving fields of the metaverse, artificial companions, and related technologies.

MetaACES 2024 features a comprehensive program with keynote speeches, panel discussions, a teacher forum, and parallel sessions led by renowned scholars and practitioners. Our conference focuses on three key tracks, exploring the impact of AI, AR, VR, XR, and the metaverse on education and society. The Teacher Forum offers K-12 educators a space to share insights on integrating these technologies into classroom teaching, fostering professional development and mutual learning.

I extend my gratitude to our track chairs, co-chairs, keynote speakers, panelists, and participants. Your engagement makes MetaACES 2024 an enriching and inspiring event. Welcome to MetaACES 2024. Let us explore the transformative potential of the metaverse and artificial companions in education together.

Warm regards,

Ying-Tien WU
Local Organization Committee Chair

National Central University, Taiwan

ABOUT THE CONFERENCE

MetaACES is one of the APSCE Theme-based International Conference Series. The 2nd International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2024), organized by National Central University in Taiwan, will be held on 19 - 21 June 2024.

MetaACES 2024 aims to provide an interactive platform for academics, researchers, practitioners, and professionals in the education sector to share and exchange research agenda, innovative ideas as well as practices of promoting and exploring metaverse, AI companions, and related technologies. MetaACES 2024 comprises keynotes, seminars and panels delivered by internationally renowned scholars, researchers, and practitioners. Catalysed and facilitated by emerging technologies, the metaverse and related Artificial companions will affect us in every aspect of our lives.

The conference program includes keynotes, seminars, presentations, and panels. All the accepted papers and abstracts of the conference will be published in ISBN-coded proceedings. Accepted full papers will be selected and invited to submit to one of the following Open Access journals: Research and Practice in Technology Enhanced Learning, and IEEE TCLT's Bulletin of the Technical Committee on Learning Technology.

ORGANIZATION

Conference Chair
Maria Mercedes T. RODRIGO
Ateneo de Manila University, Philippine

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Chee-Kit LOOI
The Education University of Hong Kong

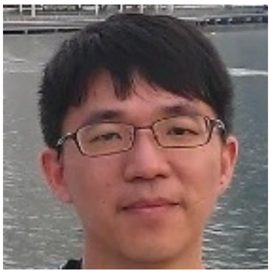
International Program Chair (Executive)
Ying-Tien WU
National Central University, Taiwan

Secretary (Executive)
Li-Jen (Tommy) WANG
National Central University, Taiwan

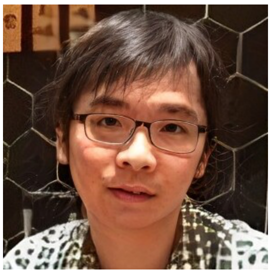
Program Tracks

Track 1: AI and Artificial Companions in Education

Track Chair
Tanja MITROVIC
University of Canterbury, New Zealand



Track Co-chair
Zhi-Hong CHEN
National Taiwan Normal University, Taiwan



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National Central University, Taiwan

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Taiwan Normal University, Taiwan

Track Co-chair
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Wen-Chi (Vivian) WU
Asia University, Taiwan

Track 3: Social Issues

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Taiwan Normal University, Taiwan

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Jiun-Yu WU
National Yang Ming Chiao Tung University

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Hong Kong Baptist University, Hong Kong

Teacher Forum

Track Chair
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National Pingtung University

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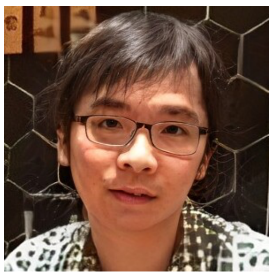

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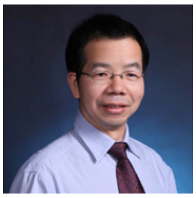

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Chih-Hsiao TSAI, National Taipei University of Education
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Yun WEN, National Institute of Education, Nanyang Technological University, Singapore
Xiaokun ZHANG, Athabasca University

Social Issues Track

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Secretary

Yu-Pei HSU, National Central University, Taiwan

Assistant Secretary

Yi-Hong ZENG, National Central University, Taiwan

PROGRAM AT A GLANCE

19 - 21 June 2024

Taiwan Time (GMT+8)

Physical Venue: Engineering Building 5, NCU

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By Prof. Lewis Johnson
Moderator:
Prof. Tak-Wai CHAN</td><td rowspan="2">Panel discussion 1
Main Theme: Metaverse
Chaired by
Prof. Yu-Ju LAN</td></tr>
<tr><td>09:40-10:30</td><td colspan="2">Keynote 1
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Moderator:
Prof. Chen-Chun LIU</td></tr>
<tr><td>10:40-12:00</td><td colspan="2">Paper Session 1
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Prof. Ivica Boticki
(Track 2: L*1+S*3)
ID:0877, 0963, 5263, 3617</td><td>Paper Session 4
Moderator:
Prof. Yun WEN
(Track 2: L*1+S*4)
ID:6634, 9244, 8741, 8573, 6242</td><td>Panel discussion 2
Main Theme: AI
Chaired by
Prof. Siu-Cheung KONG
(10:40-11:30)
Closing Ceremony</td></tr>
<tr><td>12:00-13:30</td><td colspan="2">Lunch Break</td><td>Lunch Break</td><td rowspan="5"></td></tr>
<tr><td>13:30-14:30</td><td colspan="2">Keynote 2
By Prof. Maria Roussou
Moderator:
Prof. Chee-Kit LOOI</td><td>Keynote 4
By Prof. Yu-Ju LAN
Moderator:
Prof. Yun WEN</td></tr>
<tr><td>14:30-15:35</td><td>Paper Session 2
Moderator:
Dr. Charles Y. C. YEH
(Track 1: L*1+ S*2)
ID:2342, 3403, 7021</td><td rowspan="3">Teacher Forum</td><td>Paper Session 5
Moderator:
Prof. Chang-Yen LIAO
(Track1: S*1)
ID: 7806</td></tr>
<tr><td>15:35-16:10</td><td>Coffee Break</td><td rowspan="2">Coffee Break
&
Poster Presentation</td></tr>
<tr><td>16:10-17:15</td><td>Paper Session 3
Moderator:
Prof. Li-Jen WANG
(Track 2: L*1)
ID:4377</td></tr>
</table>

*Poster presentation ID: 4083, 9776, 6378, 6764, 0009, 2316. The poster session is from 16:10 to 17:15 on June 20, 2024.

*The conference banquet will be held on June 20th at Picture of Eatogether (饗食天堂) in Zhongli City. Transportation will be provided by the conference.

KEYNOTE

Title: Envisioning AI Learning Companions

Date: 19 June 2024 (Wednesday)

Time: 09:40 - 10:30

Speaker: Tak-Wai CHAN
National Chair Professor,
National Central University, Taiwan

Speaker Bio:
Professor Tak-Wai CHAN is a visionary. In 1988, he published his PhD thesis on AI learning companions, a groundbreaking research on AI in education (AIED). After completing his PhD in the USA in 1989, he worked on a series of network learning research projects at National Central University. Together with his colleagues, he developed the first dedicated network learning system in the world to support collaborative learning and competitive game-based learning, published in 1992. He launched the world's largest online learning community, EduCities, in 2000. He has been at the forefront of research on intelligent classrooms, one-to-one technology-enhanced learning, and mobile learning, and proposed the notion of Seamless Learning in 2006. To support the long-term transformation of Asian education from examination-driven to interest and creation-driven, he developed the Interest-Driven Creator (IDC) Theory with Asian scholars in 2018. Currently, he promotes Global Harmony and Wellbeing (Global Harwell) as a shared Global Educational Goal. Professor Chan was a key co-founder of the Asia-Pacific Society for Computers in Education (APSCE) and the Global Chinese Society for Computers in Education (GCSCE). These societies organize annual conference series ICCEs and GCCCEs and publish their official journals. He also founded the Association of Reading for Tomorrow and a mini experimental elementary school in Taiwan.

Abstract
In 1988, I proposed the concept of AI companions for learning and developed a prototype of it. Today, AI is seen as a potential threat to human beings. In fact, humanity is facing unprecedented challenges—millions of lives lost to COVID-19, climate change, resource depletion, environmental pollution, and wealth disparity. Furthermore, the escalation of global conflicts raises concerns about the possibility of a nuclear apocalypse and World War III. The world is teetering on the brink of peril. We must ask: What is the very reason for the existence of the human knowledge and technologies we have created? What is the meaning of going to school? What is education?

However, researchers in our field have long been focusing on how students learn and what they learn, but not why they learn. The resurgence of AI, particularly AI companions, therefore, must be able to guide us from how we learned and what we knew in the past to how we'll learn and what we need to know in the future. Much more important is that we must adopt Global Harwell (a term combining harmony and wellbeing) as a shared global educational goal and build AI companions to assist in achieving this goal. This talk is based on a series of nascent thoughts on AI learning companions developed with my colleagues in Taiwan, as well as on the Global Harwell Goal in collaboration with international researchers.

KEYNOTE

Title: Pedagogical Agents in the Age of Generative AI

Date: 19 June 2024 (Wednesday)

Time: 13:30 - 14:30

Speaker: W. Lewis Johnson
Professor,
University of Southern California

Speaker Bio:

Dr. W. Lewis Johnson co-founded Alelo in 2005 as a spinout of the University of Southern California, under his leadership Alelo has developed into a major producer of innovative learning solutions. Alelo's AI-powered pedagogical agents to help people rapidly learn new skills. Alelo has developed learning products for use in a number of countries around the world, with over 500,000 learners to date. Dr. Johnson is a co-winner of the DARPATech Technical Achievement Award, the IFAAMAS Influential Paper Award, and the XPRIZE Rapid Resklilling Competition. He speaks Chinese, Russian, and other languages of the East Asian region.

Abstract

Generative AI is powering a new generation of pedagogical agents that are highly effective and can transform how people learn. Pedagogical agents are now more adaptive and personalized than has ever been possible before. They give learners opportunities to practice new skills in a safe environment, resulting in rapid learning gains and improved retention. Generative AI is also transforming the workforce, and this poses challenges for training, education, and society at large. As organizations adopt generative AI, jobs are being transformed and entry-level positions are being eliminated. Pedagogical agents can help people quickly develop the skills that they will need to succeed in the workforce of the future, including people skills, critical thinking, and responsible use of AI. This talk will discuss current trends in generative AI and pedagogical agents and also look toward the future, as generative AI expands its capabilities and is integrated into education and training.

KEYNOTE

Title: Designing Reflexivity into Extended Reality Experiences for Learning

Date: 20 June 2024 (Thursday)

Time: 09:30 - 10:30

Speaker: Maria Roussou
Professor,
National and Kapodistrian University of Athens

Speaker Bio:

Dr. Maria Roussou is an Associate Professor in Interactive Systems at the University of Athens. Her career-long explorations of Virtual Reality and Human-Computer Interaction have been positioned at the nexus of education and culture, specializing in designing, developing, and evaluating digital environments and XR experiences for formal and informal education. She holds a PhD in Computer Science from the University of London (UCL); a Master in Fine Arts in Electronic Visualization and an MSc in Electrical Engineering & Computer Science from the University of Illinois at Chicago; and a BSc in Applied Informatics from the Athens University of Economics and Business. She is the recipient of the 2013 Tartessos Award in Digital Heritage and Virtual Archaeology.

Abstract

The integration of immersive experiences into learning has reached a pivotal stage, coinciding with the emergence, accompanied by heightened expectations, of the metaverse and its promise to revolutionize social dynamics. Cultural institutions are actively exploring the metaverse's potential to enrich visitor engagement. In this keynote, I draw from case studies of extended reality applications, emphasizing their role as exploratory tools to foster reflexivity, sociality, hybridity, and historical empathy across diverse cultural landscapes. My aim is to address the complexities encountered during design and implementation, particularly focusing on aspects that may undermine the authenticity of social and cultural nuances within shared physical and virtual spaces. By examining both sophisticated XR applications and lower-end mobile applications, I showcase the evolution of immersive experiences evolving from didactic presentations to interactive, emotive, and socially engaging environments. Through leveraging interactive storytelling and participatory elements, immersive technologies in informal learning can facilitate deeper learning, reflective practices, and historical resonance while preserving the essence of human interaction.

KEYNOTE

Title: New Realities in Language Education: Enhancing language Learning through the metaverse and AI

Date: 20 June 2024 (Thursday)

Time: 13:30 - 14:30

Speaker: Yu-Ju LAN

Research Chair Professor,

National Taiwan Normal University

Speaker Bio:

Dr. Yu-Ju LAN is a Research Chair Professor in the Department of Chinese as a Second Language at National Taiwan Normal University. She is currently the Editor-in-Chief of Educational Technology & Society, Associate Editor of Language Learning & Technology, and on the editorial board of Ampersand. She was awarded the Outstanding Research Award by the Ministry of Science and Technology (MOST), Taiwan, in 2022. Dr. Lan is the founding president of the Taiwan Pedagogy and Practice in TELL Association. Her research interests include technology-enhanced foreign language learning, virtual reality, AI, and online synchronous teacher training.

Abstract

Artificial intelligence (AI) has long been playing an essential role in language education. However, the recent emergence of generative AI models like ChatGPT and Midjourney has reignited interest in the potential of AI applications in education, prompting both excitement and caution. Generative AI holds considerable promise for revolutionizing education across various fronts. With the advent of the Metaverse era, hailed as a transformative phase in internet evolution, there's an urgent need for educators and researchers to reassess the relationship between humans and AI as we reshape our teaching, learning, and everyday experiences. As educators, it's imperative that we engage in open conversations about integrating the Metaverse and AI into language learning, topics that are currently at the forefront of academic discourse. In light of this, the speech will cover several key areas, including an introduction to the Metaverse and generative AI, their practical application in language learning, the opportunities they present, the challenges they pose, and recommendations for future research.

PANEL 1

Title: Transforming Education Through the Metaverse: Unlocking Innovation Beyond Traditional Boundaries

Moderator: Yu-Ju LAN, National Taiwan Normal University, Taiwan

Date: 21 June 2024 (Friday)
Time: 09:40 − 10:30

As we stand at the cusp of a digital revolution, the integration of the metaverse into education heralds a transformative era for teaching and learning. The metaverse, a collective of immersive technologies, expands the reality continuum and has the potential to reshape educational paradigms by creating interactive learning environments that transcend traditional classroom boundaries. This panel explores the transformative potential of the metaverse in education, highlighting its ability to unlock innovative learning experiences and move beyond conventional educational limitations by simulating real-life scenarios, enhancing presence, and providing hands-on learning experiences that enhance comprehension and retention.

Our expert panelists will delve into the multifaceted impact of the metaverse on education, examining its potential to foster creativity, collaboration, and engagement among students. We will also address the challenges associated with implementing the metaverse in education and propose potential solutions to these issues.

Panelist 1: Gwo-Dong CHEN

Personas and Spatial Intelligence of Digital Reality for Learning

National Central University, Taiwan

Panelist 2: Jon-Chao HONG

Training Escaping Skills with Immersive Virtual Reality

National Taiwan Normal University, Taiwan

From the perspective of brain science, when learners perform virtual actions, individual mirror neurons will be activated, and transfer those skills to real environment. Moreover, embodied cognition can make activate prefrontal cortex of the brain, thereby improving learning effects. In line with these, immersive virtual reality (IVR) can simulated virtual environment for learners to practice procedural skill and declarative knowledge. For example, the "Earthquake Escaping", “Fire Escaping” and “Sense of Danger” are developed with IVR, users can learn procedural knowledge and develop “Conditional Response” to cope disaster. In these three IVR, the content includes (1) "Unit training": in different situations for mastery learning. (2) "Situated training": string several units for learners to cope serious dangerous matters. The training system includes (1) Practice module: training on-the-spot reactions and anchoring correct escape knowledge to long-term memory, and scaffolding in mis-steps to reduce the damage that may be caused by misconceptions. (2) Assessment module: learners are allowed to conduct situated assessments, the real responses in cope disaster are recorded through the learners' embodied operations. Expectedly, through the design mechanism in IVR, learners can practice repeatedly to develop disaster response skills to save life from earthquake, fire disaster.

Panelist 3: Yun WEN

Sustainable Use of AR: Cases of Integrating AR in Singapore Primary School Science Classes

National Institute of Education, Nanyang Technological University, Singapore

The use of AR in classrooms to promote collaborative learning and inquiry is not a new topic. However, how to sustainably and on a large scale implement AR-based learning activities in schools remains a challenge. In this talk, Dr. Wen will share her ongoing project about designing, implementing, and scaling up the integration of AR in Singapore primary school science classes. The sharing seeks to provide insights into how to synergize teachers, researchers, and developers to promote pedagogical innovations using emerging technologies like AR.

PANEL 2

Title: Emerging Research Directions in the Era of Generative Artificial Intelligence and Spatial Intelligence

Moderator: Siu-Cheung KONG, The Education University of Hong Kong, Hong Kong

Date: 21 June 2024 (Friday)
Time: 10:40 – 11:30

Panelist 1: Hao-Chiang Koong LIN

National University of Tainan, Taiwan

Panelist 2:W. Lewis Johnson

University of Southern California

Panelist 3: Ting-Chia HSU

National Taiwan Normal University, Taiwan

Panelist 4: Hui-Chun HUNG

National Central University, Taiwan

Panelist 4: Yin YANG

The Education University of Hong Kong, Hong Kong

PROCEEDINGS

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以多維度鷹架機制開發 AI 教育桌遊融入華語教學之研究

A Study on Integrating Mandarin Chinese Teaching through the Development of AI Educational Board Games with a Multidimensional Scaffolding Mechanism

溫如梅 [1*]，鄔湘儀 [2]，黃譯萱 [3]
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【摘要】

本研究以多維度鷹架機制(Hou, 2022）為基礎，設計對外華語 AI 教育桌遊及自編教材。讓機器人擔任輔助的角色，期望學習者能更加沉浸地輸出目標語，並減少焦慮。研究目的以多維度鷹架機制開發 AI 教育桌遊。本研究以「住」為主題的 AI 教育桌遊採用多維度鷹架機制（Hou, 2022）進行設計。在設計和實施教學方法時，使用了多維度鷹架機制中的認知、元認知、策略、同儕和程序，以滿足學生的需求和學習目標。研究工具為桌遊設計評鑑項目表、課室活動觀察表、訪談表。研究結果顯示以多維度鷹架機制開發的 AI 教育桌遊有助提升心流體驗、增進口語練習機會。研究建議未來教學者能應用此模組開發 AI 對外華語教育桌遊與教材，應用在中高級學習者。

【關鍵字】：AI 教育桌遊；華語教學；心流體驗；外語學習焦慮；鷹架理論

Abstract: This study is grounded in the multidimensional scaffolding mechanism proposed by Hou (2022) and aims to design AI educational board games and self-authored teaching materials for teaching Mandarin as a foreign language. By employing robots in auxiliary roles, the intention is to facilitate a deeper immersion of learners in producing the target language and alleviate anxiety. The research objective is to develop AI educational board games utilizing the multidimensional scaffolding mechanism. Focused on the theme of "housing," this study's AI educational board game was designed using the multidimensional scaffolding mechanism (Hou, 2022). In both the design and implementation of teaching methods, various aspects of the scaffolding mechanism including cognitive, metacognitive, strategic, peer, and procedural dimensions were utilized to address students' needs and learning objectives. Research tools included board game design evaluation checklists, classroom activity observation forms, and interview guides. The results indicate that AI educational board games developed using the multidimensional scaffolding mechanism contribute to enhancing flow experiences and providing more opportunities for oral practice. The study recommends that future educators could apply this framework to develop AI Mandarin educational board games and teaching materials, particularly targeting intermediate to advanced learners.

Keywords: AI Educational Board Games, Mandarin Teaching, Flow Experience, Foreign Language Learning Anxiety***, Scaffolding-based Gamification***

1. 研究動機與研究問題

隨著社會進步，遊戲與教育結合成為引人注目的教學模式。馬美娟（2019）研究發現將遊戲融入紅樓夢教學能引發心流體驗並降低學習焦慮。在傳統對外華語教學，學習者在輸出目標語時因考試類似而難以沉浸。因此，本研究以「住」為主題，融合 AI 機器人，開發教育桌遊及自製教材，打破傳統學習方式。讓機器人擔任輔導角色，減少學生語言輸出焦慮。

基於上述，本研究針對 TOCFL A2 等級的華語學習者，研發以「住」為主題的華語教育桌遊及教材、整合機器人輔助，探討教育桌遊在對外華語教學中對學習者的影響。研究問題為：

第一：AI 教育桌遊融入對外華語教學中，開發者的看法為何？

第二：AI 教育桌遊融入對外華語教學中，使用者的看法為何？

2. 文獻回顧與探討

2.1. 桌遊與學習者的心流經驗：心流經驗指在專注執行任務時的愉悅感（Csikszentmihalyi, 1997）。而正向學習態度能提升心流經驗，學習焦慮則降低其程度（譚華德等，2021）。心流經驗的提升可促進學習者自信心。然而，遊戲太難和冗長設計可能降低滿足度，進而影響心流經驗，對學習成效產生負面影響（陳宥瑄等，2022）。因此，本研究將桌上遊戲納入對外華語教學，關注如何維持學生正向學習態度，並引發心流經驗，以提高學習者的學習成效。

2.2. 桌遊與學習者的學習焦慮：學習焦慮是影響學習成效及動機的主因。當人產生苦惱、負向期待、憂慮等情緒反應，容易面臨焦慮（蔡秀玲、楊智馨，1999；Myers, 2004）。此焦慮常源自對不明確或不可控狀態的恐懼，並在學校環境中主要由對失敗的害怕引起，進而影響學習者的自尊心。而外語學習焦慮是一種特殊的焦慮狀態（Horwitz et al., 1986），而其又可分為潛在因素、個人態度及考試焦慮等，其中焦慮與考試成績呈現負相關(Young, 1991)過度可能抑制學習成就(張春興，1999)。研究者發現學習焦慮會影響學習者的表現及成果，而結合桌遊的課程或許能增加趣味，進而提升學習者信心並降低焦慮。

2.3. 多維度鷹架機制融入對外華語教學： 多維度鷹架機制(multidimensional scaffolding mechanism)以 Vygotsky’s (1978)的近側發展區(ZPD)為基礎，形成現實情境、策略監控、實時診斷與協作互動等四大模組。旨在提供玩家全面的互動環境，使其在遊戲中有效學習戰略規劃(Hou, 2022)。近年來，多維度鷹架機制已應用於不同教育領域，如歷史教育手遊等(Chou, et al., 2021)。然而，將多維度鷹架機制運用於對外華語領域的研究尚不充分。因此，研究者欲以多維度鷹架機制設計 AI 對外華語教育桌遊，並探討其影響。

3. 研究方法及步驟

3.1.研究設計：本研究為單組前後測設計，實驗組 15 人，以多維度鷹架機制開發的 AI 教育桌遊「小布住哪兒」進行教學。研究場域以實體教學活動進行實驗，針對此次設計「小布住哪兒」AI 教育桌遊進行探討教育桌遊是否能提升學習者心流經驗、降低學習焦慮。研究場域以實體教學活動進行實驗，針對「小布住哪兒」AI 教育桌遊來探討教育桌遊是否能提升學習者心流經驗並降低學習焦慮。

3.2 .桌遊開發流程：本研究以「住」為主題的 AI 教育桌遊採用多維度鷹架機制（Hou, 2022）進行設計。在設計和實施教學方法時，使用了多維度鷹架機制中的認知、元認知、策略、同儕和程序，以滿足學生的需求和學習目標。以下分別簡述之：

3.2.1.認知鷹架（Cognitive Scaffolding）： 認知鷹架為一種教學策略，目的是協助學生逐步學習新的概念或技能。透過將複雜的任務拆解成小而容易達成的目標，並提供相應的幫助，以協助學生順利完成任務。在遊戲中，我們以認知鷹架設定了目標及遊戲設定，通過遊戲教導在台灣的「住宿」知識、技能，並將學習目標轉化為遊戲內容和機制，確保遊戲能夠促進玩家的學習和成長。

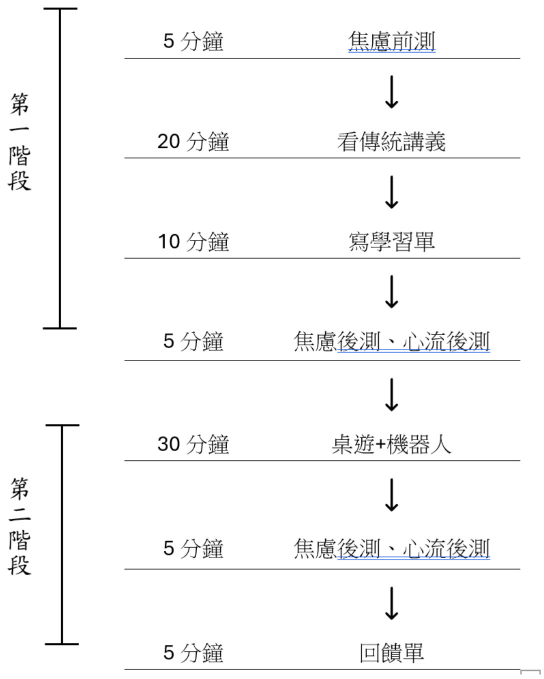
3.2.2.元認知鷹架（Metacognitive Scaffolding）： 強調學生對學習過程的反思和調節。透過支持和指導，教師培養學生元認知能力，提高對學習方式的理解和管理。在「小布住哪兒」桌遊設計中，定期反思和評估遊戲效果、學習者反饋是必要的。完成桌遊後，進行模擬施測，由專家試玩，填寫「桌遊設計評鑑項目表」，收集回饋後進行修正。在實際施測中，機器人輔助能即時給予學習者反饋，促進其了解自身表現。

3.2.3.策略鷹架（Strategic Scaffolding）： 教師提供的各種策略和技巧，能夠協助學生更有效地學習和解決問題，包括記憶技巧和問題解決策略，以提高學習效率和成效。故在遊戲和教學設計中，當學習者遭遇困難時，機教師將適時的提示，協助解決問題，同時激發學習者的學習興趣。

3.2.4.同儕鷹架（Peer Scaffolding）： 指同儕相互支援和學習的過程，透過交流、合作和分享知識，學生能夠互相幫助，一同學習。此 AI 教育桌遊採合作模式，鼓勵玩家合作和互助，共同解決問題和完成任務。

3.2.5.程序鷹架（Procedural Scaffolding）： 此提供對學習過程的程序性的支持和指導，包括教學的組織、安排以及學習活動的指導和監督，確保學生能夠順利完成任務。故在教學指導方面，由教師依教學安排進行授課，教學流程表如表 1，而教育桌遊作為課室活動，讓機器人為學習者提供遊戲教學和指導，並使其正確地應用學習內容。

表 1 課堂活動流程表（總時長：80 分鐘）



3.3.AI 教育桌遊介紹： 本教育桌遊期望讓學生邊玩邊練習聽力及口說，增加趣味性，機器人透過扮演櫃台人員的角色從旁協助，讓學生更沉浸並能輸出目標語。表 2、表 3 詳細介紹：

表 2 AI 對外華語教育桌遊介紹表 (融合鷹架)

小布住哪兒		
背景	朱蒂要來台灣旅遊，請大家依照條件，幫助朱蒂入住、退房。	
目標	以**同儕鷹架**引導學習者深度參與，共同協助朱蒂入住、退房。並透過**程序鷹架**，設計提問、回答問題、購買道具等程序完成遊戲。	
規則	遊戲前	1.抽取角色卡。 2.擲數字骰子，選定本次遊戲條件。 3.擲角色骰子決定第一順位玩家，由第一位玩家決定遊戲方向。
	進行中	1.學習者抽取問題卡，並擲骰子與同儕問答。雙方都可獲得獎勵。（**同儕鷹架**） 2.可購買及使用道具卡，改變遊戲情勢。（**策略鷹架**）
	結束	當有一位玩家成功幫助朱蒂入住及退房，遊戲即結束。
	勝利條件	成功幫助朱蒂入住及退房各乙次。

表 3 遊戲內容物

模型	卡牌	其他道具
公仔、行李箱、金幣、房卡	問號卡、道具卡、對話卡、角色卡	骰子、說明書

3.4.教材設計介紹: 研究者發現華語學習者在目標語輸出時，容易產生焦慮。因此，以AI 教育桌遊為主體，並結合以「住」為主題的教材進行教學，期望以此降低學生的焦慮。而本設計的教材基於多維度鷹架理論，內容包括課文、生詞、語法和相關學習活動，同時結合數位影音呈現。在詞彙設計上，參考「國教院教材編輯輔助系統」和「國教院華語教學標準體系應用查詢系統」中認可的 1-3 級詞彙進行設計。透過主題式教學，使學習者更迅速掌握並能在實際生活中應用。以下是教材語法及詞彙的示意表（表 4、5）。

表 4 語法示意表

語法（英語翻譯）	
恐怕… (probably)	只要……就(as long as...)
先...再(first... then)	V 來 V 去(Repetitively, Back and Forth with V)

表 5 詞彙示意表

房型	櫃台人員	住宿	預訂	旅遊

3.5.研究工具: 為檢測效果，將使用桌遊設計評鑑項目表、課室活動觀察表，並訪談學習者以更深入了解他們的觀點。各工具說明如後:

3.5.1.桌遊設計評鑑項目表: 評估分為四部分：認知設計（50%）包括心流、動機、認知歷程、認知負荷、線索錨定等多種評估，以及社會心理學的互動適切性評估；遊戲性（30%）包括遊戲機制和體驗是否具有樂趣；創新性（15%）不僅指科技運用，還包括主題題材、創新遊戲機制等；視覺呈現（5%）評估整體視覺呈現是否具備美感和協調，以及是否適用於教學。

3.5.2.課室活動觀察表: 在活動中，研究者重點觀察學生間的互動、氣氛、趣事，以及解決問題的效率。此外，活動的流程、進行狀況，以及可能的問題和求助頻率也是觀察的焦點。

3.5.3.訪談紀錄表: 請參與研究的學習者進行訪談，以深入了解他們的觀點和想法。透過比較不同信息和陳述，確保研究的完整性和準確性。有助於研究者提出具說服力的建議。

3.6.資料收集方式與分析: 實驗結束後，將收集資料編碼分析，包括課室觀察、訪談，整理相關資料以備最後的撰寫。開發者的代碼為 D，使用者的代碼為 U，例如:開發者一的觀察結果一，編碼為 D1-1，使用者三的訪談第二項看法，編碼為 U3-2。

4. 研究結果

本研究的 AI 教育桌遊及教材旨在透過結合機器人的方式帶給學習者正向影響：首先，透過桌遊設計根據多維度鷹架理論，提升學習者的心流體驗，豐富的娛樂性有助於專注，增進心流體驗。其次，結合 AI 機器人「小布」作為教學輔助者，擔任學習者的夥伴，減輕學習者的心理負擔，達到降低學習焦慮的效果。

4.1 AI 教育桌遊融入對外華語教學中，開發者的看法為何？

4.1.1 開發者觀察認為 AI 教育桌遊可以提升使用者的心流沉浸感，觀察自述如下:

D1-1: 共分成七組，前四組(小布機器人組)經過幾次講解後，大致對於遊戲規則都能了解。投入程度也比較高，遇到問題會主動詢問。後三組(純人工組)，其中一組，無法理解遊戲規則，過程中情緒比較緩和。

D3-2: 過程中非常沉浸在遊戲中，但這建立在組員間本就有一定的關係基礎。

D5-3: 有些開放性的問題卡可引起討論，例如:你喜歡去哪個國家，能引起他們的思考，其他人也會很好奇別人的答案，進而專注在遊戲中，整體來說，是能有效增進學習興趣的!

4.1.2 遊戲規則應簡化說明，才能讓遊戲順利進行，降低焦慮，觀察自述如下:

D3-1: 大多數組別一開始都不清楚遊戲內容，但如果有我們幫忙帶著開頭後面就幾乎都是順利進行。

D4-1: 今天特別觀察某一組（小布組），發現他們對於規則並不清楚，甚至從一開始就是錯誤的，過程中都需要一直提醒跟詢問。

D5-2: 遊戲前沒有提醒要洗牌，所以抽到入住退房卡的機率很小，少了一些陷害別人的體驗。

4.1.3 遊戲機制與教學應平衡，可玩性和教學性必須兼顧，觀察自述如下:

D1-2: 遊戲過程歡悅，使用者提供許多更改遊戲的思路，例如:主張陷害其他玩家不能達成獲勝條件。

D2-2: 如果是有一定感情基礎的學員一起玩，使用道具卡的趣味性會大大提升，缺點是學生們沈迷於互相陷害的感覺，導致遊戲很難分出勝負。

D4-2: 有少數人對於遊戲積極度不高，有拒絕練習入住對話的情形，大多數時間氣氛都還蠻開心的，

D4-3: 因為組員沒有買道具卡的打算，所以少了一點刺激性。

D5-1: 有一個主持人較好，尤其是對彼此不熟悉的玩家，避免因不了解遊戲規則而熱絡不起來的情況。

4.1.4 實驗環境應該單純化，避免互相干擾，影響機器人的辨識力，觀察自述如下:

D2-1: 因為和小布練習住宿是隨機性的，因此只要抽到小布，學生們都會非常興奮。不過由於教學現場太過吵雜的關係，小布接受不到問題，常常聽不見，容易降低學生的自信心及耐心。

D3-3: 跟小布對話的同學幾乎沒有一次成功的，有兩到三位是因為成為眾人焦點而感到害羞導致緊張、音量變小等，但鼓勵他們完成後反而能更好的活躍遊戲氣氛。

4.2 AI 教育桌遊融入對外華語教學中，使用者的看法為何？

4.2.1 本桌遊與 AI 機器人結合，是否可以幫助你學習語言，並提高學習的興趣?

U5-1: 是，可以練習口語對話、U9-1: 可以 因為可以修正學生音調、U14-1: 可以，改善發音問題

U10-1: 可以提高，因為互動性很強

U16-1: 很好玩，只是講話要字正腔圓並快速，有同學會說到生氣，因為小布聽不懂

U20-1: 可以 透過遊戲的方式可以增加學習華語的興趣和動力，用 AI 可以幫助改正學生的中文發音

U24-1: 應該可以吧，可以提高學習興趣，因為玩遊戲使學生會喜歡思考

U26-1: 可以，能夠與機器人溝通與對同學說話的感覺不一樣，可以更真實的感受實境。

U27-1: 是 透過遊戲可以增加投入感

U28-1: 可以。因為透過遊戲可以在情境中反覆操練。

4.2.2 您對這款桌遊的評價是什麼？是否有需要改善的地方？

U2-1: 我覺得很有趣，不過可以在每一套桌遊裡面有遊戲說明書。

U20-2:還不錯的桌遊，可以把抽問題和回答者的卡牌用成一款手機軟體 這樣比較輕便且快速，不用滿滿抽問題和骰骰子決定回答者

U25-1: 流程有點煩瑣，題目類型不夠多，會一直重複問題。

U28-2: 滿好玩的，第一次玩很好懂。

5. 討論與建議

AI 教育桌遊互動性強，提供情境達到反覆練習、增加投入感與修正聲調的效果。開發者遊戲規則應該用簡化清楚的方式說明，遊戲中才能避免焦慮產生，實驗環境應該單純化，避免各組互相干擾，影響機器人的判別能力。

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A preliminary study on using Generative Artificial Intelligence with an idea-centered approach for SSI-based online inquiry learning.

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Abstract: Online inquiry is a highly recommended instructional strategy *within SSI-based instruction aiming to cultivate students' ability in utilizing scientific knowledge in making thoughtful decisions regarding socio-scientific issues. For most secondary students, they may have insufficient ability and need more scaffolds during SSI-based online inquiry. The use of generative AI (GenAI) with proper instructional designs may improve the effectiveness of SSI-based online inquiry learning. Therefore, this study designed two different approaches (Idea-GenAI and C-GenAI) to integrate GenAI into secondary school students' SSI-based online inquiry learning. Also, the effects of these two approaches were examined. The results show that compared with the students in C-GenAI group, those who in Idea-GenAI group significantly perceived a more idea-generation-supporting learning environment. More importantly, they also outperformed their counterparts in their SSI-based informal reasoning performances after online inquiry.*

Keywords: Socio-Scientific Issues, Generative Artificial Intelligence, Online inquiry learning, Knowledge Building

1. Introduction

Socio-scientific issues (SSIs) are complex and controversial issues caused by the rapid development of science and technology. In recent years, SSI-based instruction has been widely recognized as a valuable and potential instructional method to foster students' scientific literacy and abilities for future citizens (Chen & Xiao, 2021; Sadler, 2004). As SSIs are typically contentious, open-ended, ill-structured problems, the negotiation and resolution of such complex problems are generally characterized by informal reasoning (Wu & Tsai, 2007).

Online inquiry often involves generating questions, searching for relevant information online, understanding and evaluating the information, and integrating relevant information to form solutions. Undoubtedly, acquiring sufficient conceptual understanding and gathering diverse perspectives on an SSI is crucial for reasoning, argumentation or decision-making on this issue. Consequently, online inquiry is often employed in SSI-based instruction to facilitate this process. (e.g., Wu & Tsai, 2010). However, prior studies (e.g., Lim, 2008) have identified some challenges that students encounter during SSI-based online inquiry. For example, during online inquiry, students may struggle with identifying relevant information and screen out irrelevant information on retrieved relevant websites, requiring extensive time and effort. Besides, due to having limited cognitive ability, they may tend to quickly skim webpages to locate the "right answer" to their questions rather than engaging deeply with the content on the webpages, leading to superficial comprehension.

In response to the aforementioned challenges, the current study attempted to integrate generative artificial intelligence (GenAI) during SSI-based online inquiry. GenAI can be used to filter and summarize content from existing website data and generate customized content based on the prompts provided by users. (Miao & Holmes, 2023). In recent years, the emergence of GenAI has provide some promising opportunities for transforming students' learning process and promoting their learning outcomes. In particular, the use of GenAI in SSI-based online inquiry could provide collaborative opportunities for students to work with "others" to produce meaningful artifacts (Hwang & Chen, 2023).

This study is one of the initial attempts to integrate GenAI in secondary students' SSI-based online inquiry learning. In this study, two different approaches in integrating GenAI was designed and implemented. One is C-GenAI approach in which GenAI was used by students in conventional ways, while based on Knowledge Building (KB) Theory (Scardamalia & Bereiter, 2003), an Idea-GenAI approach was also designed to promoting students' idea generation with GenAI during online inquiry process. Then, the effects of the two different approaches integrating GenAI on secondary students' SSI-based online inquiry learng outcomes were also investigated.

The research questions of this study are as follows:

(1) Do the students in Idea-GenAI and C-GenAI groups have significant different perception of their learning environments after SSI-based online inquiry learning?

(2) Do the students in Idea-GenAI and C-GenAI groups have significant differences in their SSI-based reasoning performance after SSI-based online inquiry learning?

2. Method

2.1. Participants and learning contexts

This study aimed to examine the effects of two SSI-based online inquiry learning integrating GenAI with various approaches. The participants were two classes of 8^{th} graders from a middle school in southern Taiwan. The students were taught by the same science teacher. With a quasi-experimental research approach, one class of 26 students was assigned as the Idea-GenAI group, while another class of 25 students was assigned as the C-GenAI group.

2.2. Research Design

Two different SSI-based online inquiry instructions were designed and implemented respectively in the two groups.

Table 1. The two SSI-based online inquiry instructions in the second phase

Online inquiry process	C-GenAI Approach	Idea-GenAI Approach
Ask	An overarching SSI problem regarding the dilemma between technological development and ecology is provided as a springboard. The teacher articulates common problem.	Teacher and Students discuss the SSI problem regarding the dilemma between technological development and ecology through local case studies, stimulating learners' curiosity and encouraging them to articulate their own questions.
Plan	Teacher help Students to form learning plan and problems solving strategies.	Students design their own learning plan and problems solving strategies by engaging in peer-to-peer discourse in class.
Explore	Students carry out the learning plan to solving the SSI problems by using GenAI to gather the information. The GenAI provide just-in time help if necessary.	Students carry out the learning plan to solving the SSI problems by interact with GenAI to build idea. They were encouraged to elaborate ideas by criticizing the contents that GenAI generated.
Construct	Students making meaning out of the data, reasoning and construct their claim for the SSI problem.	Students making meaning out of the data, reasoning and construct their claim for the SSI problem.
Reflect	Students reflect on their conclusion and their inquiry process. Teacher mentions new question for a next cycle of inquiry.	Students reflect on their conclusion and their inquiry process. They apply their conclusion to a new situation and prepare new questions for a next cycle of inquiry.

As shown in Table 1, both of two instructions consist of three phases. In the first phase (1 week), the teacher introduced Generative AI tools and demanded students conducting an online inquiry with GenAI for the SSI issue regarding the dilemma between technological development and ecology and finish a pretest informal reasoning report. In the second phase (5 weeks; one hour for one week), the teacher provides two mini-lessons on socio-scientific issues related to climate change, with the themes "air pollution" and "disasters caused by climate change." The students were asked to conduct an online inquiry with GenAI, and each participant needed to form their claim of socio-scientific issues. In the third phase, students finish a posttest informal reasoning report for the first-phase socio-scientific issue.

In the second phase, the online inquiry learning process proposed by Lim (2008) was used to design the two SSI-based online inquiry instructions. In this phase, different approaches for using GenAI were also integrated into the two SSI-based online inquiry instructions.

2.3. Data collection and analysis

To explore the participants' perception of the learning environment created by the two different approaches, the student's perception of the learning environment was assessed with Knowledge Building Environment Survey (KBES) before and after SSI-based online inquiry. The KBSI includes the following three scales: *Working with Idea* (assessing whether students can facilitate idea exchange and enhance the improvement of ideas during discourse), *Assuming Agency* (examining whether students perceive themselves as learning agents in the environment) and *Fostering Community* (assessing students' perception of shared responsibility within the learning community) (Lin et al., 2014).

Moreover, to evaluate students' SSI-based online inquiry learning outcomes, the two groups of students' SSI-based reasoning performance were examined before and after learning activities. The students' SSI-based reasoning performance were examined with the two aspects: *decision-making mode* and *SSI-based reasoning performance level* (Wu & Tsai, 2007). The students' decision-making modes are categorized into *intuitive* or *evidence-based* decision-making modes. The *SS*I-based reasoning performance were categorized as high-level only when they could generate supportive arguments, counterarguments, and rebuttals on an SSI. (Wu & Tsai, 2007)

4. Results and discussion

4.1. Students' perceptions of the learning environments

As shown in Table 2, the ANCOVA results revealed that the two groups of students show significant differences in perception of the learning environment for Work with Idea (F=8.612**) and Assuming Agency (F=4.210*). The results showed that compared with the students in the C-GenAI group, those in the Idea-GenAI group significantly perceived a more idea-generation-supporting learning environment. This study showed the feasibility of employing Idea-GenAI for SSI-based online inquiry learning, fostering an environment conducive to students' idea generation.

Table 2. The ANCOVA analyses results of students' perception of learning environments

		Mean (adjusted)	Standard error	*F*-value
Work with Idea	Idea-GenAI group(n=26)	3.33	.07	8.61**
	C-GenAI group(n=25)	3.03	.07	
Assuming Agency	Idea-GenAI group(n=26)	3.40	.07	4.21*
	C-GenAI group(n=25)	3.21	.07	
Forster Community	Idea-GenAI group(n=26)	3.34	.07	0
	C-GenAI group(n=25)	3.34	.07	

*p<.05; **p<.01

4.2. Students' SSI-based Reasoning performance

4.2.1. Students' decision-making modes

As revealed in Table 3, the students in the two groups had no significant difference in their decision-making modes before and after the SSI-based online inquiry in this study ($p<0.05$). However, it should be noticed that most of the students in both groups made evidence-based decisions (Idea-GenAI group, 69%; C-GenAI group, 56%) after the SSI-based online inquiry.

Table 3. Students' decision-making mode

	Decision-Making Mode	Idea-GenAI	C-GenAI	$\chi 2$
Pretest	Evidence-based	8(31%)	8(32%)	.009 (n.s.)
	Intuitive	18(69%)	17(68%)	
posttest	Evidence-based	18(69%)	14(56%)	.954 (n.s.)
	Intuitive	8(31%)	11(44%)	

4.2.2. Students' SSI-based reasoning performance

The current study investigated students' construction of arguments for different purposes (i.e., supportive-argument construction, counter-argument construction, and rebuttal construction). The results in Table 6 revealed that the two groups of students showed significant differences in supportive-argument construction and rebuttal construction. It was found in the current study that the two group students were categorized as having "higher reasoning level" because they were capable of constructing not only simple claims (supportive argument) and counterarguments but also rebuttals, and the Idea-GenAI group students showed better performance on the reasoning level rather than the C-GenAI group. However, the existing literature lacks relevant empirical research, thus necessitating further investigation. Additional studies are required to explore the potential enhancement of students' informal reasoning through integrating GenAI into SSI-based online inquiry learning.

Table 4. The ANCOVA analyses results of students' SSI-based reasoning performance

	Group	Mean (adjusted)	Standard error	*F*-value
Supportive-Argument construction	Idea-GenAI group (n=26)	1.67	0.16	7.15*
	C-GenAI group (n=25)	1.06	0.16	
Counter-Argument construction	Idea-GenAI group (n=26)	0.68	0.09	0.27
	C-GenAI group (n=25)	0.61	0.09	
Rebuttal construction	Idea-GenAI group (n=26)	0.81	0.12	5.29*
	C-GenAI group (n=25)	0.40	0.12	

5. Conclusion

This study preliminarily explored the effect of integrating GenAI into SSI-based online inquiry learning on secondary school students' perception of learning environments and SSI-based reasoning performance. It was revealed that compared with the students in the C-GenAI group, those in the Idea-GenAI group significantly perceived a more idea-generation-supporting learning environment. More importantly, they also outperformed their counterparts in their SSI-based informal reasoning performances after online inquiry. In conclusion, Idea-GenAI approach is more beneficial for students' SSI-based online learning.

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具備學科專業知識之生成式 AI 學習同伴系統開發

Development of a Generative AI Learning Companion with Disciplinary Knowledge

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【摘要】 隨著 AI 技術快速發展，各種學習系統應運而生。但現有之 AI 學習同伴存在即時互動性不足、缺乏非正式學習支持、自然語言處理能力有限等限制。相較現有 AI 學習同伴，聊天機器人技術可提供更人性化的互動式學習體驗。例如將 ChatGPT 等生成式 AI 應用於教學領域，具有自然語言理解、個性化學習、知識基礎廣泛等優勢，有利於提升學習動機及解決複雜問題，但因學科專業知識有限，無法提供符合教材之回應。為滿足學生學習需求，本研究開發一套具備學科專業知識之生成式 AI 學習同伴系統，可根據教師上傳之教材內容與學生對話，期能提升 AI 在教育領域的應用價值。

【關鍵字】 學習同伴；AI 學習同伴；生成式 AI；聊天機器人

Abstract: *Various learning systems have emerged with the rapid advancement of AI technology. However, existing AI learning companions suffer from insufficient real-time interactivity, lack of support for informal learning, and limited natural language processing capabilities. In comparison, chatbot technology can offer a more human-like interactive learning experience. For instance, applying generative AI such as ChatGPT in educational settings brings advantages like natural language comprehension, personalized learning, and extensive knowledge bases, which can enhance learning motivation and complex problem-solving. Nevertheless, due to limitations in disciplinary knowledge, they may not provide responses aligned with the curriculum. This study aims to develop a generative AI learning companion system with disciplinary knowledge to address students' learning needs. Conversations with students will be based on the teaching materials uploaded by teachers, potentially increasing the application value of AI in education.*

Keywords: learning companion, AI learning companion, generative AI, chatbot.

1. 簡介

由於 AI 技術的快速發展，各式的學習系統應運而生，包括個人化學習系統、對話式教學系統、以及融合聊天機器人技術的學習支援系統等。這些 AI 學習同伴，已證實能顯著提升學習成效。然而，這些 AI 學習同伴仍存在諸多限制，如即時互動性不足、自然語言處理能力有限、適應性和持續學習能力不夠以及缺少社交和情感支持(Chou, Chan & Lin, 2003)。以聊天機器人技術為基礎的學習同伴能夠補強這些不足，進而增強

學生的參與度和學習效果。然而，這些聊天機器人在處理多輪對話及理解複雜問題方面還存在局限性(El Janati et al., 2020)。

隨著生成式 AI 技術的進步，如 ChatGPT 等 AI 聊天機器人已被廣泛應用於教學領域。以生成式 AI 為基礎的聊天機器人在自然語言處理能力、個性化學習體驗、廣泛的知識基礎以及即時反饋與支持等方面具有相當大的優勢，不僅可提升學生的學習動機和參與度，還能支持複雜問題解決和創造性思考，並適應不同的學習風格。然而，其知識庫的範圍限制了其所提供資訊的完整性與準確性，無法滿足專業領域的學習需求(Feuerriegel et al., 2023)。

鑒於上述之原因，本研究開發一套具備學科專業知識的生成式 AI 學習同伴系統，此系統使用 Open AI 所研發之大型語言模型 GPT 3.5 做為答覆綜整之工具，並且研發學科專業知識訓練的功能，讓此 AI 學習同伴具備答覆學科專業問題的能力。透過這套生成式 AI 學習同伴系統，學生可以及時獲得學習上所需的專業知識支援，幫助學生提升學習效率與學習成效，提升 AI 聊天機器人在教育領域中的應用價值與效能。

2. 文獻探討

2.1. 學習同伴(Learning Companion)

學習同伴(Learning Companion) 是一種教育代理人，它具有人類的特徵，例如領域能力、情感和其他個人特質，並透過文字、圖形、多媒體或虛擬實境等方式表達或呈現給使用者(Chan et al., 1992;Chou, Chan & Lin, 2003)。學習同伴的目的是增強社會性學習環境的豐富性和動機性，並促進使用者的知識建構和社會互動(Biswas et al., 2001;Chou, Chan & Lin, 2003)。例如：分散式西部系統(Distributed West)這個分散式的學習同伴系統，是由兩臺連線的計算機組成，學生可以在不同地點協同學習和或競爭性學習。該系統還提供了作為學生對手的學習同伴，而不是真正的學生(Chan et al., 1992;Chou, Chan & Lin, 2003)。隨著科技的不斷進步與發展，人工智慧(AI)技術的出現，使創新的教學方法成為可能和學習，人們也運用人工智慧技術為學習同伴解決瓶頸(Holmes et al., 2023)。

2.2. AI 學習同伴(AI Learning Companion)

AI 學習同伴(AI Learning Companion)是利用人工智慧技術來支援教學和學習的系統，包括個性化和對話式教學系統、自動評分和評估以及學習者支持聊天機器人等。然而，AI 學習同伴需要具有透明度，以建立信任並促進學習者的自我反思。它們需要讓人類參與其中，向學習者傳達系統對學習者的信念，並允許學習者檢視模型的參數和模型對學習者的認知。這種溝通應該以一種對學習者來說友好和直觀的方式進行。例如，通過建立能夠與學習者互動的聊天機器人(Chatbot)，可幫助他們複習和解釋學習者知識缺口中的概念(Bulathwela & M. S. S., 2023)。

2.3. 生成式 AI(Generative AI)

生成式 AI 是指能夠從訓練資料中生成看似新穎、有意義的內容的計算技術，它可以以無法與人類區分的方式生成新的內容(Feuerriegel et al., 2023)。隨著使用這項技術的 GPT-4 和 Copilot 的廣泛傳播，我們彼此溝通的方式正在徹底改變(Gimpel et al., 2023;Feuerriegel et al., 2023)。生成式 AI 系統的應用範疇遠超過藝術創作領域，它們不僅能仿效作家的寫作技巧或插畫家的繪畫風格，創造出全新的作品，同時還能作為先進的智慧問答系統，在資訊科技（IT）服務檯、知識性的工作任務以及滿足日常需求（例如烹飪食譜與醫療建議）等領域發揮其功能(Haase et al., 2023;Feuerriegel et al., 2023)。

2.4. 聊天機器人(Chatbot)

以聊天機器人做為 AI 學習同伴解決了 AI 學習同伴只能提供單調的學習內容，無法根據學習者的目標和情緒進行個性化和情感化互動的問題(El Janati et al., 2020)。Chatbot 是一個虛擬助理，能夠與使用者聊天並回應他們的請求。當使用者輸入問題時，它透過機器學習和深度學習技術，分析學習者的行為，根據學習者的特徵和偏好，提供適合的學習策略以及適時的鼓勵(Bulathwela & M. S. S., 2023)。Chatbot 的可靠性和準確性是影響學習者信任和接受度的關鍵因素，但 Chatbot 仍然存在一些缺陷，例如：無法理解複雜語境的問題、處理多輪對話，或者提供不相關的回答(El Janati et al., 2020)。

3. 系統開發

本研究所開發的系統架構如圖 1 所示，包含 6 個模組：教材管理模組、學科知識訓練模組、學習歷程瀏覽模組、學科知識解析模組、回覆內容綜整模組、學習歷程模組；2 個資料庫：教材資料庫、學習歷程資料庫；並且會建立學科知識模型以及使用大型語言模型。

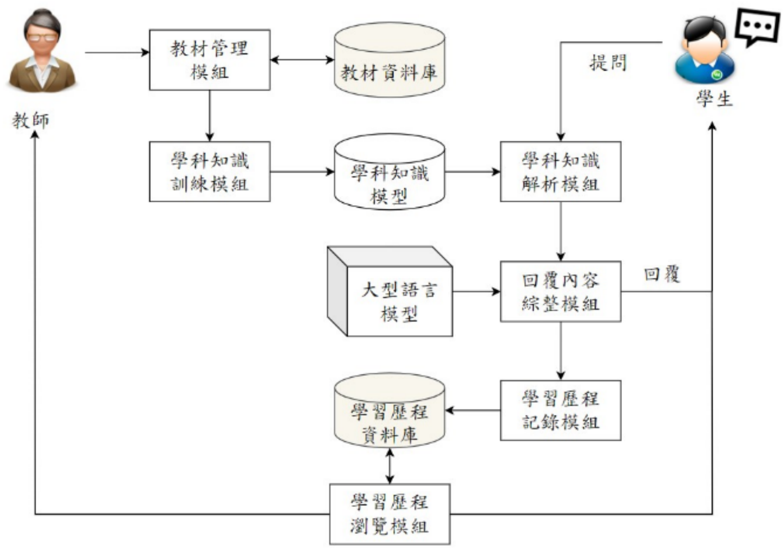


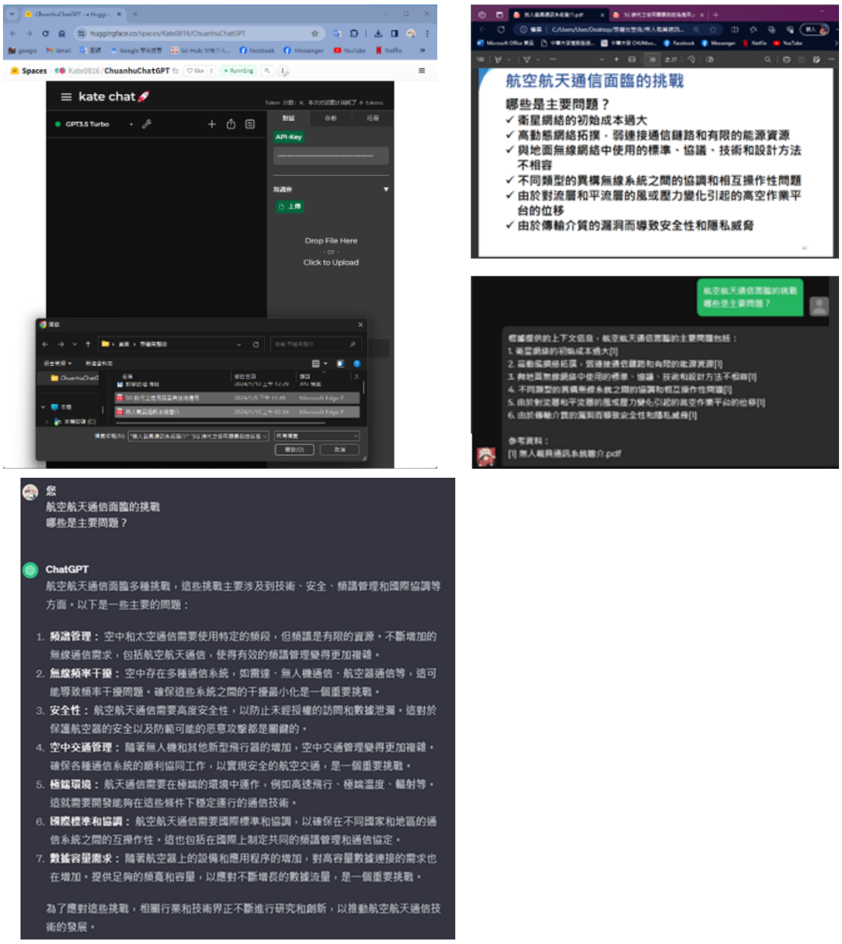
圖 1 系統架構圖

教師透過教材管理模組將 PDF 格式的教材上傳後，即納入教材資料庫。接著，透過學科知識訓練模組利用 OpenAI embedding 將教材內容轉成向量後，使用 FAISS 將向量儲存於學科知識模型中。當學生提問時，系統先呼叫學科知識解析模組，利用 OpenAI embedding 將問題轉成向量後，再利用 FAISS 將問題向量和學科知識模型中的教材向量以餘弦相似性進行快速索引，以萃取出最符合學生問題的教材內容，再將學生的問題以及教材內容傳送給回覆內容綜整模組，利用大型語言模型強大的語意理解與資料整理的

能力，將教材內容整理成學生容易理解的回覆回傳給學生。系統會自動將與學生的對話透過學習歷程記錄模組儲存至學習歷程資料庫，教師和學生均可透過學習歷程瀏覽模組，觀看學生的對話紀錄，以便了解學生的學習狀況。

4. 研究成果

本研究所開發的具備學科知識之生成式 AI 學習同伴系統介面以及問答結果和 ChatGPT 的比較如圖 2。



(a)教師上傳教材介面　(b)教材內容(上)及問答結果(下)　(c) ChatGPT 問答結果

圖 2 系統介面及問答結果比較

教師上傳教材介面如圖 2(a)；所上傳的部分教材內容如圖 2(b)上；學生與 AI 學習同伴的聊天介面如圖 2(b)下，可看到本系統會根據教師所上傳的教材內容回答學生的問題；同一個問題使用 ChatGPT 的問答結果如圖 2(c)，可看到其回覆內容與教材相去甚遠。由此可見，相較於所訓練的知識廣泛且來源不明確的 ChatGPT，本研究所開發的 AI 學習同伴，能提供符合教材內容的答覆，對學生在專業學科上的學習更有幫助。

5. 結論與未來展望

為滿足學生在專業學科上的學習需求，本研究開發一套具備學科專業知識的生成式 AI 學習同伴系統，可針對學生所提出的問題提供符合教師所使用的教材內容之回覆，有

效地提升學生的學習效率，並且具備即時反饋、行動學習...等優點。由於本系統優先利用教師所上傳的教材來取得回覆學生問題的素材，僅利用大型語言模型進行資料綜整，因此回答之內容較一般大型語言模型的回覆，更能夠貼合教師的教學內容。此外，利用 AI 學習同伴與學生進行人機互動，可避免學生礙於害羞不敢發問，同時讓學生因應現代科技趨勢，善用利器。

為驗證本系統對學習的效益，未來本研究將設計教學實驗，將本系統實際應用在教學現場，以實證研究來探討本系統是否能夠有效地提升學生的學習成效。此外，未來本系統也將導入提示語工程，提高系統對回答學科問題的精確度和正確性。同時也將進一步優化使用者介面、支援多平台及擴增多種檔案格式的輸入，使系統更符合教學現場的需求。

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Design and Implementation of a Primary School Reading Learning Companion System Integrated with Generative Artificial Intelligence

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Abstract: *Modeled Sustained Silent Reading is commonly practiced in Taiwanese primary schools. Reading's role in the physical and mental growth of children is consistently highlighted. Nevertheless, the large number of students per teacher makes assessing individual reading impact difficult. The research uses a Generative Artificial Intelligence (GenAI) chatbot and the 4F Active Reviewing Cycle theory to tackle this problem as a reading aid. The reading companions adapt their inquiries to each individual student, drawing on the book's content and the student's previous answers. This method offers a customized reading journey that mirrors the interaction one might have with an actual person. The objective is to boost students' willingness to read and their understanding of texts by employing AI chatbots as educational partners. The system incorporates a reading portfolio dashboard, providing real-time insights. This feature helps teachers accurately assess student reading levels and refine their instructional approaches accordingly. The research aims to reveal the capacity of GenAI chatbots in improving learning, particularly in boosting reading engagement and results among primary school students. This pioneering approach serves not only to heighten their enthusiasm for reading but also assists educators in effectively assessing the reading progress of students.*

Keywords: Reading companion, Generative Artificial Intelligence, 4F Active Reviewing Cycle, Chatbot

1. Introduction

Extensive reading involves students selecting books they find interesting and reading broadly to aid language development, especially improving reading comprehension and vocabulary expansion (Schmitt, 2008). However, even structured tasks that require students to complete reading assignments and collect data on book borrowing cannot ascertain if students are genuinely reading the books (McQuillan, 2019). In recent years, a focus on individual abilities and interests has led to personalized learning, tailoring teaching strategies according to students' individual needs.

Generative Artificial Intelligence (GenAI) plays multiple roles in education—as a teacher, student, expert, and learning partner. It helps with information-driven questions and supports student projects, leading to a more student-focused learning approach and relieving educators of some pressure (Hwang & Chen, 2023). Chatbots demonstrate the potential of artificial intelligence in education, serving not only as a learning aid for students by providing instant problem-solving but also by offering personalized learning materials and content based on students' needs, thereby enhancing learning efficiency and motivation. A significant advantage of learning with chatbots is the ability to study anytime and anywhere, unrestricted by time and location, and the ability to provide interactive engagement for multiple students simultaneously, overcoming traditional educational challenges related to teacher time and environmental constraints (Essel et al., 2022).

The study explores using a GenAI chatbot in Modeled Sustained Silent Reading (MSSR) for primary education. The goal is to have the chatbot interact with students, asking 4F questions to evaluate their understanding of books. The research also examines how these interactions influence student engagement and interest in reading, by analyzing their interaction processes. A dashboard that highlights students' interaction processes will be available for teachers, offering insights into learning behaviors and variances among students. This tool aims to help educators easily grasp students' progress in reading and take necessary follow-up actions, leading to more effective teaching strategies.

2. Literature Review

2.1. Generative Artificial Intelligence (GenAI)

Generative Artificial Intelligence is a type of unsupervised or semi-supervised machine learning framework that generates human-like behaviors through the use of statistics, probability, and other methods (Jovanovic & Campbell, 2022). For students, it can serve as a means for translation, essay writing, seeking answers to questions, and receiving formative feedback (Qadir, 2023). ChatGPT (Generative Pre-trained Transformer, GPT) is a chatbot based on GenAI developed by OpenAI. It is pre-trained on a large scale to understand and generate natural language text. The ChatGPT integrated learning system not only can handle large amounts of data, but can also be used to create more engaging learning experiences (Javaid et al., 2023). Chatbots demonstrate the potential of AI in the educational field, not only serving as a learning support tool providing instant answers to students' questions but also offering personalized learning materials and content based on students' needs, thereby enhancing learning efficiency and motivation (Essel et al., 2022).

2.2. Learning Companions and Chatbots

Learning Companions, also referred to as learning partners, play a pivotal role in educational activities, acting as peers who learn alongside students or collaborate with them to achieve learning tasks or engage in mutual competition. This engagement is instrumental in enhancing students' motivation, participation, and attention, while the dynamics of competition and collaboration stimulate learning, yielding positive outcomes for students (Chen et al., 2011). Learning companion systems offer immediate and personalized guidance, catering to the diverse needs of students and fostering effective learning. By analyzing learning histories and performances, these systems can provide precise recommendations, aiding students in overcoming difficulties and boosting their motivation for learning.

Chatbots simulates human conversation through voice or text modalities. Through Natural Language Processing (NLP) technology, they can comprehend human language and mimic interaction with humans while performing specific tasks. Utilizing chatbots as a dialogic reading interactions with students has been shown to enhance participation in the reading process and support children's vocabulary learning and comprehension (Liu et al., 2022; Xu et al., 2022), proving to be as effective as human companions in improving students' reading comprehension abilities (Zhou & Yadav, 2017).

2.3. Reading-Related Theories

Extensive reading typically involves reading a large amount of material where students can read books of their choice at their own pace. Chan et al. introduced MSSR in 2015, emphasizing the importance of choosing books freely and reading quietly undisturbed for a period, thereby fostering reading habits among students. Teachers serve as role models for students reading continuously in a quiet classroom environment, facilitating the formation of sustained reading habits among students, aligning with the ten principles of extensive reading instruction proposed by Day and Bamford (2002).

Interactive reading involves teachers or parents reading and discussing stories, words, and themes with students. The 4F strategy, which stands for Facts, Feelings, Findings, and Future, is a widely used approach in education. This strategy was developed based on Roger Greenaway's "Active Reviewing Cycle" theory (Greenaway, 2018). It helps students progress from basic factual recall to more advanced levels of thinking and application by utilizing different levels of questioning. This structured questioning not only promotes multi-faceted thinking among students but also provides a clear framework for guiding reading discussions. Xu et al. (2022)'s research demonstrated that dialogic reading with conversational agents could achieve effects comparable to those with human companions, also showing that invisible conversational agents could effectively engage children in dialogic reading activities.

3. System Design

This study has developed a Reading Companion Platform aimed at providing personalized interaction for primary school students' reading learning, assisting teachers in real-time monitoring of students' reading progress. This effectively addresses the challenges inherent in traditional reading instruction, such as confirming whether students are genuinely engaged in reading and the delayed identification of students facing reading difficulties. Through interaction analysis from chat records and learning analytics dashboards generated by Tableau, a profound understanding of students' reading outcomes and challenges encountered throughout the course is attained.

This research employs the OpenAI Assistants API to develop a chatbot tailored for each book, enhancing students' reading comprehension through interactive learning. By integrating retrieval technology, the bot answers students' queries based on book content. The 4F question module guides students through different story aspects: Facts about plot and characters, Feelings to explore character emotions, Findings for analytical perspectives, and

Future scenarios for creative thinking. This method enhances students' comprehension and creative thinking, creating an interactive environment that encourages proactive exploration and learning.

The system architecture with three main components: interaction log data collection, data storage and processing, and visualization. It starts with setting up a dedicated reading server and installing software and log collection packages to gather students' reading interaction logs in real time. A dedicated database processes and updates these data instantly, while Tableau merges and links data tables to ensure data integrity. Through Tableau Cloud, visualized dashboards are created and embedded into the platform. This innovative approach aims to enhance the quality and efficiency of reading education for primary school students.

After reading the books, students interact with the chatbot through text dialogue, reviewing both questions and feedback provided by the bot. This interaction is not limited to answering questions but also includes discussion and understanding of the feedback provided by the bot. Moreover, both students and teachers can view their own and their class's reading portfolio dashboard. The dashboards illustrate the various interaction scenarios that occur between students and the system, including the total number of user interactions, the number of module activations, the number of book interactions and dialogues, the trigger sequence, and the detailed interaction content. This not only helps teachers develop more personalized teaching plans but also encourages students to reflect on themselves, thereby promoting a deeper understanding of the reading material.

4. Expected Outcomes and Discussion

To investigate the impact of reading companions and assess the effectiveness of this approach, this study anticipates applying the system to primary school students. It is anticipated that students will engage in book talks with chatbot after reading books chosen based on their interests. Subsequently, a learning portfolio dashboard detailing students' reading status and interaction will be provided to teachers. Allows teachers to swiftly understand students' reading and interaction situations through dashboard analytics and offer further interaction to students who need it, thus addressing the challenge of high student-to-teacher ratios in large classrooms that prevent teachers from interacting with all students simultaneously. This research plans to collect pre- and post-tests, questionnaires, and system log from students and establish a reading portfolio dashboard for them. Overall, this study aims to demonstrate the potential of GenAI chatbots in the educational field, especially in enhancing students' reading participation and outcomes. This innovative approach is intended to not only increase students' interest in reading but also provide teachers with an effective tool for assessing student learning.

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Revolutionizing Shared Reading:

Supporting Teacher-Student Book Conversations with AI Companions

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Abstract: *This study explores the development of an AI Companion designed to enhance book conversations between teachers and students. The system tackles the challenges of facilitating effective book conversations by analyzing audio recordings to gain deeper insights into student participation. 1) analyzing student book conversations involves transcribing audio recordings to text, allowing for a comprehensive review of student interactions. 2) creating student book conversation portfolios establishes a personalized record for each student, capturing their progress, comprehension, and reflections. 3) providing subsequent book reading recommendations offers teachers guidance on future book choices based on the student's interests, reading level, and academic goals. Five teachers participated in a two-month trial to assess the impact of the AI Companion. Preliminary findings indicate that the system significantly reduces teachers' workloads during book conversations by automatically transcribing and analyzing discussions. Additionally, teachers found it easier to select and recommend suitable books for students using the system's filters and curated reading lists. The AI Companion demonstrated its potential to streamline book conversations and enhance the educational experience.*

Keywords: Shared Reading, AI Companion, Teacher-Student Book Discussion

1. Introduction

When students participate in shared book-reading activities with peers, teachers, or family members, these activities significantly impact their language and literacy skill development. According to a meta-analysis by Noble et al. (2018), shared reading interventions positively affect language development. However, challenges in shared book-reading activities can be categorized into three primary aspects: student-related, teacher-related, and student-teacher interaction. Each of these aspects contributes to the overall effectiveness of book discussion sessions. It is worth noting that teachers face multifaceted challenges in shared book-reading sessions. According to Hindman, Wasik, and Bradley (2019), teachers often rely on closed prompts during shared reading, which limits the depth of discussion and exploration of ideas. Despite the recognized importance of shared book reading, schools often lack more opportunities for students to engage in such activities. To address this gap, the current research proposes AI companions to support teachers and students in book conversations, aiming to facilitate more effective student-teacher interactions. The goal of introducing structured support for shared reading is to enrich the book conversation experience, enhancing the educational outcomes of these activities.

2. Developing an AI Companion to Support Book Conversations

This study developed an AI Companion to supprot book conversations between teachers and students. The primary function is based on analyzing audio recordings of teacher-student interactions to capture and understand student participation in book conversations. The AI Companion aims to analyze conversation content, create student book conversation portfolios, and offer subsequent reading recommendations to students and teachers.

Analyzing Student Book Conversations: Conversations were transcribed into text using OpenAI Whisper, which provided a text base for OpenAI GPT to summarize and generate recommendations. The 4F reading strategy (Facts, Findings, Function, Future) was used to assess students' performance in book conversations and refine the analysis. A "Book Conversation History" portfolio was created for each student, capturing their engagement, comprehension, and responses to the reading material. The AI-generated insights, enhanced by the 4F reading strategy, gave teachers a comprehensive understanding of each student's reading experience.

Creating Student Book Conversation Portfolios: The goal of building these portfolios is to document the student's development over time through book conversations. Each portfolio showcases the student's growth and participation, highlighting their critical thinking, interpretive skills, and personal reflections on the books they have read. It is a tangible representation of their evolving relationship with literature and progress as reflective readers. With these portfolios, educators can provide personalized support for future conversations, fostering an environment that promotes literacy growth.

Providing Subsequent Book Reading Recommendations: Recommendations for future book conversations emphasize offering guidance and direction following the conversation. Suggestions include thematic or conceptual connections with other texts, critical questions for exploration, and activities that deepen comprehension. This approach reinforces understanding, encourages deeper literary analysis, and nurtures enthusiasm for reading. Recommending books tailored to each student's interests, reading level, and educational goals will help them grow academically and personally. The recommendations should challenge them appropriately, expand their literary horizons, and boost their confidence. This will ultimately foster a lifelong love of reading and learning.

3. Preliminary Findings

In this study, we collaborated with five teachers in a two-month trial and collected data through system records, field observations, and interviews to assess whether the AI Companion can facilitate book conversations between teachers and students. Preliminary Findings: 1) Reducing Teachers' Workload During Book Conversations: Initial classroom observations indicate that teachers are using the book conversation recording system to document and transcribe student discussions, removing the need for manual notetaking. This approach allows teachers to fully participate in the dialogue, potentially enhancing the quality and efficiency of book conversation sessions. 2) Easier Selection and Recommendation of Suitable Books: Operational logs from the system reveal that teachers often use the filters to recommend books tailored to each student's individual needs. Some educators even choose from a list of suggested readings generated automatically by the system. This access to the Student Book Conversation Portfolios simplifies the process of selecting suitable books for students.

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Modelling and Optimising Evolution of Self-organising task specialisation in ant-inspired AI swarms

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Abstract: *This research endeavours to model and optimise the evolution of self-organising task specialisation in ant-inspired AI swarms, drawing inspiration from the intricate behaviour and evolution observed in ant colonies. The primary motivation stems from the remarkable efficiency and adaptability of Pheidole megacephala (Fabricius) ant colonies in task allocation, particularly the evolution of specialised castes such as soldiers with larger heads for nest defence and smaller workers for food collection. We use an agent-based simulation model, set in a grid-based environment, to simulate ant colonies tasked with collecting and transporting food. Intriguingly, colonies face decisions on energy allocation for ant production, introducing a size mutation rate that influences the percentage of ants produced with larger sizes. Larger ants are not only more energy-intensive to produce but also serve a defensive role against predators. We aim to investigate the impact of such size mutations on the colony's overall efficiency and survival, drawing parallels to Pheidole megacephala ants, where bigger heads aid in nest defence. The simulation provides a platform to study the optimal spread of mutation rates that maximises resource gathering, and through generational analysis, this study attempts to identify adaptive strategies that balance energy allocation, defence mechanisms, and foraging efficiency in ant-inspired AI swarms.*

Keywords: Ant-inspired AI swarms, Task allocation, Agent-based simulation model, Genetic algorithm

1. Literature Review

Task-partitioning refers to the splitting of tasks to be accomplished by different agents, it typically involves task-specialisation in which the agent taking up the task develops traits that make it better at accomplishing it. Most models assume that task partitioning and specialisation emerge to increase the efficiency of the colony. The first type of model utilises ants with varying threshold levels towards certain stimuli such that in the presence of a stimulus that exceeds the threshold, the behaviours of the individual ant would change accordingly. The latter type of model utilises environmental modifications such as pheromone trails to provide feedback to individual ants and influence their actions. However, to the best of our knowledge, despite being factors that contribute to how ants task partition, predatory pressure and polymorphism have not been widely explored within simulations that aim to simulate the emergence of task partitioning and specialisation within swarm agents. Predatory pressure, which refers to the availability of predators that attack the ant has been speculated to drive the evolution of certain ants. One example is the *Cephalotes*, also known as turtle ants. To prevent predators in the form of nest-site competitors from usurping and taking over their nest, such ants have evolved to have armoured heads which they use to block the entrance of their nest and fend off predators. Such adaptations eventually lead to specialised ants taking up specialised tasks such as defending the nest or fighting against predators. Polymorphism which involves ants developing features in two or more distinctive ways also seems to help drive task-partitioning. Research found that larger-sized Majors from the genus *Oecophylla Smaragdina* exhibited a higher frequency of aggressive behaviours than their smaller-sized Minor counterparts. This would mean that the larger ants, which are more adapted towards fighting predators would likely be ‘assigned’ to the role of fighting and fending off predators as they tend to be more aggressive. Thus it would suggest that ants which experience morphological variation would be conditioned or assigned to perform the task which their features are adapted for. In view of this, our simulation seeks to find how the presence of polymorphism and predatory pressure affect how the colony interact and task partition.

2. Methodology

The simulation model attempts to simulate the emergence of task-partitioning of food foraging and fighting off predators through stigmergy in the form of the presence of predators and the amount of food available as well as polymorphism in the form of size variation. It is then subsequently optimised through a basic classical Genetic algorithm to partition tasks more effectively. Following the basic principles of a classical genetic algorithm, our algorithm is split into the four main parts, encoding, selection, crossover and mutation. The inputs of our model were chosen to be the percentage of large ants, the probability of large ants being highly aggressive and the probability of small ants being highly aggressive. The percentage of large ants determines the population distribution of large and small ants. To mimic resource constraints, we decided to allocate an arbitrary amount of resource points and make it such that each large ant spawned takes up 2 points and each small ant spawned takes up 1 point. The total number of ants was determined through the following formula:$(x-1)n+ 2xn =$ resource points where n is the total number of ants and x is the percentage of large ants. To represent the presence of polymorphism, we assumed that larger ants are more effective at fighting prey as observed in Pheidole megacephaly. We thus simulate the large ants to be more adept at surviving and fighting against predators. This also works to offset the disadvantage of having a smaller overall ant population with each increasing number of large-sized ants. Finally, the probability of large ants being aggressive and small ants being aggressive are given as probabilities of the large ants or small ants having their aggression level. The aggression level is dichotomous and can either be set to high or low. If the aggression level is high, the ants have an 80% chance that they will decide to attack predators when encountering them. Conversely, aggression level is low, ants only have a 20% chance that they will decide to attack the predator. The encoding function generates a random genome that provides variable inputs to the model and determines the characteristics of each individual. In the case of our model, real value encoding was utilised where each value generated within the genome was used to represent the value of a specific gene. The genome was structured to generate 3 random floating point numbers that serve to represent the percentage of large-sized ants, the probability of large-sized ants being aggressive and the probability of small-sized ants being aggressive within each colony. The selection function evaluates the fitness score of each individual in each generation and chooses a specific number of parents that would subsequently provide their genes to future generations based on their individual scores. In our model, we decided to select colonies based on their score which is calculated as the number of food collected by the ants generated by each colony. This was chosen as the selection function under the assumption that colonies that collected the most food before dying to predators were the most effective in how they partitioned the task of food foraging and fending off predators. The selection function first sorts through the list which contains nested dictionaries that collect data on each colony and arrange the colonies based on their scores. After which another list is set to collect the top few best-performing ants information such as their genome sequence. The crossover function is used to generate the genome of offspring by splicing the genome of the selected parents. Our model utilises a single-point crossover function where a random gene within the genome is selected to be the crossover point where the genomes of parents are swapped, giving rise to diversity within the off-spring colonies. It first selects two random parent genomes from the parent list that was obtained through the selection function. After which a random gene in the genome is selected to be the crossover point and the genomes of the parents are separated and combined to form the new offspring genome which is then stored within the respective offspring list. The mutation function is responsible for mutating the genes of the genomes of the next generation to further increase diversity within the offspring. In our model, each gene within the genome has a chance of mutating the agents defined by the mutation rate which was set to be 0. 4 to mutate each of the genomes. Due to limited available documentation of similar setups to run genetic algorithms through the MESA framework, we had to devise ways to set how the genetic algorithm to run each colony individually within the model. As we were unable to get the Mesa Model to render visualisations without calling the step function, we chose instead to utilise conditional to represent when each colony is represented and when each generation happens. However, doing so made data collection more difficult than expected as we had to run through each colony and generation manually. We decided to run a simulation using 5 colonies and ran it for 10 generations. The number of food is set constant at 30 and its position is randomly generated but remains constant throughout the entire simulation to minimise randomization.

3. Results and Discussion

For our simulation, we decided to collect information on the scores of the colonies across generations through the use of heat maps. The results showed that as the generation increased, the max score of 30 also became more frequent amongst the ant colonies as observed in the darker hue concentrated at the top left-hand corner of the heat map. This suggests that the algorithm was able to optimise the task partitioning of ants to collect the food and fend off predators. However, the line graph where we plotted the average score of colonies against generations demonstrated conflicting results. The results in contrast show that the mean score fluctuates as generation increases. This discrepancy could be attributed to the failure of the algorithm to enable task partitioning and optimisation to happen effectively. However, it is likely that the model was not calibrated appropriately in terms of the quantities of food, number of predators as well as the population and generations to run. This might have resulted in a local maximum easily, preventing further optimisation with subsequent generations. As such we are unable to conclusively determine whether the algorithm was able to optimise and allow for task partitioning of ants to happen effectively.

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How Lecturer Avatar Visual Realism Influences Students in Metaverse: A Comparative Experiment Using Low-, Medium-, and High-Realism Avatars

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Abstract: *Metaverse has immense potential in the next-generation education, and avatar is an important component in metaverse. Herein, a university-oriented metaverse system called "Tokudiverse" was prototyped. In this study, focusing on lecturer avatar visual realism, three avatar levels were defined and implemented: low-realism avatar (LRA), medium-realism avatar (MRA), and high-realism avatar (HRA). Subsequently, a comparative experiment was conducted to investigate the influence of LRA, MRA, and HRA on students in Tokudiverse. Experimental results indicated that avatars did not demonstrate great differences in terms of learning effect and impressions and should be improved in terms of being humanlike, natural, and creepy.*

Keywords: avatar, visual realism, metaverse, semantic differential method

1. Introduction

Metaverse is becoming widespread as the next-generation virtual reality (VR) and social media, exhibiting immense application potential in various fields, including education (Jim et al., 2023). For example, the possibility of applying metaverse to language learning was discussed in a previous report (Wu et al., 2023), and a fusion of metaverse and artificial intelligence was applied to experiential learning (Nagendran et al., 2022). The author's group has prototyped a university-oriented metaverse system called "Tokudiverse," which enables users (i.e., students and professors) to communicate via human avatars in a three-dimensional virtual world modeled on the blueprint of a real university campus. In this system, professors can deliver lectures while presenting a slideshow on a front screen in lecture rooms and pointing to slides with a laser pointer. Tokudiverse works not only as a university-oriented metaverse system but also as a metaverse-based evacuation training system that instantly generates an earthquake and begins evacuation training in the virtual world (Oe et al., 2022).

Currently, the author is focused on avatars, which can influence user perceptions and experiences in any types of metaverse. For example, group work inclusion in a virtual classroom setting was influenced by avatar customization (Buck et al., 2023). Especially, the influence of avatar visual realism (appearances) can be remarkable because visual perception is the most dominant among other perceptions in humans. For instance, a study investigated how people rate real humans after seeing attractive and unattractive avatars (Leding et al., 2015). Furthermore, an investigation regarding the avatar-self appearance similarity revealed that avatars without appearance similarity promoted self-disclosure in personal-topic discussions (Ichino et al., 2022). In a virtual remote lecture, different avatars delivering divided short-time lectures activated students rather than one avatar giving a long-time lecture (Mizuho et al., 2023).

2. Avatar Visual Realism

Avatar creation/customization systems have been popularized to reduce the burden on metaverse users in creating their resemblance or favorite avatars. These systems automatically create an avatar from a user's uploaded face image (s) and/or enable the user to customize the avatar by selecting preset elements (e.g., facial parts, face shapes, and hairstyles).

Avatar visual realism is a key factor for ensuring better user experiences in a metaverse, such as smooth and continuous user-to-user communication. Kim et al. (2023) categorized avatar realism into visual and behavioral realisms. Visual realism consists of two dimensions: anthropomorphism and fidelity. Behavioral realism consists of two dimensions: kinetic conformity and social appropriateness. The anthropomorphism dimension, which represents the level of similarity between avatars and humans, is a prerequisite in Tokudiverse that adopts human avatars. In addition, the fidelity dimension, which represents the level of similarity between avatars and real humans in terms of audiovisual aspects (i.e., rendering, shading, and naturalness of voice), must be considered but has not yet been investigated in the Tokudiverse.

Focusing on the fidelity dimension, the author categorized visual realism into three levels as follows (Figure 1):

Low-Realism: Low-realism avatar (LRA) is created in the form of preset elements combined by a user. Due to limited preset elements, users experience difficulty in developing a resemblance between the avatar and themself or someone else intended. For example, avatars created with Vroid (https://vroid.com/studio) can be categorized as LRA.

Medium-Realism: Medium-realism avatar (MRA) is automatically created as a default avatar comprising preset elements estimated from a user's face image. Subsequently, the user can create a resemblance between the default avatar and themself by customizing it (i.e., modifying preset elements). For example, avatars created with ReadyPlayerMe (https://readyplayer.me/) can be categorized as MRA.

High-Realism: High-realism avatar (HRA) is automatically created as a default avatar, whose face is modeled and rendered from a user's face image(s). The default avatar's face is not customizable but resembles the user face at the polygon level. Subsequently, the user can customize face-excluded parts (e.g., hairstyle and clothes). For instance, avatars produced with Avaturn (https://avaturn.me/) can be categorized as HRA.

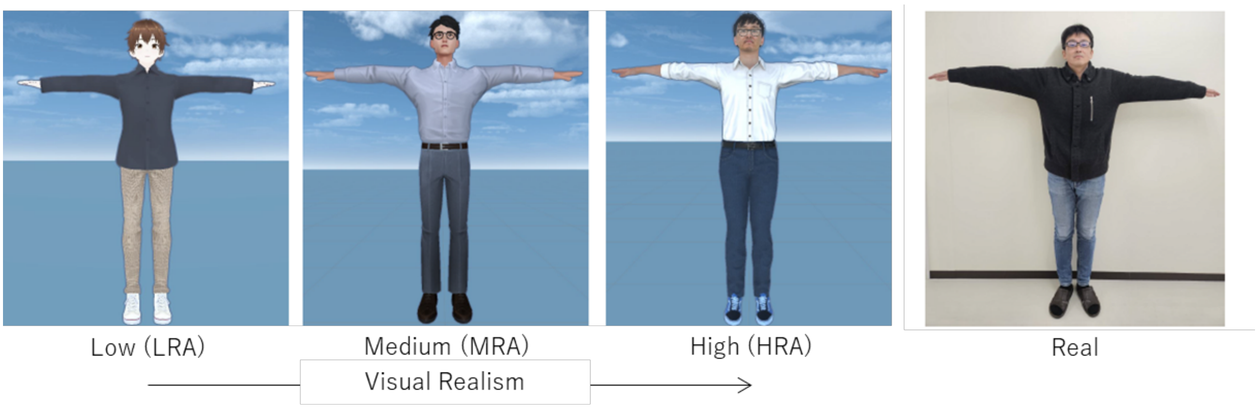

Figure 1. Spectrum of avatar visual realism in Tokudiverse.

3. Comparative Experiment

After preparing the LRA, MRA, and HRA of a lecturer, a crossover-trial-style comparative experiment was conducted to investigate the influence of lecturer avatar visual realism on students in Tokudiverse. Crossover trials, often conducted in the field of medical research, prioritize effective experiments with fewer-participant conditions and require a relatively long duration, including time intervals (washout) between phases (Li et al., 2015).

The author hypothesized that differences among avatars would not influence the learning effect (acquired knowledge) because the lecture contents (i.e., slides and speeches) were fixed.

3.1. Settings

For the experiment, two functions were implemented in Tokudiverse. The lecture recording function records the movement and voice, timing of slide switching, and other data related to the lecturer wearing Meta Quest 2 (goggles and controllers). The lecture replaying function replays the lectures by animating the avatar (switchable among LRA, MRA, and HRA), playing the voice, and switching the slide based on the recorded data.

3.1.1. Lecture Topic

In the experiment, the targeted lecture was "Multimedia Engineering," which included four topics: T1: Multimedia Fundamentals (e.g., analog/digital data), T2: Digitization Methods (e.g., sampling theory), T3: Image Data (e.g., BMP), and T4: Data Compression (e.g., JPEG). The author delivered lectures as the lecturer avatar.

3.1.2. Participant

Sixteen students taking science and engineering courses at Tokushima University voluntarily participated in the experiment by responding to a demographic questionnaire. Their responses revealed that the participants were aged between 21 and 24 years (one female and fifteen males), and 14 of them had VR experience.

3.1.3. Flow

The experiment was conducted in the form of short-duration three-way crossover trials that were completed within less than two hours. Before the experiment, the participants were encouraged to become acquainted with multimedia technology for information literacy through a sequence of lectures and were informed to take three mini tests.

I. The participants watched a video lecture on T1 to recognize the lecturer's real appearance and lecture style.

II. They responded to a pre-questionnaire comprising the following questions:
   - "Have you been taught by the lecturer before?" Option: "Yes" or "No"
   - "Have you acquired knowledge explained in the video lecture before?" Option: "Yes," "Partially yes," or "No."

III. They were divided into three groups—A ($N = 6$), B ($N = 5$), and C ($N = 5$)—to categorize the participants as evenly as possible based on their responses. For each group, topics were aligned in the same order, but avatars, i.e., LRA (Vroid), MRA (ReadyPlayerMe), and HRA (Avaturn), were arranged in different orders. In other words, all participants took lectures by all avatars.

IV. At different times, each participant wore a goggle (Meta Quest 2) and took lectures following the designated order (Figure 2). During lectures, they could look around from a fixed position (almost center) in the lecture room but could not move around. All lectures have duration of approximately 20 min.

V. Immediately after each lecture, the participant was given a five-question mini test to test their knowledge of the topic explained in the lecture. Furthermore, a questionnaire was provided to the participants inquiring about their impressions of the corresponding avatar. The questionnaire included an open-ended question for collecting their frank opinions and further questions based on a semantic differential (SD) method. The participants provided answers regarding their impressions of avatars by selecting one among five choices in each of the 20 pairs of two polarized adjectives (e.g., 1: Boring–5: Interesting).

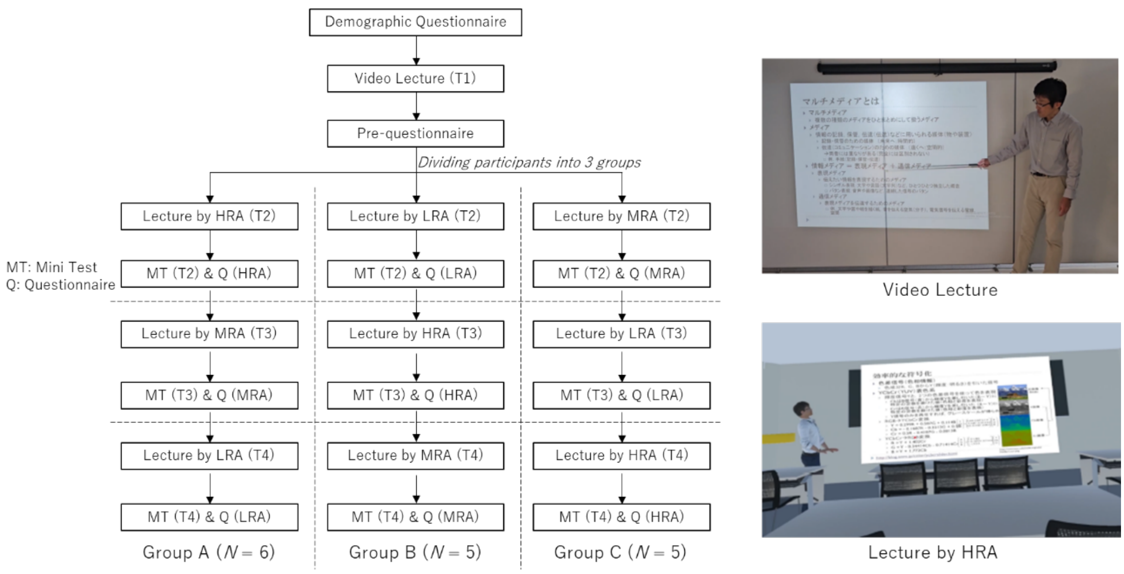

Figure 2. Experimental Flow and screenshots.

3.2. Results

Five participants in Groups A and C and four participants in Group B had been taught by the lecturer before. Four participants in Group A and two participants in Groups B and C already had knowledge regarding the topic covered in T1. The other participants had partial knowledge of the above-mentioned topic.

3.2.1. Learning Effect

The mean scores of the mini tests on the lectures by the LRA, MRA, and HRA were 5.06, 6.62, and 5.0, respectively. Note that the maximum score was 15. Multiple comparison tests revealed no significant differences among the avatars.

3.2.2. Impression

Table 1 illustrates the mean values of answers to 5-Likert scale questions that inquired about the rough impressions of the participants on the avatars in terms of being humanlike, natural, and creepy. Multiple comparison tests revealed no significant differences among the avatars.

Figure 3 shows the mean values of the detailed impressions on the avatars via the adjective pairs in the SD method. Multiple comparison tests revealed significant differences with respect to dark–bright (p = .0119*), light–heavy (p = .0095**), and weak–strong (p = .0318*) between the LRA (Vroid) and HRA (Avaturn). These significant differences indicate that the LRA was brighter, lighter, and weaker than the HRA. From the opposite viewpoint, the HRA was darker, heavier, and stronger than the LRA. No significant differences were found between the LRA and MRA as well as MRA and HRA.

Table 1. Mean values of rough impressions on avatars.

	LRA	MRA	HRA
Q1. Do you agree that you felt the avatar to be humanlike?	1.87	2.56	2.75
Q2. Do you agree that you felt the avatar to be natural?	1.5	2.25	2.12
Q3. Do you agree that you did not feel the avatar to be creepy?	2.47	2.43	2.06

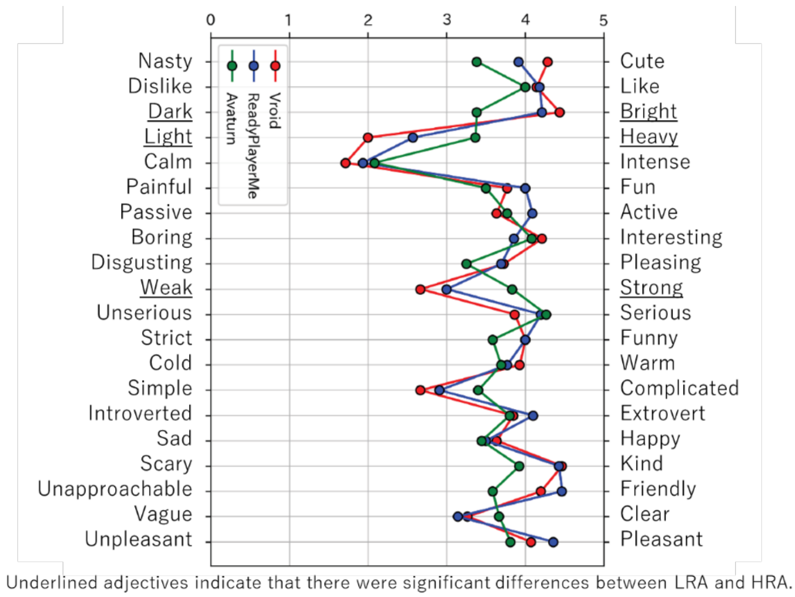

Figure 3. Detailed impressions of participants on avatars.

3.3. Considerations

3.3.1. Learning Effect

With respect to all the avatars, the mean scores of the mini tests were low and not significantly different. Although the mean values may have depended on the participants' pre-acquired knowledge about the topics, the author infers from the results that the lecturer avatar visual realism did not influence the learning effect. Thus, the hypothesis is verified. However, the positional settings may have led to a similar learning effect. In the lecture room, the front screen (slideshow) and the lecture avatar were set straight and toward the left side, relative to the participant position. In other words, the avatars may not always have been within the view of the participants.

3.3.2. Impression

All mean values of Q1–Q3 were lower than 3 and not favorable. The mean values of Q3 for the LRA, MRA, and HRA were 2.47, 2.43, and 2.06, respectively. These results indicate that the participants felt avatars are slightly creepy. Especially, the HRA had the lowest mean value, implying that it may have made the participants fall in the uncanny valley (Mori, 2012). Originally, several participants may have faced difficulty in accepting avatars as substitutes for human lecturers. Although there were not significant differences, the LRA was inferior to the MRA and HRA in terms of being humanlike and natural. LRA-related opinions collected via the open-ended question included "The anime-like avatar is not humanlike (N = 4)," "The avatar made strange actions (N = 2)," and "Humanlike but not human lecturer had the lecture (N = 2)." These opinions indicate that some participants felt that the LRA is different from the real lecturer due to its anime-like appearance. Students decide whether the LRA (anime-like avatar) can be recognized as humanlike or not. Additionally, low mean values indicate that the MRA and HRA were not necessarily being humanlike and natural. Especially regarding Q3, the HRA was inferior to the LRA and MRA in terms of being creepy. HRA-related opinions included "The avatar's motions were unnatural (N = 5)," "The avatar's posture was unnatural (N = 2)," and "The avatar had no facial expression (N = 2)." Meanwhile, LRA-related positive opinions were also obtained, such as "I did not feel the avatar creepy thanks to anime-like avatar." Thus, the LRA may be allowed to take actions that slightly vary from the reality, while reminding anime characters. Furthermore, the actions of the HRA must be as much realistic as possible to the real human. Thus, the author assumes that the HRA possibly invokes unnaturalness due to a certain gap between the avatar's face (visually realistic) and motions (unrealistic at times). Overall, the results related to rough impressions indicate that the MRA was the most acceptable as the lecturer avatar.

In several indices for the detailed impressions, significant differences were not observed among the avatars. However, significant differences were found in the three indices between the LRA and HRA. The LRA provided bright, light, and weak impressions. Contrarily, the HRA provided dark, heavy, and strong impressions. These impressions cannot be easily differentiated between superiors and inferiors. For example, communication-oriented lectures require an atmosphere that motivates students to talk to or interact with lecturers; thus, the LRA is considered suitable for communication-oriented lectures. Meanwhile, knowledge-transfer-oriented lectures need an atmosphere that enables students to listen silently; hence, the HRA is considered suitable for knowledge-transfer-oriented lectures. Overall, the results regarding the detailed impressions indicate that lecturer avatar visual realism should not be considered more carefully than required.

3.4. Limitations

The experiment demonstrated limitations with respect to the number and demographics of participants. In addition, the order effect was not completely considered, and various positional settings could generate different experimental results. Although the effect of the positional settings may often be observed in real lecture rooms, it is possible that the positional settings reduced the need to look at avatars; accordingly, these settings did not result in differences in the learning effect. This possibility is applicable to participants' impressions of avatars.

4. Conclusion

This paper reported a comparative experiment to investigate the influence of differences in the lecturer avatar visual realism, i.e., LRA, MRA, and HRA, on the learning effect and impressions regarding avatars among university students in a university-oriented metaverse (Tokudiverse). The experimental results indicated that avatars did not demonstrate great differences with respect to the learning effect and impressions and should be improved in terms of being humanlike, natural, and creepy. Especially regarding the HRA, gaps between the face and motions should be reduced. In addition, the effective use of each avatar should be considered. For example, the LRA should be used for communication-oriented lectures, and the HRA should be used for knowledge-transfer-oriented lectures.

Moreover, the experiment was conducted at a small scale and had limitations. Therefore, the author is planning to collect and analyze more data to clarify the influences of avatar visual realism on learning activities and outcomes. Additionally, the uncanny valley should be discussed because it will exist in not only physical robots but also in avatars in metaverse (Hepperle et al., 2022).

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Epistemic Network Analysis for Competency-Based Learning with Text Mining and Social Network Analysis

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Abstract: *This study employs text mining and social network analysis to apply epistemic network analysis (ENA) methods for exploring and analyzing the learning connotations in courses related to competency-based learning (CBL). The research begins with the analysis of ENA and sets the target learning content as homework. Then, following the spirit of CBL, the competencies are defined to be cultivated in the course and their ENA coding, and then introduce text mining technology from competency coding and concept coding to obtain the competency concept matrix (CCM). This CCM can be used to define an epistemic network, called a competency concept graph (CCG), which is a 2-mode social network for the application of social network analysis (SNA), such as community clustering. Finally, the learning process of the actual implementation of the soft power course is used to prove its practicability, the four competencies C1-C4 in the course are analyzed, and the CCM and CCG corresponding to the four competencies are calculated. From the discussion of the experimental results, it can be concluded that C1 (Turning ability) and C3 (Waiting ability) are deeply entangled, C2 (Persistence ability) is an ability that has nothing to do with emotions, and C4 (One-Step ability), although it has nothing to do with the concept of planning, is related to goals. These results are in line with the original settings of the four competencies, and moreover, more specific connotations can be obtained through this ENA analysis.*

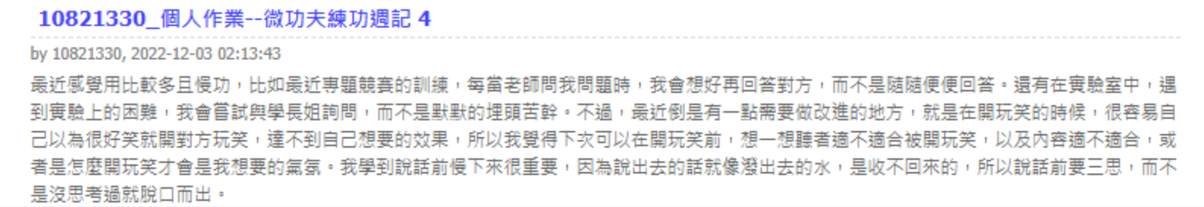
Keywords: Epistemic network analysis, Competency-based learning, Text mining, Social network analysis, Soft power

1. Introduction

Epistemic Network Analysis (ENA) is a powerful method for understanding and quantifying connections among elements in coded data (Shaffer et al., 2016). ENA was developed to model the structure of relationships among Codes in a Discourse over time. ENA enables researchers to identify and quantify connections between different elements (such as codes or concepts) within coded data. It represents these connections as dynamic network models. The key feature of ENA is its ability to compare different networks visually and through summary statistics that reflect the weighted structure of these networks (Shaffer et al., 2016).

By modeling the connections between posts, threads, and users, researchers gain insights into information flow and community dynamics. (1) Textbooks and Educational Materials: ENA has been used to explore how students engage with textbooks, readings, and other educational resources. (2) Homework and Assignments: While ENA is not limited to homework analysis, it can certainly be applied to study student interactions related to assignments. (3) Learning Analytics Platforms: ENA can be integrated into learning analytics platforms to visualize and quantify student interactions (Elmoazen et al., 2022). In practice, ENA is a versatile method that can be adapted to various learning materials, including classroom discussions, textbooks, online forums, and collaborative assignments. Its flexibility allows researchers to explore diverse educational contexts and gain deeper insights into knowledge dynamics.

This paper aims to utilize text mining and social network analysis techniques to process real learning material as shown in Figure 1, and to employ ENA methodology to explore the learning insights of a competency-based course. The second section will define the competency and its ENA coding in the course in accordance with the spirit of CBL, and gradually obtain the competency concept matrix CCM using text mining technology. This CCM will be used to build the epistemic network in ENA, called the competency concept map CCG, and conduct social network analysis. Section 4 will explain the learning process of a practical course, whose CCMs and CCGs of each competency will be interpreted in section 5.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最近感覺用比較多且慢功，比如最近專題競賽的訓練，每當老師問我問題時，我會想好再回答對方，而不是隨隨便便回答。還有在實驗室中，遇到實驗上的困難，我會嘗試與學長姐詢問，而不是默默的埋頭苦幹。不過，最近倒是有一點需要做改進的地方，就是在開玩笑的時候，很容易自己以為很好笑就開對方玩笑，達不到自己想要的效果，所以我覺得下次可以在開玩笑前，想一想聽者適不適合被開玩笑，以及內容適不適合，或者是怎麼開玩笑才會是我想要的氣氛。我學到說話前慢下來很重要，因為說出去的話就像潑出去的水，是收不回來的，所以說話前要三思，而不是沒思考過就脫口而出。

Figure 1. a homework of a CBL course.

2. Competency-Based Learning and its ENA Coding

Competency-Based Learning (CBL) is an educational approach that centers on students demonstrating specific learning outcomes or competencies as the core of their learning process (Henri et al., 2017). There are several key elements of CBL: (1) Progression through Mastery: Students advance based on their ability to master specific competencies rather than traditional credit hours or seat time. (2) Personalization: Learning is tailored to individual needs, allowing students to progress at their own pace. (3) Flexible Assessment: Assessment methods focus on measuring mastery, not just time spent in class. (4) Skill and Disposition Development: CBL emphasizes both knowledge and practical skills (Henri et al., 2017).

CBL competencies may include critical thinking, clinical reasoning (in medical education), ethical decision-making, teamwork, and communication skills. The specific competencies targeted can vary depending on the subject area and learning objectives of the CBL activity. There are several detailed concepts of Competency-Based Learning (CBL): (1) Learner-Centric: CBL places individual learners at the center of the learning process. (2) Outcome-Based: CBL starts by clearly defining learning outcomes. These outcomes specify what learners should achieve by the end of a course or module. (3) Differentiated/Personalized: CBL recognizes that learners have diverse needs, backgrounds, and learning speeds (Henri et al., 2017). Here, the learning material in Figure 1 is adopted as the student-centric interview outcomes which display as a mastering progress.

For understanding of competency-based learning, ENA can dissect student activities, compare teaching practices revealing content flow dynamics. In ENA, "codes" are the basic units used to categorize and quantify qualitative data. Such ENA codes might include specific problem-solving strategies, references to theoretical concepts, expressions of ethical considerations, or instances of collaborative discussion (Ferreira Mello & Gašević, 2019). When transferred to CBL, these codes are derived from the content of learners' discussions, reflections, or other forms of interaction within the CBL activities. Each code represents a specific concept, theme, or aspect of the competency being developed.

For example, some senior tutors propose the competencies of the course Soft-Power can be concluded as Turning ability (轉身功, C1), Persistence ability (終始功, C2), Waiting ability (且慢功, C3), and One-Step ability (一步功, C4). These four competencies can be coded as a four-digit vector C = [C1, C2, C3, C4] or C = C1C2C3C4, which can be used to indicate a competency combination (competency set); for example, C = 1010 means the co-occurrence of C1 and C3.

For one learning homework, there are not only the competencies C (for example, C3 且慢功 in Figure 1), but also many related concepts (for example, keywords 老師, 內容, 學長, …). Thus, text mining is applied to students' homework, including weekly diaries, final reports, etc., as a survey expression of the mastering process, and conduct the analysis of competencies and related concepts (keywords) (Albrecht et al., 2020). Moreover, these keywords (concepts) are clustered to get more precise representation. Finally, the relationship matrix between each competency set and concept (keyword) set, called Competency-Concept Matrix (CCM), can be obtained, as Figure 2 shown. Note that the element in (competency, concept)-cell means its occurrence.

關鍵字類＼功法	1000	1001	1010	1011	1100	1110	1111	S
實際/學長/共識/訊息/過程	1	1	0	1	1	0	1	
對方/同學	0	0	0	0	0	1	4	
對方/店家/講話/運用/對話/主題	2	0	0	1	0	1	1	
同學/經驗	3	0	0	0	1	0	0	
情緒/對方	0	0	3	0	0	0	1	
規劃/主題	0	0	0	0	0	1	2	
禮拜/影片/媽媽/功夫	2	0	0	0	0	1	0	

Figure 2. Competency-concept matrix (CCM).

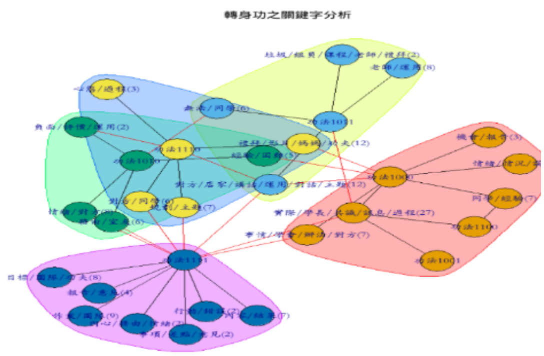


Figure 3. a homework of a CBL course.

3. Epistemic Network of Competencies and its SNA Analysis

An epistemic network, often abbreviated as an "epinet," represents the knowledge-sharing dynamics within a social network. It focuses on what each agent knows about others and their knowledge (Bowman et al., 2021). Epinets help us understand how information flows, trust is established, and coordination occurs within a social context.

The symbolic representation of Epinets is directed graphs that capture the epistemic connections among networked agents. These connections involve key facts, statements, or other propositional beliefs relevant to their actions. ENA is grounded in formal mathematical terms, although it is often applied in educational research and qualitative analysis. It constructs matrix representations of discourse data, generates networks for units of analysis, and places these networks in a metric space.

A similar concept is social networks, which represent the interpersonal relationships among individuals. They highlight who interacts with whom, forming a web of connections. In general, social networks can also be visualized as graphs, where nodes represent individuals, and edges represent relationships (e.g., friendships, collaborations, family ties) (Otte & Rousseau, 2002).

Epistemic networks and social networks are not mutually exclusive. There are several intersections between EN and SN: (1). Epistemic Glue: Epinets serve as the epistemic glue underlying social interactions. What individuals know about each other influences their social connections. (2). Shared Knowledge: Social connections facilitate the exchange of knowledge. When people interact, they share information, beliefs, and perspectives, contributing to the epistemic fabric.

The above Competency-Concept Matrix (CCM) can be used to construct an epistemic network, called Competency-Concept Graph (CCG), as shown in Figure 3. With nodes being competencies and concepts (keywords), such CCG is a typical 2-mode social network, therefore many SNA techniques, such as SNA clustering (shown as colored clusters), can be introduced, as the following experiment shown (Ardanuy & Sporleder, 2015).

4. Experiment for ENA of CBL Courses: Soft Power

An experiment course is held for the above-mentioned epistemic network at a university of northern Taiwan in 2023. This course lasts for half a year. The course name is Soft Power, which mainly introduces and cultivates students' soft power before entering the workplace. There are 20 students, including freshmen to seniors, taking the course.

The course content is divided into three homework itineraries, including a total of 11 topics. (1) Itinerary 1 includes Topic selection (主題選定) and Action plan formulation (行動計畫擬定). (2) Itinerary 3 has only one topic: Final report (期末報告). (3) There are eight Weekly diaries (週記) in Itinerary 2.

The student participation and learning outcomes are listed in Figure 4, which gives the following outlines: (1) 1st grade accounts for about 1/3 (6/20), the other 2-4th grade is pretty average (4-5 students). (2) Approximately 1/3 ((6-4)/6, (4-3)/4, (5-4)/5, (4-4)/4) of grades 1-4 do not finish Final Report (期末報告). (3) 3 (20-17) students have not completed their Topic selection (主題選定) and Action plan formulation (行動計畫擬定), and 1/3 ((20-12)/20) have no Final report (期末報告). (4) Almost all Weekly diaries (週記) are completed.

年級\主題	主題選定	行動計畫擬定	期末報告	週記1	週記2	週記3	週記4	週記5	週記6	週記7	週記8	Sum
1	6	5	4	6	6	6	6	6	6	6	6	63
2	3	3	2	4	4	4	4	4	4	4	4	40
3	3	4	2	5	5	4	5	5	4	5	5	47
4	4	4	3	4	4	4	4	4	4	3	3	41
7	1	1	1	1	1	1	1	1	1	1	1	11
Sum	17	17	12	20	20	19	20	20	19	19	19	202

Figure 4. Student participation of the experiment course.

5. Discussion through Social Network Analysis

With the 202 learning results in Figure 4, the aforementioned text analysis and social network analysis is carried out. First, 202 homework from 20 students were analyzed through text analysis to remove single-character words and some meaningless words, and only nouns were taken, then 79 keywords (concepts) could be obtained. Then the document-term matrix is clustered to obtain 36 keyword categories.

Then the CCM/CCG based on the four main competencies (C1-C4) are subsequently obtained in Table 1. With four kinds of main competency, the second column in Table 1 shows the competency concept matrix CCM (note that only the first several ones with larger weights are listed), and a preliminary interpretation is provided. The third column in the table is the competency concept map CCG obtained from CCM, and is clustered and displayed using social network cluster analysis technology.

From the CCG interpretation obtained in the third column of the table, we can get the following key points:

(1) Competency C1 (轉身功) and C3 (且慢功) are deeply intertwined.

(2) There is no independent concept about C2 (終始功), which shows that it is closely related to other competencies, but does not contain keyword '情緒'.

(3) C3 (且慢功) is related to keyword set 老師/同學.

(4) Although C4 (一步功) does not include concepts such as '規劃/主題', it does have concepts such as '目標/結果'.

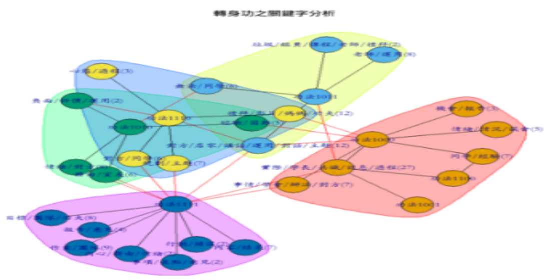
Table 1. CCMs and CCGs of the experiment course.

Competency-Concept Matrix (CCM) | **Competency-Concept Graph (CCG)**

C1 轉身功

關鍵字類\功法	1000	1001	1010	1011	1100	1110	1111	Sum
實際/學長/共識/訊息/過程	1	1	0	1	1	0	1	5
對方/同學	0	0	0	0	0	1	4	5
對方/店家/講話/運用/對話/主題	2	0	0	1	0	1	1	5
同學/經驗	3	0	0	0	1	0	0	4
情緒/對方	0	0	3	0	0	0	1	4
規劃/主題	0	0	0	0	0	1	2	3
禮拜/影片/媽媽/功夫	2	0	0	0	0	1	0	3

(1) All competencies have the first three keyword combinations (實際/學長/.., 對方/同學, 對方/店家/...).
(2) Only the competency C1 (轉身功) has keyword '同學/經驗'.
(3) The three competencies C1 (轉身功) and C3 (且慢功) have '情緒/對方', but C4 (一步功) also has '情緒'.

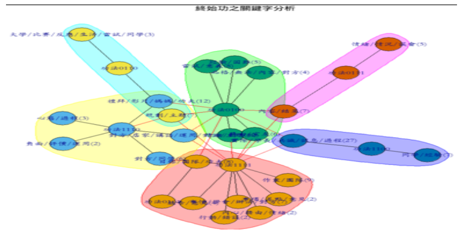


(1) There are five epistemic groups: 2 are relatively isolated and 3 are intertwined.
(2) The most isolated group is composed of all competencies 1111, followed by 1000+1100+1001, which can be seen that 1000 (轉身功) is the core.
(3) The three intertwined groups are composed of 1110, 1011 and 1010, that is, concepts based on C1 (轉身功) and C3 (且慢功).

C2 終始功

關鍵字類\功法	0100	0101	0110	0111	1100	1110	1111	Sum
規劃/主題	2	0	1	0	0	1	2	6
對方/同學	0	0	0	0	0	1	4	5
目標/團隊/功夫	1	1	0	0	0	0	2	4
實際/學長/共識/訊息/過程	2	0	0	0	1	0	1	4
對方/店家/講話/運用/對話/主題	2	0	0	0	0	1	1	4
內容/結果	1	0	0	1	0	0	1	3
報告/意見	0	2	0	0	0	0	1	3

(1) C2(終始功) and C3(一步功) have 3 kinds of keywords:'目標/團隊/功夫','內容/結果', '報告/意見', '內容/結果'.
(2) C1-C3 (轉身功, 終始功, 且慢功) have common keywords ('規劃/主題').
(3) The unique features of C2 (終始功) are: (3A) no keyword 情緒; (3B) no independent keywords.

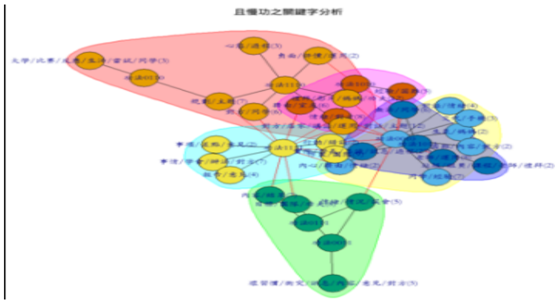


(1) This CCG is divided into 6 cognitive groups around competency 1000 (終始功): 3 groups are relatively isolated and the others are somewhat interwined.
(2) The two most isolated groups are centered on competencies 0111 and 1101 respectively, while the other isolated group includes competencies 1111 and 0101.
(3) The three intertwined groups are based on two concept sets "規劃/主題" and "禮拜/影片/..", then extended to three competency groups: 0100, 0110, and 1110.

C3 且慢功

關鍵字類\功法	0010	0011	0110	0111	1010	1011	1110	1111	Sum
情緒/對方	2	0	0	0	3	0	0	1	6
老師/運用	4	0	0	0	0	1	0	0	5
無法/同學	3	0	0	0	1	1	0	0	5
實際/學長/共識/訊息/過程	3	0	0	0	0	1	0	1	5
對方/同學	0	0	0	0	0	0	1	4	5
規劃/主題	0	0	1	0	0	0	1	2	4
對方/店家/講話/運用/對話/主題	1	0	0	0	0	1	1	1	4

(1) The competencies C1 (轉身功) and C3 (且慢功) have '情緒/對方', but C4 (一步功) also has '情緒'.
(2) C1-C3 (轉身功, 終始功, 且慢功) have common keywords ('規劃/主題').
(3) C3 (且慢功) has unique keywords: '老師/運用' and '無法/同學'.

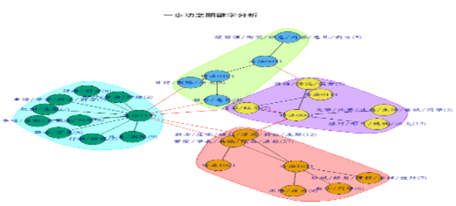


(1) These six groups is the most interwined competencies. Except for the two groups of competencies 1111 and 0011+0111, which are relatively isolated, the other four groups are all interwined together.
(2) Two most interwined groups are 0010 and 1010, which are related to the concept sets of "情緒/對方" and "無法/同學".
(3) The other two more distant interwined competency groups are 1010 and 0110+1110.

C4 一步功

關鍵字類\功法	0001	0011	0101	0111	1001	1011	1111	Sum
實際/學長/共識/訊息/過程	2	0	0	0	1	1	1	5
目標/團隊/功夫	0	1	1	0	0	0	2	4
報告/意見	1	0	2	0	0	0	1	4
對方/同學	0	0	0	0	0	0	4	4
內容/結果	1	0	0	1	0	0	1	3
情緒/情況/誤會	1	1	0	1	0	0	0	3
對方/店家/講話/運用/對話/主題	1	0	0	0	0	1	1	3

(1) C2(終始功) and C3(一步功) have 3 kinds of keywords:'目標/團隊/功夫','內容/結果', '報告/意見', '內容/結果'.
(2) C4 (一步功) also has '情緒', but C1 (轉身功) and C3 (且慢功) have '情緒/對方'.
(3) C4 (一步功) has no keywords ('規劃/主題').



(1) Although this group only has 4 competency groups, they are the most scattered and there is almost no overlap between keywords.
(2) There are 2 groups that only include a single competency group: 1111 and 1011, both of which contain more (more than 6) but less overlapping concept sets.
(3) The other two groups each have two competency groups 0011+0101 and 0001+0111, and the maximum number of concept sets is no more than 3.

The above observations are in line with the assumptions of each competency, but give more clear concept (keyword) instructions. This shows that in CBL learning, very helpful information can be obtained by constructing the ENA network and using technologies such as text analysis and social network analysis.

6. Conclusion

This paper aims to utilize text mining and social network analysis techniques to process real learning materials and apply ENA method to explore learning insights for competency-based courses. We start with the analysis of ENA and define the target learning content - homework. Secondly, following the spirit of CBL, we define the competencies to be cultivated in the course and their ENA coding, and then introduce text mining technology from competency coding and concept coding to obtain the competency concept matrix CCM. In ENA's research, CCM can be used to define an epistemic network, called the competency concept graph CCG. A CCG is a 2-mode social network that can perform social network analysis, such as community clustering. This paper uses the learning process of the recently implemented soft power course to analyze four abilities C1-C4, and calculates the CCM and CCG corresponding to the four competencies. From the discussion of the experimental results, it was found that competencies C1 and C3 are deeply intertwined, competency C2 is an ability that has nothing to do with emotions, and although competency C4 is not related to the concept of planning, it is still related to goals. These results are consistent with the setting of the four competencies and have gained more specific connotations.

Due to the length and time constraints of the paper, the scope of the current research is limited to a static analysis of the learning content of a semester. In the future, there will be opportunities to conduct a longitudinal analysis of competency cultivation on a timeline. At the same time, there are more social network analysis techniques, such as centrality and hubs, which can be introduced into ENA to obtain richer connotations in the epistemic network. Finally, for CBL courses, it should be possible to analyze more competencies and their concepts, resulting in a broader analysis procedure. Of course, It can be expected that in addition to CBL, there will be opportunities to promote it to more learning courses.

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The Impact of Creating Metaverse Worlds on Intercultural Understanding: A Comparative Analysis of Multimedia in International Collaborative Presentations

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Abstract: *This paper evaluates the impact of creating various multimedia formats, particularly Metaverse worlds, on the intercultural understanding of students in international collaborative presentations. The study leverages a "Metaverse International Virtual Exchange" course, using virtual reality (VR) technology to bridge cultural gaps among students from diverse backgrounds. It examines how tools such as images, videos, 360-degree videos, and Metaverse environments contribute to cross-cultural learning. A comparative analysis highlights the qualitative and quantitative effectiveness of these tools, with a focus on Metaverse worlds as the most potent medium for fostering deep cultural understanding. The paper also addresses the challenges and limitations associated with Metaverse content creation, proposing solutions based on student feedback.*

Keywords: Metaverse Worlds, Intercultural Understanding, International Collaborative Presentations, Virtual Exchange

1. Introduction

The "Metaverse International Virtual Exchange" course leverages VR technology and the Metaverse to connect students from diverse linguistic and cultural backgrounds worldwide, facilitating mutual learning through collaborative projects. This educational initiative aims to enhance intercultural understanding by allowing students to interact with international partner universities virtually, thus eliminating the need for physical travel. Within this framework, Japanese and international students work together to prepare and deliver presentations, sharing and discussing their cultural and linguistic heritages. Such interactions cultivate profound appreciation and respect for their own and others' cultures and languages.

To overcome language barriers in intercultural collaborative learning, this course employs multimedia—such as images, videos, 360-degree videos, and Metaverse worlds—instead of traditional text-only materials to enrich the learning experience. Traditionally, images and videos have been integral to presentations and are acknowledged for their effectiveness in enhancing intercultural understanding. Çiftçi (2016) reviews the literature on intercultural learning through digital technologies and highlights their role in increasing cultural awareness and competence. Similarly, Coffey et al. (2017) found that immersive 3D virtual environments significantly improve intercultural sensitivity compared to traditional 2D web environments. Recent research has increasingly focused on 3D content, particularly through applications utilizing 360-degree videos and Metaverse environments. 360-degree videos capture a spherical scene from all directions using omnidirectional cameras, providing an interactive viewer experience by allowing perspective rotation within virtual reality settings. Similarly, the Metaverse, a collective virtual shared space, merges virtually enhanced physical reality with physically persistent virtual spaces.

Studies have shown that 360-degree videos enhance intercultural competence and information literacy skills and are instrumental in the communication and exchange of culture-related information (Rupp et al., 2019). Additionally, Metaverse worlds have been recognized for their dual benefits of providing enjoyment and educational effectiveness, thus promoting intercultural understanding (Li et al., 2020; Inaba et al., 2023) and ensuring memorable presentation experiences (Hayashi et al., 2023).

Although the use of Metaverse worlds has proven effective, there remains a gap in the literature regarding the educational impact of content creation within these worlds on intercultural understanding. While Shadiev et al. (2023) reported enhanced intercultural understanding among students creating 360-degree videos, further exploration is needed to assess the effectiveness of different multimedia forms in this context.

This research aims to explore which types of multimedia creation most effectively contribute to intercultural understanding, focusing specifically on the act of creation and comparing various multimedia types. Thus, this study will examine whether creating in Metaverse worlds and other forms of multimedia can deepen intercultural understanding and enhance learning effectiveness. This inquiry is critical as while the "use" of such media has proven beneficial, it is unclear whether the process of "creation" is equally effective in fostering intercultural learning. Based on this, the following research questions have been formulated:

RQ1: Do students evaluate the creation of each multimedia for cultural introduction in collaborative presentations as effective in deepening their own intercultural understanding?

RQ2: Which of the following multimedia is rated highest by students as the most effective in deepening intercultural understanding through its creation: images, videos, 360-degree videos, or Metaverse worlds?

RQ3: Which aspects of each multimedia creation do students find effective or ineffective in terms of deepening the creator's own intercultural understanding?

2. Methodology

The questionnaire survey was conducted during the first semester of the 2023 academic year within the "Intercultural Communication" course, with the class subject being "Multimedia Based Introduction of Culture and Intercultural Understanding." A total of 40 students from 15 countries and regions participated in the study, including 17 Japanese students, 13 international students, and 10 overseas students. Only responses submitted by the deadline were considered for analysis. The number of valid responses for questions 1 and 3 was 28, consisting of 15 Japanese, 11 international students, and 2 overseas students. For question 2, one international student did not respond, resulting in 27 valid responses. International students who submitted responses hailed from Germany, the

United States, France, China, Korea, United Kingdom, Hong Kong, Bolivia, and Italy. Overseas students who submitted responses from partner universities in Kenya and Indonesia.

The groups were a mixture of Japanese and overseas students and were organized so that each group had at least one overseas student participating. They worked together to make collaborative presentations across national borders. In addition to slide presentations, students created worlds in the Metaverse and projected 360-degree videos they had created, comparing their own culture with that of their group members' countries and regions.

After all lessons were finished, a survey was conducted on the following topics.

Question 1)

For the Intercultural Collaborative Learning class, do you think that creating the presentation using the following types of multimedia is effective in terms of deepening the presenter's own intercultural understanding? Please rate on a 5-point scale from Strongly Disagree=1 Disagree=2 Neutral=3 Agree=4 Strongly Agree=5.

The overall score that each multimedia receives is calculated based on the number answered by the students and the points assigned to each answer. For example, if the answer number is 1, it will be counted as 1 point.

Question 2)

Please rank from first to third the items that you think would be effective in deepening intercultural understanding if created for the presentation of Intercultural Collaborative Learning classes. A) Images, B) Videos (but not VR videos), C) 360-degree videos, D) Metaverse worlds.

Question 3)

For the Intercultural Collaborative Learning class, do you think that creating the presentation using the following types of multimedia is effective in terms of deepening the presenter's own intercultural understanding? If you think it is effective, please state what aspects of it are effective. If you do not think it is effective, please state why. A) Images, B) Videos (but not VR videos), C) 360-degree videos, D) Metaverse worlds.

The most common reasons are examined.

3. Results

3.1. Results of Question 1

Figure 1 shows the results of the survey for Question 1. (The number of valid responses is 28.)

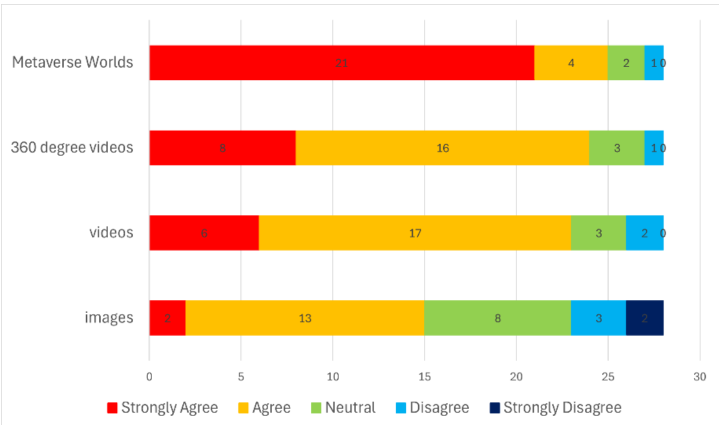

Figure 1. Results of Question 1.

Metaverse Worlds (21) received the highest number of 'Strongly Agree' responses, followed by 360-degree videos (8), videos (6), and images (2). Likewise, in the overall scoring, Metaverse Worlds (129) achieved the top score, followed by 360-degree videos (115), videos (111), and images (94).

3.2. Results of Question 2

The results of the survey for Question 2 are shown in Figure 2. (The number of valid responses is 27.)

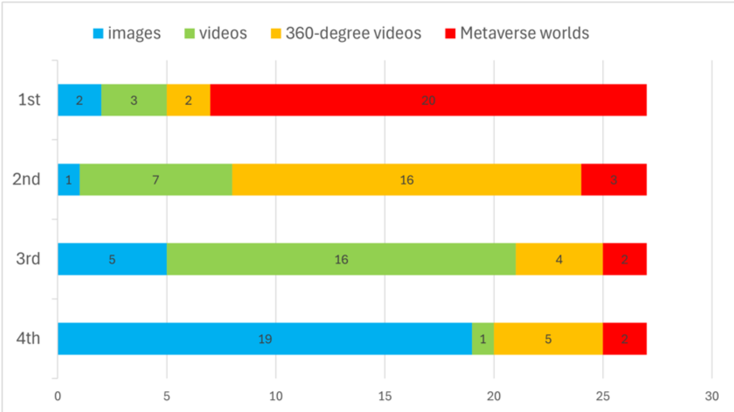

Figure 2. Results of Question 2.

Metaverse worlds was the highest ranked, followed by 360-degree videos in second place, and videos in third place.

3.3. Results of Question 3

The survey results for Question 3 are presented in “effective” and “not effective” categories for each multimedia. (The number of valid responses is 28.)

Images

Effective: “It gives the creator the opportunity to think about what kind of material he or she wants to create, and it also allows the creator to think carefully about the culture during the creation process”.

Not effective: “Images are only an experience of that one moment in time, and I feel that there is not much more memorable for the creator than for other multimedia”.

Videos

Effective: “Videos are more effective than still images in deepening intercultural understanding because they can convey more realistic situations and activities”.

Not effective: “They may also be poorly edited. In such cases, students quickly become bored and do not leave the same lasting learning effect as with images”.

360 videos

Effective: "I think this will allow the creators to observe their own culture from a different perspective than usual and deepen their intercultural understanding as well as their own".

Not effective: "Even though it is effective for understanding a culture through firsthand experience, since the process of walking around the site and experiencing it in order to shoot the video inevitably takes place, since the creation of a video is completed by simply taking pictures of the scenery in front of the camera".

Metaverse world

Effective: "While there are various methods of creation, full-scratch world creation, in which everything is created from scratch, is a process in which the creators themselves learn a great deal. They refer to a variety of images, videos, and documents, so their knowledge of the object naturally becomes more advanced during the process of creating the 3D data".

Not effective: "As for the Metaverse world, although it may be possible to understand cultural buildings structurally, I feel that it does not lead to a deeper understanding other important aspects of intercultural understanding that are not physical, such as the background and history of the buildings, how they were built, how they are perceived by the public".

4. Discussion

Regarding Research Question 1 "Do students evaluate the creation of each multimedia for cultural introduction in collaborative presentations as effective in deepening their own intercultural understanding?", Metaverse worlds were by far the most popular, with many students rating the creation of worlds as effective in deepening the creator's own intercultural understanding. This was followed by 360-degree videos, videos, and images.

Regarding Research Question 2 "Which of the following multimedia is rated highest by students as the most effective in deepening intercultural understanding through its creation: images, videos, 360-degree videos, or Metaverse worlds?", 20 of the 27 students chose Metaverse worlds as their first choice, and the overwhelming majority of students chose Metaverse worlds as the multimedia that would be effective in deepening intercultural understanding through its creation. Similar to Question 1, Question 2 had the same order of priority: Metaverse worlds, 360-degree videos, videos, and images.

Regarding Research Question 3 "Which aspects of each multimedia creation do students find effective or ineffective in terms of deepening the creator's own intercultural understanding?", students cited "that the process of creating 3D content requires a deep understanding of the subject" and how "the creator has infinite possibilities to create everything" as reasons for the effectiveness of Metaverse worlds.

One student said the following regarding Metaverse worlds: "It is really effective, because given the possibility for the people to go around the world, the presenter must think about all the possibilities and for it to be useful, must research deeply about its own culture." To create spaces that closely reflect the real world, a deeper understanding is required, which contributes to intercultural understanding as a result. “Compared to other multimedia, Metaverse worlds are effective in that they allow for a great deal of freedom in their creation and allow for the actual spatial representation of what one wants to create in one's mind. It gives the creator the opportunity to think about what kind of material he or she wants to create, and the creator can also think carefully about the culture while creating,” another student shared.

There is also another student who stated that “the first step in the creation process is to do in-depth research on the target culture and develop an in-depth plan for what to introduce and how to compare it to one's own culture. In the process, it is necessary to exchange ideas with co-creators, learn about their culture, and communicate with them. Although worldbuilding is time-consuming and labor-intensive, it is the most effective way to deepen intercultural understanding.”

Metaverse worlds enable students from diverse cultural backgrounds to collaboratively create multiple cultural introductions, transcending national borders by juxtaposing them within a single space for simultaneous comparison. When it comes to other multimedia, foreign students and Japanese students in Japan can collaborate on planning, filming, and recording as they can interact in person. However, it becomes challenging for students residing in other countries to collaborate on creating one piece of content at the same time.

In addition, if they do collaborate, the target object tends to be limited to a single culture. In contrast, students appreciate that in a Metaverse world, group members can exchange opinions, compare, and discuss cultural content from multiple countries while the creators themselves can learn a lot through this process. In fact, many students commented in Question 3 that creating was effective in deepening the creator's own intercultural understanding.

On the other hand, as cited in section 3.3, regarding the effectiveness of other multimedia and the reasons behind it, the majority of students who deemed videos effective cited its role in enhancing their classmates' intercultural understanding. Notably, there was no indication that it contributed to deepening the creator's own intercultural understanding. Additionally, the students who responded with opinions expressing the ineffectiveness of Metaverse worlds primarily commented on external factors rather than the creator's own intercultural understanding. These factors included the technical challenges of world creation and the difficulty in providing stable worlds.

The opinion that Metaverse worlds are not effective in deepening intercultural understanding is one example mentioned in section 3.3, the students compensated for the negative aspects of creating Metaverse worlds. Each group that created worlds in the Metaverse not only presented the virtual environments but also enhanced their presentations by introducing background information, history, and national perspectives on their slides to further promote intercultural understanding.

5. Conclusion

This study investigated whether the creation of Metaverse worlds, 360-degree videos, videos, and images in Intercultural Collaborative Learning presentations is effective in deepening creators' intercultural understanding. It examined this by surveying students involved as presenters and audience members in the multimedia creation process, using three specific questions to gauge their evaluations.

The results showed that Metaverse worlds were rated highest in the 5-point Likert scale (Question 1) and in the ranking order (Question 2).

In response to Question 3, which asked about the reasons behind their evaluation, many students stated that creating Metaverse worlds would lead to a deeper intercultural understanding for the creators themselves, as extensive research would be necessary to complete the project. Many students also commented that the space could be used freely, other cultures could be juxtaposed and compared, and collaboration would lead to discussions between group members throughout the creation process.

On the other hand, there were also opinions that suggested that Metaverse utilization did not lead to effective learning on cultural background and history. However, many students in the second semester of 2023 were seen utilizing slides, images, and videos within the Metaverse world to provide supplementary information. This suggests that overcoming this negative limitation is possible through creative thinking.

Due to space constraints, this paper does not discuss how the “use” of each multimedia type deepens intercultural understanding. However, this aspect has been investigated, and a comprehensive evaluation of both the “creation” and “use” of multimedia is planned for future research.

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TechTopia: The Development of Technology-driven Sustainable Wellbeing Game

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Abstract: *This study aims to develop TechTopia, a sustainable wellbeing game to enhance students' awareness of technology and industry and promote understanding of Sustainable Development Goals (SDGs). The study will conduct pre- and post-tests along with satisfaction questionnaires, with approximately 24-30 elementary school students participating in the gaming process. It is anticipated that students' awareness of the connection between technology and industry will increase, and there will be active engagement and high satisfaction with the sustainable wellbeing game.*

Keywords: Game-based Learning, Issue-Based Game, Sustainable Development Goals

1. Introduction

In the era of artificial intelligence, students are confronted with exceptional challenges and opportunities. The rapid development of technology not only alters our lifestyles but also profoundly impacts future career paths and societal structures. Particularly within the relationship of technology and industry, students need to acquire interdisciplinary understanding and application skills to adapt to the rapidly changing technological trends. This study developed the game TechTopia to guide elementary school students in comprehending the relationship between technology and industrial domains. Through this interactive learning approach, we hope to stimulate students' interest, inspire their thinking, and develop the cognitive and literacy skills they will need in the technological society of the future.

2. Literature Review

2.1. Game-Based Learning

Game-based learning (GBL) plays a significant role in today's educational landscape (Hui & Mahmud, 2023). Research indicates that GBL not only positively impacts students' knowledge and skills but also affects emotional domains, thus being recognized as one of the valuable educational methods of the 21st century (Ward, 2022). This study will employ game-based learning approaches, attempting to enhance students' awareness in the fields of technology and professionalism.

2.2. Issue-Based Game

Issue-based games play a crucial role as educational tools in the field of education. These games often employ a simulated scenario approach, allowing participants to take on specific roles and address challenges and issues from real life (Hegade, Patil, & Shettar, 2023). Through the interactivity of the game and the contextualized setting, students can explore various perspectives and solutions, leading to a deeper understanding of the complexity of social issues (Cheng et al., 2020). This study aims to integrate game-based learning with issue-based games, developing a game designed to cultivate students' technological awareness.

3. Game Design

The game TechTopia developed in this study integrates Game-Based Learning and Issue-Based Game, aims to enhance students' awareness of technology and industry through gameplay, fostering an understanding of how technology impacts society and promoting concepts of sustainability.

TechTopia uses a turn-based system in which players are divided into six nations, each specializing in a particular industry. Each country consists of three to five players who take on the roles of Commander, Diplomat, Merchant, and Technician. At the beginning of each round, various societal issue events will occur, and countries must negotiate to resolve these events. After resolving the issues, players engage in exploration and communication on the game board (*Figure 1*) to gain technology cards.

Figure 1. TechTopia game board schematic diagram

Industries specialized in each country and their corresponding technologies composition is shown in *Table 1*. Players will develop their countries based on the technology cards explored on the game map, formulating strategies and actions. Each country has different objectives, but cooperation is necessary to build a near-utopian sustainable wellbeing world in order to win.

Table 1. Industries specialized in each country and their corresponding technologies composition.

Countries	Industries	Technologies					
		IoT	AI	VR	GIS	Big Data	Networking
Metal	Transportation	✓	✓	✕	✓	✓	✓
Wood	Textile	✕	✓	✓	✓	✓	✓
Water	Tourism	✓	✕	✓	✓	✓	✓
Fire	Catering	✓	✓	✓	✓	✕	✓
Earth	Architecture	✓	✓	✓	✓	✓	✕
Air	Healthcare	✓	✓	✓	✕	✓	✓

The societal issue events occurring at the beginning of each round is designed according to the Sustainable Development Goals (SDGs) (Looi et al., 2023), and each event is related to the countries' industries. These events will directly involve the industrial development of various countries and take into account the connections between industries in different countries and the SDGs. *Table 2* is a clearly outline of the relationships between different industries in each country and the SDGs, providing players with guidance to better understanding in a sustainable wellbeing world.

Table 2. Relationships between different industries in each country and the SDGs

Countries	Industries	SDGs
Metal	Transportation	SDG7 (Affordable and Clean Energy), SDG9 (Industry, Innovation and Infrastructure), SDG11(Sustainable Cities and Communities)
Wood	Textile	SDG15 (Life on Land)
Water	Tourism	SDG14 (Life Below Water), SDG15 (Life on Land)
Fire	Catering	SDG2 (Zero Hunger)
Earth	Architecture	SDG9 (Industry, Innovation and Infrastructure), SDG11 (Sustainable Cities and Communities)
Air	Healthcare	SDG3, (Quality Education) SDG6 (Clean Water and Sanitation)
SDGs within the overall game content		SDG5 (Gender Equality), SDG8 (Decent Work and Economic Growth), SDG17 (Partnerships for the Goals)

4. Research Design

The activity process will be conducted in several stages. Firstly, we will conduct a pre-test to assess participants' level of understanding of the connection between technology and industry, expected to last 30 minutes. The target participants for these assessments will be 24-30 upper-grade elementary school students. Following that, 30 minutes will be spent introducing the SDGs, followed by another 30 minutes introducing technology-related content to ensure participants have a basic understanding of the game content.

Subsequently, participants will enter the gaming phase, which will last for 150 minutes. After the game concludes, we will spend 30 minutes for participants to engage in reflection and discussion to share their experiences and thoughts during the game.

Finally, a 60-minute post-test evaluates participants' understanding comprehension of: a) recognition/endorsement of technology applications, b) the concept of sustainable wellbeing, and c) interest and motivation (interest-driven). The process is illustrated in *Figure 2*.

Figure 2. Activity Process

5. Expected Result

This study anticipates to enhance students' levels of awareness regarding the connection between technology and industry after playing the TechTopia game. It is expected that students will gain a deeper understanding of the impact of technology on society, further enhancing their comprehension of the Sustainable Development Goals (SDGs), in order to achieve a sustainable wellbeing society. Additionally, students are likely to demonstrate active participation, high interest and maintain an engaged attitude throughout the gaming process. These outcomes contribute to a better understanding of the role and value of this game for achieving a sustainable wellbeing society.

6. Conclusion

This study develops TechTopia, a board game that educates elementary school students about the correlation between technology and industry. In hopes that students will gain a deeper understanding of the importance of the SDGs in the game, and demonstrate an attitude of active participation and cooperation. More importantly, this study seeks an enhancement in students' levels of awareness regarding the connection between technology and industry after playing TechTopia. This supports and provides reference for the application of game-based learning in promoting students' technological literacy and social awareness.

7. Acknowledgement

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Using Virtual Reality for Learning about Algorithms:

The Importance of Institutional Support and Technology Skills

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Abstract: *This paper examines the potential use of Virtual Reality (VR) in computing education. In this study, engineering and computing students and professionals participate in a VR escape room game where they complete algorithm tasks which are formulated as challenges. The final goal of the VR escape room game is to complete tasks in limited time to exit the escape room. The students participated in a VR game session which begins with an introduction to VR use, followed by a round of the VR escape room game, a questionnaire, and a focus group interview. The questionnaire is structured according to the Unified Theory of Acceptance and Use of Technology (UTAUT) theory and examines how the constructs of performance expectancy, effort expectancy and social influence affect the students' intention to use VR in future educational activities. The main findings indicate that engineering and computing students and professionals are motivated by the educational benefits of VR use, they do not perceive VR as difficult to use in education and that there is limited institutional support for such use.*

Keywords: virtual reality, algorithms, generative AI, education

1. Introduction

This study examines the use of Virtual Reality (VR) for learning algorithms by engineering and computing students and professionals experiencing such tools for the first time in an educational context. Although most of the participants have experience with gaming in general, virtual worlds remain an untapped potential due to the novelty of the technology, hardware and approaches. Since the students needed to complete algorithm tasks in a VR educational game, the aim of this research was to examine the acceptance and potential of VR in educational contexts.

To conduct such a study, a custom VR-based escape room game was designed to provide students with a virtual world in which they would interact with algorithm tasks. All the participants were already familiar with this study area, but this time they were required to engage in a designed VR world and solve algorithm challenges to complete the escape room in a limited time. The participants were challenged in several ways: they needed to master the use of VR equipment, adapt to completing the tasks in a virtual world and complete the tasks in a limited time frame.

This study presents a novel approach for students, teachers, and VR solutions designers due to its emphasized educational component. The authors were therefore keen on examining the participants' experiences during the educational VR escape game. All participants were required to complete a questionnaire and take part in focus groups aimed at discussing their experiences and the perceived affordances of VR. The survey was organized and analyzed using the Unified Theory of Acceptance and Use of Technology (UTAUT) model to explain users' intentions to use VR educational tools in the future. This is done via a standardized questionnaire exploring how users' performance expectancy, effort expectancy together with the social influence around technology affects users intention to use the technology.

The paper is organized as follows: after the introductory chapter, theoretical background is given followed by the methodological chapter which includes the VR tool design description. The paper continues with the results chapter and ends with conclusions.

2. Theoretical Background

VR environments are wholly synthetic computer-generated environments in which users experience sensor stimuli provided by a computer. Users' actions determine what happens in these environments since they can manipulate objects and thereby impact the virtual environment. Virtual environments are typically experienced through the output devices such as head-mounted displays (HMDs) or headphones, and users use input devices such as controllers to manipulate or navigate through the virtual world.

The research in technology-enhanced learning covers a wide spectrum of virtuality: some tools are less virtual in nature (Horst et al., 2019), while others are designed to completely immerse learners in a virtual learning experience (Yigitbas et al., 2020). As a key component of such environments, visualizations and animations can help achieve learning outcomes by making relatively abstract phenomena more concrete, while virtual reality environments can provide new forms for interacting with visualizations and might foster motivational, emotional, and perceptual factors that influence learning processes. Research indicates that learners experience higher presence, absorption, flow, psychological immersion and positive emotions in a virtual reality setting compared to a standard desktop setting (Pirker et al., 2021).

As in other areas of technology-enhanced learning, the importance of pedagogical approaches and adequate instructional design principles remains emphasized with the use of VR in the classroom. Since the pedagogical value of VR learning experiences "is enabled through immersion in a reality-based environment, engagement with complex and ambiguous situations and information, and interaction with the space, other students, and teachers", ensuring a high level of interactivity remains a challenge when designing such environments (Schott & Marshall, 2018). Researchers have found that an adequate design of virtual reality-based experiences plays a key role in sustaining learning outcome gains and report that if students use VR for a longer time and their learning gains are repeatedly measured while participating in a VR learning environment, their learning gains could possibly deteriorate (Merchant et al., 2014).

The field of programming and algorithms entails a level of complexity due to the need for different levels of abstraction of programming entities in the process. Abstraction and related concepts are needed to overcome the complexity of managing code, but the issue of distraction and being overwhelmed remains, especially for novice programmers and students. In a virtual reality learning environment designed to promote immersion and engagement with abstract Object-Oriented Programming (OOP) concepts, students have shown a significant improvement in their ability to visualize the OOP concepts with the use of VR. A small-scale study reports on positive experiences and the designed VR experience being an effective learning tool in addition to the lectures when studying OOP (Tanielu et al., 2019).

It is the pedagogical approach and learning design that play key roles in learning coding in VR as well. A study compared two methods of coding in a VR environment: one approach where students wrote code to solve problems in art and design, and a traditional approach in which students were to demonstrate comprehension of programming principles by directly coding them. The results indicated that the problem-oriented strategy for solving computational problems made a great difference and resulted in higher scores. The authors report "positive impact on computer science education by increasing engagement, knowledge acquisition, and self-directed learning" (Banic & Gamboa, 2019).

This study further explores the notion of immersive VR environments and embodiment in VR approaches to learning programming (Parmar et al., 2023) and problematizes the manner in which they need to be contextualized and executed to sustain and entice interaction to leverage the best affordances of VR technology environments. In doing so, it focuses on a gamified approach to learning computing concepts in VR (Yigitbas et al., 2024) and aims to take a step further in exploring such an approach by designing and trialing a VR escape room game for learning programming.

3. Methodology

In this study, a VR escape room game designed for learning algorithms was developed and trialed. A total of 22 participants, averaging 23 years old and holding bachelor's, master's, and doctoral level degrees, participated in the game. The total game time, including the introductory session, lasted for 60 minutes. The participation included getting introduced to the game and getting instructions on using the VR system, playing the escape room game consisting of several challenges, completing a questionnaire and participating in a focus group interview after the game. The study adopted the UTAUT (Unified Theory of Acceptance and Use of Technology) model (Venkatesh et al., 2003) as a theoretical framework for finding and examining the factors that influence users' behavioral intentions to accept and use the educational VR solution for learning. The following hypotheses were explored:

H1: Performance expectancy will have a positive influence on behavioral intentions to use VR in education.

H2: Effort Performance expectancy will have a positive influence on behavioral intentions to use VR in education.

H3: Social influence will have a positive influence on behavioral intentions to use VR in education.

3.1. Tools

The VR escape algorithms game was developed using Unity, a cross-platform game engine provided by Unity Technologies. The players used Meta Quest 2 VR devices and the corresponding controllers to engage in the game.

Figure 1 shows an uncovered game challenge behind a virtual closet that participants had to uncover and complete by examining and answering an algorithmic question. Figure 2. Depicts the experiment execution with participants using the VR equipment where up to three games could be played at the same time since the research team had three VR sets on disposal.

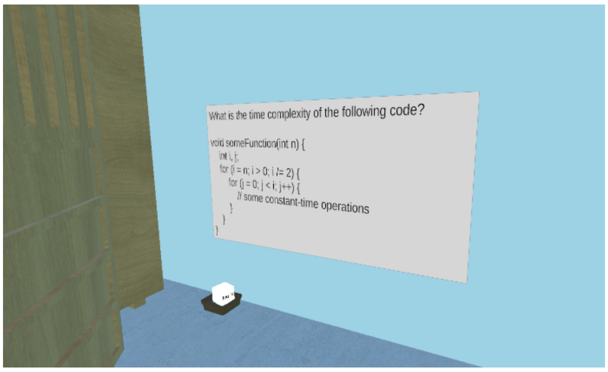

Figure 1. Escape room game VR environment with an algorithmic challenge displayed.

Figure 2. Study participants wearing VR equipment while engaging in a VR escape room game.

3.2. Escape Room Game Design

On the onset of the escape room game the player is presented with four challenges. The first challenge involves an algorithm complexity task, where players must manipulate virtual cubes dispersed throughout the room. Each cube is labeled with its own complexity level, requiring players to select and arrange them appropriately to complete the task. The next two challenges require players to manipulate numpad feature to answer the code execution results and identify code bugs. In the fourth challenge, players interact with an object that reveals a riddle hidden beneath a bed, which they must solve.

Players have ten minutes to solve all four challenges and escape the room. Upon completion of the challenges or when the time expires, the player is transported to a new room that provides explanations for the questions. Three of the challenge questions and their explanations are generated using OpenAI's generative AI services (OpenAI, n.d.), ensuring variety and replayability by offering diversified challenges in each game session. The first challenge, however, remains constant for all players.

3.3. Data Collection

Data collection mechanisms in this study included a post-game questionnaire consisting of a variety of questions querying the participants' usage experience including the UTAUT question constructs that will be used for subsequent analysis. The questionnaire was divided into different sections for easy reading and completion and used a Likert scale with seven levels of possible answers with respect to the UTAUT model (ranging from Strongly Disagree to Strongly Agree). Focus group interviews were conducted by the end of every game play whereby qualitative data on the participants' experience was collected. The interviews were recorded with a video camera. The participants gave consent for the study participation and data collection prior to the experiment onset.

4. Results

The questionnaire is composed of three main sections: the general questions which includes demographics, the questions that measure the perception of the respondents on the acceptance and use of VR games for educational purposes (UTAUT model), and the general questions querying quality of experience and satisfaction with the VR game. Although data collection included results from focus group interviews at the end of the gameplay session, these will not be presented as results in this section due to space limitations. Selected descriptive statistics variables are given in Table 1.

Table 1. Descriptive statistics.

Variable	Mean	Unit
Age	23.11	years
Level of gaming experience	3.05	years
Level of VR experience	1.96	years
Duration of game	9.80	minutes (out of 10)

The data collected from the UTAUT survey of 22 respondents were analyzed using the statistical tool Smart PLS. The study applied the Structural Equation Modelling (SEM) technique to evaluate the relationships in the UTAUT model and to test the hypotheses among the variables in the model. Structural Equation Modelling (SEM) is a statistical methodology that takes a confirmatory (hypothesis testing) approach to the structural analysis. Table 2 gives the UTAUT questionnaire items organized by the constructs.

Table 2. UTAUT questionnaire items with corresponding values organized by constructs.

	Questionnaire Item	Mean	Stdev
Performance Expectancy (PE)	I would find VR useful in learning.	5.82	0.96
	Using VR games for learning enables me to accomplish tasks more quickly.	4.27	1.32
	Using VR games for learning increases my productivity.	4.46	1.47
	If I use VR games for learning, I will increase my chances of learning.	4.77	1.51
Effort Expectancy (EE)	My interaction with VR games for learning would be clear and understandable.	5.00	1.41
	It would be easy for me to become skillful at using VR games for learning.	5.73	1.32
	I would find VR games for learning easy to use.	5.23	1.51
	Learning to operate VR games for learning would be easy for me.	5.82	1.34
Social Influence (SI)	People who influence my behavior think that I should use VR games for learning.	3.09	1.45
	People who are important to me think that I should use VR games for learning.	3.00	1.69
	My university administration has been helpful in the use of VR games for learning.	3.77	1.95

	In general, my university has supported the use of VR games for learning.	4.36	2.04
Behavioural Intention (BI)	I would intend to use VR games for learning in the next twelve months.	3.82	1.94
	I predict I would use VR games for learning in the next twelve months.	3.46	1.77
	I would plan to use VR games for learning in the next twelve months.	3.73	2.03

After the first round of analysis, items/indicators with non-significant weights and non-significant indicator loadings with values < 0.5 were removed and the analysis was re-run (Hair et al., 2021). Internal consistency measures of the constructs measured by Cronbach's Alpha indicates all values of the study instrument are reliable and exhibit good reliability (PE = 0.85, EE = 0.85, SI = 0.74 and BI = 0.96), the composite reliability results fall within reliable ranges (exceed 0.70 for all constructs with the extracted variance being > 0.50), as well at the discriminant validity (square root of average variance extracted is larger than the correlations between the constructs).

Finally, the predictors providing contribution to the explanation of the dependent variable are given in Table 3 for the purposes of hypothesis testing. The results indicate that only one hypothesis (H1) is supported from the data, while the remaining two (H2 and H3) are not.

Table 3. Hypothesis testing results.

Hypothesis	Beta	Significance
H1 (PE → BI)	0.456	p<0.05
H2 (EE → BI)	-0.005	p>0.05
H3 (SI → BI)	0.281	p>0.05

The R-square of the model was 0.344 indicating low to moderate explanatory power of the model.

5. Conclusions

The paper presented design, implementation, and evaluation of a small-scale study on using VR in the context of algorithms education. A VR escape room game was designed in which students completed a series of algorithmic challenges prior exiting the room. Students participated in an evaluation session that consisted of an introductory explanation, game trial with VR equipment, questionnaire, and a focus group.

Results confirm only one of the study hypotheses H1 whereby performance expectancy has a positive effect on behavioral intention to use VR for learning by the participants, while hypothesis H2 and H3 remain unsupported indicating effort expectancy and social influence do not exhibit such an effect. The findings related to the performance expectancy and social influence are congruent with the findings of similar studies on the use of technology in education, where performance expectancy remains as a strong predictor of educational technology use, while social influence does not predict such use. In the case of our study, the participants were convinced VR technology is a powerful tool for learning and can be used in the educational process, but state there is no institutional push to do so according to the answers given in the Social Influence category questions which of medium value and relatively high standard deviation (Abbad, 2021). What is more, the younger generation of technology professionals, who were study participants, might not seek formal educational processes to engage them in learning with technology, they would rather take their own initiative.

Interesting findings are to be reported regarding the effort expectancy questionnaire items which on average scored high, but the effort expectancy itself was not found as a predictor of in the VR technology use for learning. Although more research is needed to ascertain this relationship, the study participants were quite skillful in technology use and the fact that they needed to master novel VR tools to be able to take part in this study does not affect their intention to use the tool for learning. We believe that the complexity of VR setup, use and occasionally steep learning curve might accept users with average or under-average technology skills, however this needs to be confirmed with additional research.

The findings presented in this paper come with limitations of a small sample and could be additionally biased since most participants were very well versed in technology use and development and had above-average technology skills. In terms of future work, more algorithmic tasks should be developed, and multiple levels of the VR game should be developed to provide players with a rich gaming experience. Further research and development should be directed into ascertaining VR game elements that contribute to the enhanced learning experiences. In general, there should be more research which problematizes VR in terms of inherent gamification elements versus gamification elements embedded as part of the instructional design process.

Acknowledgements

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Future of Connectivity technology: MR with Robotic Arms

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Abstract: *This article aims to utilize mixed reality headsets (such as the Microsoft HoloLens 2) to assist students and employees in gaining a deeper understanding of the Scara robotic arm (in this article, the Scara RS406 is selected). Simultaneously, it will provide both instructional and operational modes to enhance the efficiency of operators in learning about the Scara robotic arm. It even aims to achieve industry-academic collaboration to significantly enhance its applications. For example, in default applications, educational institutions or private enterprises interested in purchasing robotic arms can conveniently utilize the research findings to effectively understand the product. Whether it's an introduction, pricing, basic information, operations, or comparisons between different models, all can be realized through this platform. Additionally, through mixed reality operations, not only can it reduce the risks of actual operations, but it can also accelerate users' familiarity with the robotic arm. Furthermore, operators can engage in remote control and multi-user collaboration, maximizing the application value of digital twin technology.*

Keywords: Mixed Reality, Robotic Arm, Remote Control, Digital Twins.

1. Introduction

In recent years, Mixed Reality (MR) technology has been increasingly utilized in the industrial sector [1], gradually emerging as a key driving force behind the industrial revolution. MR technology integrates the strengths of both Virtual Reality (VR) and Augmented Reality (AR), providing users with an environment where they can interact with real machinery while incorporating virtual objects seamlessly.

In conventional remote control systems, operators often rely on input devices such as joysticks, gamepads, keyboards, and mice to manipulate mechanical devices. However, most of these devices provide feedback based on two-dimensional planes, lacking intuitive perception of three-dimensional space, leading to a certain disconnect between the operation interface and real operation. Most critically, traditional systems are confined to a single two-dimensional perspective, failing to provide sufficient depth information, which greatly limits the operator's accurate understanding of the remote operation environment, reducing precision in operation and user immersion. Although VR is currently used for control, it still cannot overcome mobility restrictions and requires continuous use of external sensors to detect the operation of controllers [2][3].

To overcome these limitations, this study chooses to utilize Mixed Reality (MR) as the primary interactive interface, with Microsoft HoloLens 2 selected as the development platform. For the selection of robotic arms, we have chosen the widely adopted HIWIN Scara RS406 as the development model, aiming to bring a more intuitive and natural operating experience to remote control systems through this novel interaction method.

This research focuses on three main aspects: replicating real control panels, implementing inverse kinematic posture calculation, and developing user-friendly interactive functions. In the virtual control panel design, we not only incorporate buttons for four-axis rotation but also include options for speed adjustment, allowing operators to achieve precise control tailored to various job requirements. Additionally, by leveraging inverse kinematic posture calculation, we enhance operational intuitiveness, enabling more ergonomic and precise manipulation. The study further explores the integration of MR technology with robotic arm IK models, aiming to delve into theoretical foundations, implementation methods, and future applications. It begins by emphasizing user-friendly features such as web browsing and object navigation to improve system usability. Subsequently, it discusses the significance of IK in computer graphics [4][5] and tackles technical challenges in MR implementation. Through comprehensive analysis, the paper underscores the pivotal role of this integration in advancing industrial operations and professional training. Finally, it concludes by discussing the advantages and industrial applications of this technological synergy.

2. DEVELOPMENT PROCEDURE

This article is divided into two main development phases. As shown in figure 1. The first phase involves referencing the parameters and physical attributes of the robotic arm and utilizing Blender for 3D modeling. The goal is to create a model of the Scara RS406 robotic arm and refine it, including adding textures and colors. Once the model is completed, it will be imported into Unity as an .fbx file, ensuring that all materials are successfully packaged along with it. The next step involves the development of mixed reality-related functionalities, such as draggable web pages, operation modes, and instructional modes. Finally, the validated files can be uploaded to the HoloLens 2 in three ways:

2.1 Cable

Using a USB cable to transfer the files from the computer to the HoloLens 2. It's important to have the Developer Mode enabled on the HoloLens 2, and the computer needs to obtain the HoloLens 2's PIN code.

2.2 WiFi

Utilizing Wi-Fi connectivity to link the HoloLens 2 and the computer within the same network domain. In Visual Studio, input the IP address of the HoloLens 2 in the debugging options to synchronize data and transfer files to the HoloLens 2 from the computer.

2.3 Sideload

Sideloading the files as .appx packages and deploying them to the HoloLens 2 using the Window Device Portal provided by Microsoft.

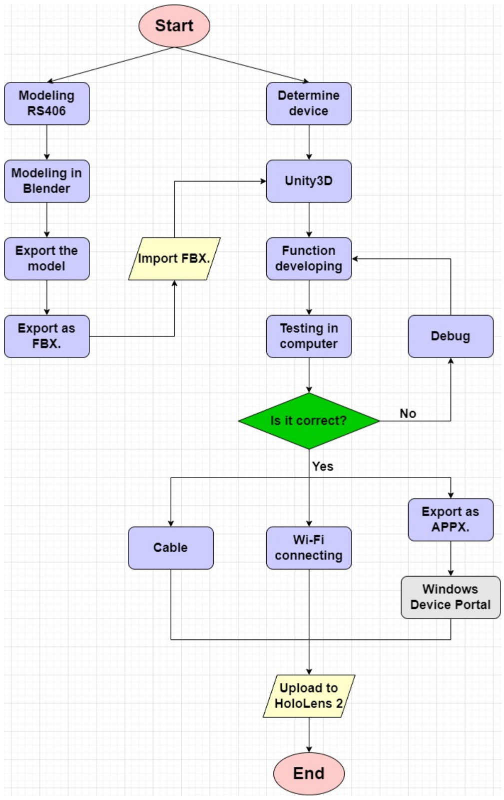

Figure 1. System development flow chart.

3 METHODOLOGY

3.1 Operation Mode

In the instructional mode of this study, the focus is on realizing manipulation of the robotic arm within a Mixed Reality (MR) environment. To provide an intuitive and efficient operational experience, functionality for controlling speed has been incorporated into the user interface toolbar, in addition to precise control over the four axes. Efforts are made to recreate an operational experience identical to real-world control. Considering potential needs during operation, such as resetting the robotic arm to its initial position, the study employs smooth linear interpolation techniques to calculate the robotic arm's trajectory for reverse rotation.

Smooth linear interpolation plays a crucial role in this application, allowing the calculation of a series of intermediate points between a known starting point (the beginning of the operation) and an endpoint (the origin of the robotic arm or another predetermined position), thus achieving smooth transitions.

In other words, the initial coordinates are known conditions, while the endpoint coordinates are the coordinates where the user's last operation of each axis of the arm stopped. Similarly, they are also known conditions. The purpose of linear smooth interpolation is to calculate a series of transitional points under the known conditions of the starting and ending points, enabling these transitional points to form a smooth transition from the starting point to the ending point. Different values of the interpolation factor will determine the specific positions of these transitional points between the starting and ending points.

By adjusting the value of the interpolation factor, a set of transitional points with any desired density between the starting point and the endpoint can be generated. This allows for the adjustment of the smoothness and accuracy of the trajectory based on operational requirements and real-time performance. This method not only ensures the continuity and naturalness of the robotic arm's motion but also enhances the intuitiveness and responsiveness of user interaction in MR applications.

3.2 Inverse Kinematics Mode

Inverse Kinematics (IK), abbreviated as IK, is a crucial aspect in robotics and computer graphics. It addresses the control of robotic arms, involving determining the motion of each joint to achieve the desired position and orientation of the end effector. Gradient descent is an optimization technique used to adjust the joint angles of the robotic arm, aiming to bring the end effector closer to or reach the target point. Below, we'll explore the basic principles of gradient descent and how it applies to the inverse kinematics of robotic arms:

Gradient Descent Inverse Kinematics: Gradient descent is an iterative optimization algorithm that aims to minimize a target function. In the context of inverse kinematics, its application involves minimizing the distance between the end of the arm skeleton and the target object. This objective is formulated as a target function, and gradient descent continuously adjusts the joint angles to reduce this target function [6].

$$\boldsymbol{f = \sqrt{[L\cos(qi) - Xt]^2 + [L\sin(qi) - Yt]^2}} \qquad \text{(2-1)}$$

$$\boldsymbol{J} = \begin{bmatrix} \frac{\partial f_1}{\partial q_1} & \cdots & \frac{\partial f_1}{\partial q_i} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_m}{\partial q_1} & \cdots & \frac{\partial f_m}{\partial q_i} \end{bmatrix} \qquad \text{(2-2)}$$

$$\boldsymbol{q_{new} = q_{previous} + \alpha \cdot JT \cdot \varepsilon}, \textbf{ where } \begin{cases} \boldsymbol{\alpha: learning\ rate} \\ \boldsymbol{\varepsilon: error} \end{cases} \qquad \text{(2-3)}$$

Upon system initialization, the program sequentially processes each joint, starting from the base, aiming to minimize the distance between the end effector and the target point. This iterative process involves calculating the gradient of rotation for each joint with respect to the distance to the target and adjusting the joint angles accordingly to reduce this distance. Iterations persist until the distance between the target object and the end of the arm's skeleton meets a predefined threshold. Essentially, the system optimizes the joint angles iteratively, progressively guiding the robotic arm toward the target point by minimizing the distance between the end effector and the target.

4 CONCLUSION

This initiative utilizes mixed reality to enhance learning and promote collaboration between industry and academia. By simulating control panels and applying inverse kinematics for intuitive interactions, it aims to improve remote control systems in industrial settings. The integration of MR technology with robotic arm models highlights its potential to advance professional training and revolutionize industrial practices.

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Using a Visual Analysis System to Explore the Abilities and Current Status of Taiwanese University Students in Digital Humanities Literacy.

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Abstract: *In recent years, digital humanities has evolved from a discipline into a field, gradually gaining influence. Studies in digital humanities have highlighted a lack of high-tech skills among humanities scholars and a shortage of humanistic theory among technology researchers. To better understand the current status of digital humanities in Taiwan, this study investigated and analyzed the humanities comprehension and technological application abilities of students in 16 Taiwanese universities. It found that over half of the students lacked understanding of humanities knowledge, and a staggering seventy percent lacked technological proficiency. Through visualization dashboards, this study preliminarily explored the relationship between Taiwanese university students' comprehension of humanities courses and their technological application abilities.*

Keywords: Digital Humanities, Digital Humanities literacy, Visualization Dashboard

8. Introduction

Schreibman et al. (2016) pointed out that in recent years, Digital Humanities (DH) has evolved from being a discipline into a field. Yuting et al. (2023) highlighted in their study that humanities scholars possess the capability for high-tech applications and operations. However, researchers in technology and technical fields lack the theoretical background necessary for engaging in digital humanities research. Nonetheless, the advancement of digital humanities inevitably requires the accumulation of substantial theoretical knowledge in both digital and humanities domains.

Previous studies have mentioned the current status of digital humanities development in various countries. In Taiwan, students in humanities and social science departments tend to consider switching to other fields due to poor job prospects. However, studies have indicated the importance of interdisciplinary talents, as acknowledged by schools in Japan and Germany. The ability to integrate humanities knowledge with technological applications fosters mutual assistance and growth, emphasizing the need for cultivating interdisciplinary skills (施如齡、曾家俊,2022).

To establish a foundation for digital humanities in Taiwan and equip students with interdisciplinary skills in humanities and technological applications to address societal issues, this study conducted a multifactorial investigation and analysis of humanities literacy and technological application abilities among students from 16 schools using a digital humanities literacy questionnaire. Through the visualization dashboard, complex and scattered information was organized using interactive charts to establish data correlations, thereby exploring the current status of Taiwanese university students' humanities literacy and technological application abilities under various factors.

To investigate the current humanities literacy and technological application abilities of Taiwanese university students, we conducted a survey among students from 16 schools and analyzed their abilities in humanities literacy and technological application across northern, central, and southern Taiwan. We posed the research question regarding these two abilities: What is the current status of Taiwanese university students' humanities literacy and technological application abilities?

9. Literature Review

9.1. Overview of Digital Humanities Research and Development in Taiwan

In the study by Su et al. (2021), it was mentioned that Digital Humanities (DH) lacks a precise definition in academia and in the scope of its coverage, making DH research diverse and exploratory. 施如齡與曾家俊(2022) noted in their research that in Taiwan, digital humanities primarily involve data analysis or data retrieval in fields such as literature, history, philosophy, sociology, and linguistics. However, in terms of technological applications, there has been no research on presenting, creating, and disseminating digital humanities knowledge using technology.

In addition to the aforementioned studies on digital humanities applications, foreign attention has been drawn to the current status and development of DH in higher education, highlighting the lack of students with interdisciplinary knowledge and skills in digital humanities education globally (Risam et al., 2017). 施如齡與曾家俊(2022) also mentioned that Taiwan is currently in a growth stage for humanities courses, but due to the job market's emphasis on STEM skills, students in humanities disciplines tend to abandon their original majors for employment purposes. Therefore, this study aims to continue establishing the roots of digital humanities in Taiwan and cultivate interdisciplinary talents. It begins by investigating and analyzing the current status of students' humanities literacy and technological application abilities, followed by establishing a visualization and analysis system using data visualization dashboards to present relevant research data.

9.2. Data Visualization and Dashboard

In the era of information technology, the generation of massive amounts of data has led to the emergence of data visualization as a means to observe correlations between data. Through data visualization, different sets of data can be connected and correlated, and the visualized data can serve as decision support tools (Bradley et al., 2018). With advancements in technology and the continuous innovation of mobile devices, there has been a push to create mobile-friendly data, resulting in the development of data dashboards. Data dashboards are currently widely used across various fields (Conrow et al., 2023) due to their characteristics of data integration, data presentation, overview reading, coordinated views, diverse visualizations, data tracking, and data sharing

(Sarikaya et al., 2019). This is why dashboards are often used as decision support tools, as they enable the analysis and speculation of data correlations. Statistical graphs are used to present this data, making it easier to query trends and correlations compared to raw numerical data.

9.3. Digital Humanities Data Visualization Research

While data dashboards are convenient and facilitate data dissemination and sharing, most digital humanities research still focuses on visualizing data. In the study by Zhang et al. (2021), it was mentioned that digital humanities visualization can be divided into three categories: 1. interdisciplinary collaboration discussions (including analyzing current situations, summarizing experiences, and enhancing interdisciplinary cooperation forms) (Su, 2020), 2. digital humanities theoretical research, and 3. analysis of digital humanities using case studies. For example, through sound recognition, visualizing sound to analyze digital humanities research on 19th-century French poetry (Ardrey, 2020). Data visualization often focuses on producing a single output for different visualization effects (such as spatial visualization, textual word frequency analysis). However, data dashboards can present data from different visualization methods in the same place, allowing for the analysis of data correlations through different visualizations.

10. Research Methodology

3.1. Data Sample

To understand the humanities comprehension and technological application abilities of Taiwanese university students regarding digital humanities, a total of 558 questionnaires were collected from 16 schools across northern, central, and southern Taiwan. Data cleaning was conducted to remove duplicate entries, erroneous responses, and responses from students not belonging to the 16 selected schools. Finally, 547 questionnaires were utilized for the establishment of the visualization analysis system.

3.2. Data Collection, Processing, and Analysis

To gain deeper insights into Taiwanese students' humanities literacy and technological application abilities in digital humanities, we categorized humanities literacy into two dimensions - humanities literacy (e.g., (interpersonal adaptation(Int. Per.), cultural comparison(Cul. Com.), Written expression(Wri. Exp.), career planning(Car.Plan.), literary appreciation(lit.App.), artistic appreciation(Art App.)) and social literacy (elf-reflection(sel-refl.), administrative leadership(Admi LEAD), social research(SS), historical analysis(HIST Anal), language communication(lg Comm.), and philosophical thinking(Phi.Thik.)) (Lin & Chen, 2004). We also referenced tools commonly used in previous digital humanities studies (e.g., 3D modeling and printing(3D MAP), big data mining(BDDE), document processing(DS), blockchain(BC),AR/VR,physiological detection systems(PDS), GIS, database reaserch (DBS), game design(GD), BOT digital multimedia (text, images, audiovisual)(DM), data visualization(DV), art (film and television media)(Art), artificial intelligence(AI), GenAI, MetaVerse, NFT, IoT, and STEAM) to assess technological capabilities. Based on literature on technological and media literacy, information literacy, and media literacy, we carefully distinguished and established levels of digital literacy required in the questionnaire (Bawden, 2001; Koltay, 2011).

The questionnaire structure and design were informed by Yoon et al.'s (2022) study on digital health technology literacy assessment, which explores digital health in terms of functionality, communication, and criticality. We extracted from the usage of technology to its application and ultimately created a questionnaire tailored to digital humanities through integration and innovation.

To understand the distribution of various humanities disciplines among students' backgrounds (school, region, gender, grade, and major) and their relationship with humanities comprehension and technological application abilities, the collected data underwent form disassembly. Given the complex interrelations of the survey data, which involve multiple factors, establishing correlations between different factors and building a multi-factor filtering visualization analysis system necessitated separating all data into various filtering data tables and establishing relationships between data (data normalization).

After data normalization, a visualization analysis system was created using Microsoft PowerBI. This system allows for the selection of filters such as school, region, gender, and grade as buttons. Through the relationships between data sets, the system restricts the scope and examines the correlations between multiple factors. The process flowchart for establishing the visualization analysis system is depicted in Figure 2. ◦

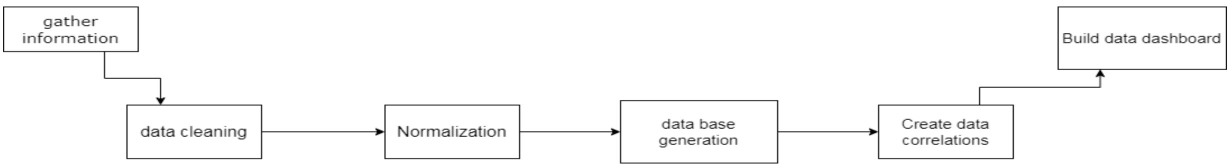

Figure 2. Digital humanities visual dashboard construction flow chart.

Clicking on the filtering conditions in the visualization analysis system will cause the charts below to change accordingly (Figure 3). Multiple selections can be made using the student background icons above for multi-correlation filtering, and it can be observed that the data in the circular statistical charts below becomes more restricted (Figure 4). Clicking on the statistical charts allows for viewing the correlation of understanding levels of different abilities (Figure 5). ◦

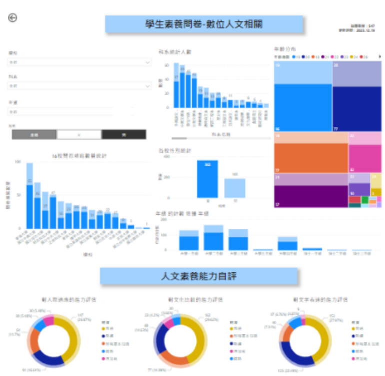

Figure 3. single filter screen.

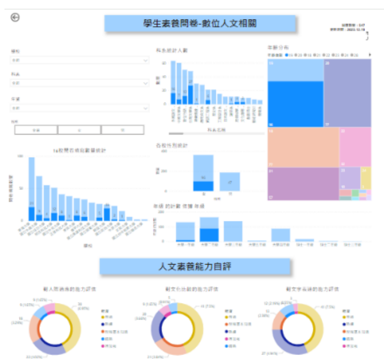

Figure 4. Multi-factor check correlation screen.

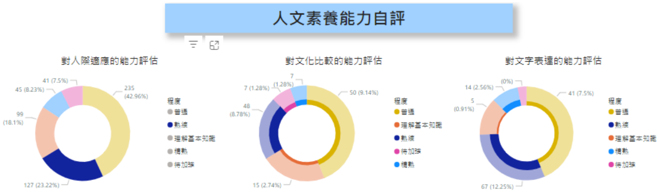

Figure 5. Understand the connection between abilities.

11. Analysis Results

Most university students consider themselves to have a moderate level of understanding in terms of humanities literacy dimensions, with approximately 36-44% of students falling into this category. They possess knowledge but may not be highly proficient in applying it. Around 7% of students have no understanding of these abilities and lack knowledge in these areas. Additionally, 12-22% of students have only basic knowledge and do not apply these abilities in their daily lives. Approximately 20-30% of students have a solid understanding of humanities literacy dimensions and can proficiently or even expertly apply them.

However, in terms of social literacy dimensions, although most students also believe they have relevant knowledge and apply it in their lives (approximately 36-44%), there are more students who completely lack understanding or possess no relevant skills compared to humanities literacy. The number of students who have basic knowledge but do not apply it in their daily lives has increased by about 10% compared to humanities literacy. Conversely, the number of students who understand relevant knowledge and can apply social literacy skills in their daily lives has decreased by about 10% compared to humanities literacy.

Table 1. Humanistic literacy ability familiarity.

	Ungrounded	Understanding basic knowledge	Normal	Practiced	Expert
Int. Per.	41/547(7.5%)	99/547(18.1%)	235/547(42.96%)	127/547(23.22%)	45/547(8.23%)
Cul. Com.	37/547(6.76%)	121/547(22.12%)	241/547(44.06%)	117/547(21.39%)	31/547(5.67%)
Wri. Exp.	17/547(6.76%)	71/547(12.98%)	239/547(43.69%)	169/547(30.9%)	51/547(9.31%)
Art App.	40/547(7.31%)	109/547(19.93%)	209/547(38.21%)	150/547(27.42%)	39/547(7.13%)
lit.App.	35/547(6.4%)	108/547(19.74%)	223/547(40.77%)	141/547(25.78%)	40/547(7.31%)
Car.Plan.	45/547(8.23%)	123/547(22.49%)	233/547(42.6%)	112/547(20.48%)	34/547(6.22%)
sel-refl.	23/547(4.2%)	53/547(9.69%)	213/547(38.94%)	167/547(30.53%)	91/547(16.64%)
Admi LEAD	103/547(18.83%)	172/547(31.44%)	191/547(34.92%)	60/547(10.97%)	21/547(3.84%)
SS	73/547(13.35%)	170/547(31.08%)	213/547(38.94%)	74/547(13.53%)	17/547(3.11%)
Phi.Thik.	80/547(14.63%)	167/547(30.53%)	205/547(37.48%)	70/547(12,8%)	25/547(4.57%)
lg Comm.	21/547(3.84%)	71/547(12.98%)	241/547(44.06%)	164/547(29.98%)	50/547(9.14%)
HIST Anal	76/547(13.89%)	152/547(27.79%)	198/547(36.2%)	99/547(18.1%)	22/547(4.02%)

The vast majority of university students have only heard of but never used most of the technologies mentioned in the questionnaire (approximately 40-70%). Around 20% of students can operate most of the technologies, but the percentage of students who can use technology for innovative applications is less than 10% on average. Although Taiwanese university students lack understanding and proficiency in most technologies, only document processing software, database information retrieval, and digital multimedia are familiar and practically applicable to them.

From the survey, it was found that about 20% of female students excel in abilities such as textual expression, literary appreciation, artistic appreciation, self-reflection, and language communication compared to less than 10% of male students, indicating that females have a higher level of understanding and application of humanities literacy abilities than males. In terms of majors, it was found that students in science and engineering departments almost have no understanding of the knowledge learned and the humanities literacy abilities required for humanities subjects.

Regarding technology application abilities, it was found that over 90% of humanities majors have never heard of the common technologies used in digital humanities research, and they only use digital tools such as document processing software and digital multimedia. This shows the weak technological operational capabilities of humanities majors. As for students in science and engineering departments, although the majority have used relevant technologies, they only know how to operate them and cannot innovate or apply technology. This also reflects that Taiwan's education in science and engineering mainly focuses on practical operations, teaching students how to use technology but not how to innovate and apply it.

Table 2. Technology application ability.

	heard of, but not used	used before	can operate	can apply creatively	can develop the tool
3D MAP	254/547(46.44%)	159/547(29.07%)	88/547(16.09%)	38/547 (6.95%)	8/547 (1.46%)
BDDE	195/547 (35.65%)	171/547(31.26%)	153/547(27.97%)	27/547 (4.94%)	1/547 (0.18%)
DS	14/547 (2.56%)	40/547 (7.31%)	394/547(72.03%)	92/547 (16.82%)	7/547 (1.28%)
PDS	407/547 (74.41%)	95/547 (17.37%)	35/547 (6.4%)	9/547 (1.65%)	1/547 (0.18%)
AR/VR	249/547 (45.52%)	202/547(36.93%)	76/547 (13.89%)	18/547 (3.29%)	2/547 (0.37%)
BC	393/547 (71.85%)	97/547 (17.73%)	48/547 (8.78%)	7/547 (1.28%)	2/547 (0.37%)
GIS	253/547 (46.25%)	162/547(29.62%)	109/547(19.93%)	21/547 (3.84%)	2/547 (0.37%)
DBS	125/547 (22.85%)	135/547(24.68%)	239/547 (8.59%)	47/547 (8.59%)	1/547 (0.18%)
GD	311/547 (56.86%)	149/547(27.24%)	63/547 (11.52%)	20/547 (3.66%)	4/547 (0.73%)
DV	184/547 (33.64%)	172/547(31.44%)	147/547(26.87%)	39/547 (7.13%)	5/547 (0.91%)
DM	39/547 (7.13%)	98/547 (17.92%)	288/547(52.65%)	111/547 (20.29%)	11/547 (2.01%)
BOT	290/547 (53.02%)	180/547(32.91%)	62/547 (11.33%)	15/547 (2.74%)	0/547 (0%)
Art	108/547 (19.7%)	129/547(23.58%)	210/547(38.39%)	86/547 (15.72%)	14/547 (2.56%)
AI	210/547 (38.39%)	201/547(36.75%)	113/547(20.66%)	22/547 (4.02%)	1/547 (0.18%)
GenAI	310/547 (56.67%)	140/547(22.59%)	79/547 (14.44%)	18/547 (3.29%)	0/547 (0%)

NFT	412/547 (75.32%)	81/547 (14.81%)	43/547 (7.86%)	8/547 (1.46%)	3/547 (0.55%)
MetaVerse	383/547 (70.02%)	102/547(18.65%)	54/547 (9.87%)	9/547 (1.46%)	0/547 (0%)
IoT	378/547 (69.1%)	105/547 (19.2%)	54/547 (9.87%)	9/547 (1.65%)	1/547 (0.18%)
STEAM	262/547 (47.9%)	132/547(24.13%)	121/547(22.12%)	23/547 (4.2%)	9/547 (1.65%)

12. Conclusion

There is still room for improvement in cultivating humanities literacy abilities among Taiwanese university students. Efforts should be made to enhance students' abilities in self-reflection, administrative leadership, social research, historical analysis, language communication, and philosophical thinking, as well as to improve their understanding of technology and familiarity with technological operations, particularly among humanities majors. Students in science and engineering departments tend to focus more on humanities knowledge and literacy abilities, along with technology applications.

To address the deficiencies in students' humanities comprehension and technological application abilities, it is essential to introduce interdisciplinary courses based on the concept framework of digital humanities. These courses can help enhance students' humanities comprehension and technological application abilities. Additionally, through project-based learning and curriculum design, students can learn how to use technology in conjunction with humanities and social knowledge to solve real-life problems. It is hoped that by enhancing digital humanities courses, the spirit of digital humanities can take root, fostering more interdisciplinary talents with both humanities and technological application knowledge.

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A Study on the Cognitive Load and Flow Experience of Students with Different Cognitive Styles Using Virtual Reality Helmet for Learning

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Abstract: *With the rapid development of digital learning, the integration of 5G new technology into teaching has become a trend in modern education. However, studies have found that virtual reality may cause students to develop a higher cognitive load. In addition, many researchers have suggested that differences in learners' cognitive styles may affect learning effectiveness. Therefore, this study explores the differences in cognitive load and flow experience of students with different cognitive styles when learning with a virtual reality helmet. A total of 36 students in the fifth grade art class and physical education class of a national elementary school in Yilan County, with 18 students in the art class as the experimental group and 18 students in the physical education class as the control group, were used as the experimental subjects. In this study, students in the art class were regarded as having an intuitive cognitive style and students in the physical education class were regarded as having an analytical cognitive style, and students in the two classes were taught natural sciences using virtual reality helmets. The results of the study showed that the cognitive load caused by the intuitive students was significantly lower than that of the analytical students in the Virtual Reality Helmets study, and that the intuitive students had a significantly higher level of flow experience than the analytical students.*

Keywords: virtual reality, cognitive styles, cognitive load, flow experience

1. Introduction

In recent years, with the rapid advancement of technology, Virtual Reality (VR) technology has penetrated into various fields, and its application in the field of education has attracted much attention. VR can break the limitation of time and space, present the learning scene in front of the learners, and allow learners to learn in an emphasized interactive way (Chen, 2016; Cheng & Tsai, 2019), because of the development of VR technology, its application has become more extensive, and the use of VR helmets is also more capable of simulating real situations, so that learners can be immersed in the learning environment to enhance their interest in learning (Chen, 2016; Cheng & Tsai, 2019).

The introduction of Virtual Reality Teaching Aids (VRTAs) not only brings a new learning experience to students, but also provides educators with a new means of teaching. In discussing the advantages of virtual reality teaching aids, we will focus on the immersive learning experience they can provide. Through virtual reality technology, students can interact with the concepts in the material as if they were in the actual scene. This immersive experience helps deepen students' understanding and makes abstract concepts more concrete and practical. By simulating actual working environments or historical events, virtual reality teaching aids enable students to better understand and apply what they have learned, and develop their practical problem-solving skills. Cognitive style refers to an individual's preference for perceiving and thinking about behavior when processing information or tasks (Messick, 1976; Morgan, 1997), learners with different cognitive styles show different learning preferences and behavioral performance, and in education, many studies have suggested that In education, many studies have suggested that differences in learners' cognitive styles affect learning performance (Saracho, 1998). There is a limited amount of research available on cognitive load and flow experience in students with different cognitive styles when using virtual reality helmet for learning. Therefore, the purpose of this study is to investigate the differences in cognitive load, mind stream experience caused by students with different cognitive styles when using virtual reality helmet for learning. The research questions of this study are as follows.

1. What are the differences in the cognitive loads of students with different cognitive styles when using VR helmets for learning?

2. How do students with different cognitive styles differ in their flow experience experiences when using VR helmets for learning?

2. Literature Review

2.1 Virtual Reality

Virtual Reality (VR) has emerged as an emerging technology in recent years, and many VR technologies are often used in learning activities in various fields, from healthcare, to language teaching, to natural sciences, etc. In education, teachers and students are mostly positive about the use of VR in teaching and learning, believing that VR can enhance the effectiveness of learning and increase the Markowitz, Laha, Perone, Pea, & Bailenson, 2018). Tarng et al.(2022) argued that virtual environments are able to present information that is invisible to the naked eye and visualize concepts, which can help learners acquire more complete concepts, and that learners can learn what they need to know through sensory stimulation and contextual connections. The learning process is very simple. Such virtual reality learning applications can help to improve learners' concentration and learning initiative, and promote learners' immersion (Cooper et al., 2018; Tcha-Tokeym, Christmann, Loup-Escande, Loup, & Richir, 2018), but some studies have found that the use of virtual reality does not fully ensure that there will be a positive learning effect (Makransky et al., 2019; Ulrich, Helms, Frandsen, & Rafn, 2019).

2.2 Cognitive Styles

Messick (1984) defined cognitive style as follows: Cognitive style refers to an individual's preference for the organization of information and the conduct of experience (Chen & Macredie, 2002; Lee, Cheng, Rai & Depickere, 2005). Cognitive style can be explained as the psychological differences between individuals, which determine differences in attitudes, choices, and decision-making habits, as well as patterns of problem solving, thinking, perceiving, and remembering.The categorization of cognitive styles varies according to the purpose of the study, the point of view, or the level of analysis. One group of scholars points out that the classification of cognitive styles is related to human brain neurological activities (Entwhistle, 1981; Wilson, 1988). Allinson and Hayes (1996) classify cognitive styles into "intuitive" and "analytical" according to the difference between the left and right brain thinking styles, and define right brain thinkers as "intuitive", characterized by their preference to think in an intuitive way. Right brain thinkers are defined as "intuitive" and their main characteristic is that they prefer to perceive or process information in a sensory or perceptual way and make decisions or judgments from a holistic point of view, while left brain thinkers are defined as "analytical" and their main characteristic is that they prefer to perceive or process information in a logical or deductive way and make decisions or judgments only after they have gained a detailed understanding of the matter (Agor, 1986).

2.3 Cognitive Load

Cognitive load is the amount of mental resources required by a learner to perform a task (Sweller, 1988). It is the total amount of mental activity in terms of mental effort and mental load on the learner's working memory (Cooper, 1998; Sweller, Van Merrienboer, & Paas, 1998).Pass (1988) suggests that cognitive load consists of two factors, mental load, which is caused by the material or the difficulty of the task, and mental effort, which is caused by the difficulty of the material or the difficulty of the task. One is the mental load, which is caused by the difficulty of the material or task, and the other is the mental effort, which is the amount of mental resources that students put into completing the task. Complex and novel tasks usually result in higher cognitive load, and learners' experience and expertise may affect their effectiveness in handling cognitive load (Su, 2016).

2.4. Flow Experience

Mindfulness is a state of mind that occurs when one is completely focused on a goal or immersed in an activity (Csikszentmihalyi, 1975) Pearce, Ainley,& Howard (2005) suggest that flow experience include aspects of control, engagement, and enjoyment (Pearce, Ainley,& Howard, 2005). The following are some of the aspects of flow experience. Control refers to the degree to which the learner can control the learning environment and activities; engagement refers to the degree to which the learner devotes attention to the learning process; and enjoyment refers to the degree to which the learner derives pleasure from the learning process. Numerous studies have indicated that enhancing the flow experience has a positive impact on learning outcomes (Erchel & Jamet, 2019) and can reduce cognitive load (Chang et al., 2017).

3. Research Methodology

3.1 Participants

This study utilized the quasi-experimental method. A total of 36 students participated in the study, including 18 students in the art class and 18 students in the physical education class of a national elementary school in Yilan County. Among them, students in the art class preferred to think freely and holistically, so the study regarded students in the art class as having an intuitive cognitive style, whereas students in the physical education class preferred to think logically and with an organized structure, so the study regarded students in the art class as having an intuitive cognitive style. Therefore, students in the physical education class were regarded as having an analytic cognitive style.

3.2 Procedure

Figure 2 shows the flowchart of the study. The flowchart of the study was two weeks, with two lessons per week, and each lesson lasted 40 minutes. In the first class, the instructor explained the wearing and basic operation of the VR helmet for about 10 minutes, and the students were asked to wear and operate the VR helmet in groups of two for about 30 minutes, and then they were asked to explore the solar system using the virtual reality software "Star Chart" and to complete the learning sheets. At the end of the activity, students were asked to complete the Cognitive Load Scale and Flow Experience Scale, which concluded the experiment.

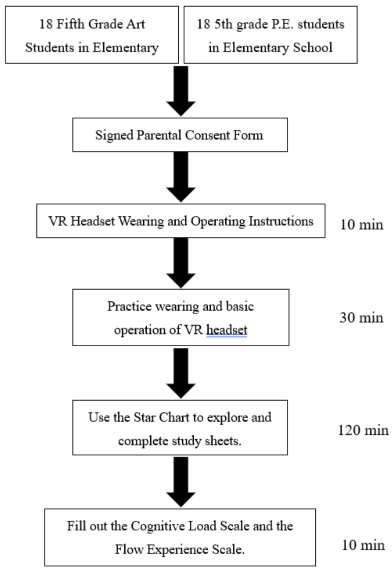

Figure 2. Research Flowchart .

3.3 Measuring Tools

3.3.1 Cognitive load scale

The cognitive load scale by Hwang, Yang & Wang (2013) was used in this study. This scale consists of 8 questions and is divided into two constructs: 5 questions on "Mental Load" and 3 questions on "Mental Effort". This scale is based on a seven-point Likert-type scale, where 1 means strongly disagree and 7 means strongly agree. The Cronbach's alpha of this scale is .88, which is in accordance with the standard proposed by Nunnally (1967), which indicates that a scale with a reliability of .70 or higher has good reliability.

3.3.2 Flow experience scale

In order to investigate what the students' flow experience is when using VR helmets for learning, a questionnaire was filled out after the experiment was completed. This study used the five-point Likert scale developed by Pearce et al. (2005), with 1 indicating strongly disagree and 5 indicating strongly agree, and the questions were divided into three directions, two questions on "Sense of control", and three questions on each of the following: "Focus" and "Sense of fun". The Cronbach's alpha for this scale is .93, with good reliability.

4. Results

4.1 Differences in Cognitive Load of Students with Different Cognitive Styles Learning with Virtual Reality Helmets

IBM SPSS Statistic 17 was used to analyze the data in this study. An independent sample t-test was used to analyze whether there was a difference in cognitive load between intuitive students and analytical students when using the virtual reality helmet for learning, and the results are shown in Table 1. The t-test results for the mental load construct were t = -2.706, p = .011 < .05, which reached a significant level, indicating that intuitive students were more comfortable and had less difficulty than analytical students in using the equipment when using the virtual reality helmet for learning. There was not much difficulty in the operation of ; the t-test analysis of the mental effort construct was t = -2.413, p = .01 < .05, which reached a significant level, indicating that intuitive students were less likely to use too much mental effort in the operation of the device than analytical students when learning with the VR helmet; and the t-test analysis of the overall cognitive load was t = -2.792, p = .009 < .01, which reached a significant level, indicating that intuitive students were more successful in the use of the device than analytical students in the operation of the VR helmet. 01, reaching a significant level, the two groups reached a significant difference and it can be seen that intuitive students caused less cognitive load when learning with the VR helmet compared to analytical students.

Table 1. Cognitive load analysis of students: independent sample t-test analysis table

facet	Intuitive students $N = 18$		Analytical students $N = 18$		t	p
	M	SD	M	SD		
mental load	2.04	1.01	3.12	1.35	-2.706	.011*
mental effort	2.24	1.18	3.37	1.60	-2.413	.021*
Overall	2.12	0.98	3.22	1.35	-2.792	.009**

*$p < .05$, **$p < .01$

4.2. Students with Different Cognitive Styles Learning with Virtual Reality Helmets Differences in Flow Experience

Table 2 Analytical results of the independent sample t-test for the students' flow experience for learning with the VR helmet. In the sense of control construct, the results of were t = 3.228, p = .003 < .01, which was significant, indicating that intuitive students of was more in control of the pace of learning than analytical students. The results of the concentration construct were t = 2.990, p = .006 < .01, which was significant, indicating that intuitive students were more focused on the task and engaged in the learning activity than analytical students. The results of the fun component were t = 2.845, p = .008 < .01, reaching a significant level, indicating that intuitive students were able to experience more fun than analytical students during the learning process using the VR helmet. The results of the overall component were t = 3.307, p = .002 < .01, reaching a significant difference between the two groups, indicating that the use of the VR helmet for the learning process in intuitive students was more effective than that of analytical students. The overall constructive analysis result was t = 3.307, p = .002 < .01, and the two groups reached a significant difference, indicating that intuitive students could have a higher flow experience when learning with the VR helmet compared to analytical students, and could put more thoughts into the learning activities, which induced a strong mental flow.

Table 2. Analysis of students' flow experience: independent sample t-test analysis table

facet	Intuitive students N = 18		Analytical students N = 18		t	p
	M	SD	M	SD		
sense of control	4.19	0.69	3.44	0.70	3.228	.003**
focus	4.69	0.55	3.96	0.86	2.990	.006**
fun	4.81	0.51	4.19	0.79	2.845	.008**
Overall	4.61	0.52	3.92	0.73	3.307	.002**

**p < .01

5. Conclusion and Recommendations

The purpose of this study is to investigate the differences in cognitive load and flow experience of students with different cognitive styles when they use virtual reality helmets for learning. The results of the study showed that in terms of cognitive load, intuitive students were less likely to experience excessive cognitive load when learning with the VRH than analytical students. In terms of mental flow experience, intuitive students could focus more on the learning activities using the virtual reality helmet than analytical students, had a higher degree of control over the learning activities, and also gained more enjoyment from the process and had a better flow experience.

Through the results of this study, it was found that intuitive students had better flow experiences and caused less cognitive load than analytical students when using virtual reality helmets for learning. Virtual reality helmets may be more suitable for intuitive students to apply to their learning activities. The limitations of this study include that the instructional design was only targeted towards natural science solar system education, and there were fewer available equipment. this study was only conducted in the natural science teaching of the art class and the physical education class at the moment, and it is suggested that the impact of virtual reality teaching materials applied to more different classes or different areas may be carried out in the future. It is suggested that in the future, the impact of using virtual reality teaching materials in more different classes or different areas could be investigated. The sample size of this study is relatively small in order to accommodate the number of teachers and equipment. It is suggested that the sample size could be increased in the future if there is enough funding and equipment to help the study results to be generalizable. In addition, interviews with students, teachers, and even parents can be added to the study in order to analyze the qualitative data and to find out the teaching mode suitable for students with different cognitive styles.

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Prerequisites for Teachers to Implement Augmented Reality: A Systematic Review

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Abstract: *The use of Augmented Reality (AR) in teaching and learning, and the pivotal role teachers play in this process has been widely recognized. However, the prerequisites for effective implementation by teachers and their specific needs remain unclear. This systematic literature review aimed to elucidate the role of teachers in AR education studies and identify the prerequisites for their competency in integrating AR into teaching and learning. The findings revealed a lack of focus on specific teaching strategies and limited attention to AR-related professional development (PD) for teachers. Practice-based collaborative teacher training was proposed as an effective approach for enhancing teachers' competency in AR implementation.*

Keywords: Augmented Reality, Teacher's role, Systematic review, K12

1. Introduction

Over the past decade, there has been an increase in the number of Augmented Reality (AR) applications used in the field of education (Chang et al., 2023). The value and effectiveness in using AR for facilitating teaching and learning has been well established (López-Belmonte et al., 2020). Its immersive qualities, achieved through the overlay of digital information on the real world, facilitate real-time interactions with both real and virtual elements (Azuma et al., 2001), thereby enriching learning experiences through its multimodal qualities, interactivity, and capacity to elucidate abstract concepts (Wen et al., 2023). Despite the advantages of AR in education, it is essential to acknowledge the challenges educators may face in integrating it into their teaching practices. It requires teachers to be sufficiently trained in using AR technologies (López-Belmonte et al., 2020; Nikou et al, 2023). While educators envision the advantages in adopting AR-enhanced instructional methods, they may be lacking in the necessary competencies for AR implementation (Nikou et al, 2023). However, there is a scarcity of studies examining prerequisites for teachers to integrate AR in teaching and learning (Nikou et al., 2023).

Studies have identified prerequisites for implementing ICT in educational practices (e.g., Heitink et al., 2016; Kippers et al., 2018; Spiteri & Rundgren, 2020). Spiteri and Rundgren (2020) conducted a systematic review exploring factors affecting primary teachers' use of digital technology and identified four main areas, including the school culture, teachers' knowledge, attitude, and skills. Similar findings were highlighted by Heitink et al. (2016) and Kippers et al. (2018). These studies emphasized the importance of teachers' self-awareness, understanding of students, and familiarity with technology. Additionally, Spiteri and Rundgren (2020) emphasized the impact of school culture on teachers' knowledge, attitudes, and skills. A supportive school culture enhances teachers’ PD by promoting collaboration, reflection, and knowledge sharing (Tondeur et al. 2017). School culture, highlighted by Heitink et al. (2016) and Kippers et al. (2018), includes factors such as support from school leaders and teacher collaboration.

Therefore, this systematic review on the prerequisites for teachers to implement AR activities was conducted by considering both dimensions of teachers and school context. It combined findings from papers published between 2011 to 2023 to provide an overview of teachers’ role in AR-related implementations in K12 schools. The study aimed to deepen understanding of the prerequisites for effectively implementing AR in the classroom and, more specifically, to provide suggestions for teachers' PD to enhance their ability to integrate AR into teaching and learning. To achieve this, the study will address the following two questions: (1) What are the purposes of existing AR-related studies investigating the role of teachers? and (2) What teacher-related prerequisites need to be considered to ensure the effectiveness of AR-supported teaching and learning?

2. Methodology

2.1. Searching Procedure

To address our research questions, we followed the PRISMA framework, comprising four phases: identification, screening, eligibility, and inclusion. Three databases (ERIC, WOS, and ES) were searched for literature on AR in education. We limited the search terms to "Augmented Reality" AND ("Teachers" OR "Educators" OR "School Staff") AND ("Classrooms" OR "Classroom Environment") across all databases. The search spanned from 2005 to 2023, yielding 314 results in the identification stage. After removing 24 duplicates, 290 articles proceeded to the screening stage. Eligibility was checked in three rounds. Round 1 involved reviewing titles, abstracts, and accessing full texts as needed, eliminating studies lacking empirical findings, not in English, not K-12 focused, or not specific to AR. We developed inclusion criteria, including scientific, peer-reviewed publications, empirical research, K-12 context, AR in classroom practice, and English full texts, resulting in 102 articles after round 1. Round 2 added criteria to exclude studies on pre-service teachers or lacking research questions about teachers, resulting in 67 exclusions. The focus shifted to understanding teachers' roles and experiences, excluding pre-service teachers. Additionally, studies without specific research questions about teachers were excluded. The remaining 35 articles underwent full-text screening, resulting in the exclusion of 15 conference proceedings and one article with insufficient information. Two more articles were identified through snowballing. The screening process concluded with 22 review articles.

2.2. Data Coding and Data Analysis

Our analysis consists of three stages. Firstly, we synthesized the findings from the 22 selected papers, identifying their research purposes, delineating the role of teachers, and extracting prerequisites for successful implementation reported in these studies. Secondly, we analyzed teacher-related prerequisites through the lens of

ICT implementation in classrooms, drawing from Heitink et al.'s (2016) and Kippers et al.'s (2018) studies as theoretical foundations. This guided the development of coding categories, which were further refined based on findings from the reviewed papers. The second and third authors independently coded the data. Thirdly, the first author clustered similar prerequisites into sub-categories, incorporating input from the other two authors, and the final dimensions of categories were confirmed collaboratively. This process was inductive, driven by the prerequisites identified in the selected studies.

3. Results

3.1. Purposes of Existing AR-related Studies Investigating the Role of Teachers

The selected papers investigating the role of teachers can be categorized into four groups based on their research objectives. The first category discusses teachers' general perspectives on integrating AR into classrooms (N=6, 27.3%). The second category focuses on teachers' feedback on specific AR-based learning designs, with most studies falling into this category (N=12, 54.5%). The third category explores teacher scaffolding strategies in AR-based learning and their effects (N=1, 4.5%). The fourth category centers on AR-related teacher training and its effects (N=3, 13.6%).

As shown in Table 1, when investigating teachers' perspectives on AR, most studies use semi-structured interviews and surveys for open coding and descriptive statistics to obtain feedback from teachers on attitudes and skills in using AR. These studies focusing on specific AR design primarily adopt a case study approach, conducting thematic and content analysis through surveys, interviews, and observations to investigate feedback from students and teachers. Additionally, in a few studies, classroom artifacts (lesson plans, final papers, etc.) or log data were used to supplement the findings of specific AR design effects. While acknowledging the importance of teachers in AR-based learning, few studies delve into specific scaffolding strategies for enhancing its effects. Moreover, limited attention is given to teachers' PD, with some studies suggesting the effectiveness of certain training approaches, such as TSED learning design by Buchner and Hofmann (2022), and others demonstrating the implementation process of teacher PD programs through design-based research (Ilona-Elefteryja et al., 2020; Meletiou-Mavrotheris et al., 2020).

Table 1. Purposes and approaches of AR-related studies investigating the role of teachers

Categories	Numbers	Research methods	Data sources
1. Teachers' view of using AR	6	Survey study (N=4) Case study (N=2)	• Questionnaires • Interview • Documents

2. Effectiveness of specific AR design	12	Survey study (N=2) Case study (N=7) Experimental/quasi- design (N=2) Design-based research (N=1)	• Questionnaires • Interview • Observation and field notes • Reflection journal • Class artifacts (lesson plan, documents, final papers) • Log data
3. Specific teaching strategies or mechanisms	1	Experimental design (N=1)	• Test • Interview
4. AR-related teacher training and its effects	3	Quasi-experimental design (N=1) Design-based research (N=1) Others (N=1)	• Questionnaire • Interviews • Activity reports

3.2. Teacher-related Prerequisites for Implementing AR

Table 2 outlines the literature on AR in education, specifying teacher-related prerequisites for AR implementation in classrooms across four categories: teachers' knowledge and skills, attitudes and beliefs, leadership and culture, and support and professional development. Key knowledge and skills required for teachers to effectively integrate AR into teaching and learning encompass: (1) proficiency in AR technology and its applications, (2) adeptness in integrating AR content and pedagogy into subject-specific teaching, and (3) ability to provide guidance to students during AR activities. Concerning attitudes and beliefs, teachers should demonstrate: (1) a willingness to learn and utilize AR technology, integrating it into curricula, (2) belief in AR's educational benefits, and (3) confidence in implementing AR activities.

Moreover, contextual factors within the school environment play a crucial role in successful implementation. Prerequisites related to leadership and culture entail: (1) alignment of leadership vision with teachers' objectives, and (2) a culture fostering collaboration and professional learning communities. Support and effective professional development programs are essential for successful AR integration. These include: (1) technical and financial assistance, (2) flexible and adaptive curricula, and (3) practice-centered collaboration within professional development programs.

Table 2. Teacher-related prerequisites for the implementation of AR

Teacher	
Knowledge and skills	**Knowledge and skills of AR familiarity and technical proficiency** • Familiarity and experience with AR technology, including AR devices, applications, and platforms (Pan et al., 2021; Ilona-Elefteryja et al., 2020) • Utilizing AR's affordances while planning the lesson outline (Tillman et al., 2019) • Ability to deal with basic technical issues related to AR (Ilona-Elefteryja et al., 2020) **Knowledge and skills of integrating AR content and pedagogy into teaching subjects** • The ability to create AR contexts for lesson plans (Tillman et al., 2019) • Proficiency in flexibly integrating AR into curricula, including selecting the specific AR application and using AR materials (Ashely-Welbeck & Vlachopoulos, 2020), and modifying them to meet teaching needs (Squire, 2010) • Incorporating educational content from other disciplines using AR (Ilona-Elefteryja et al., 2020) • Selecting, using, and even creating appropriate AR applications suitable for specific teaching subjects (Nikou et al., 2023) **Knowledge and skills of providing guidance to students during AR activities** • Playing a guiding role rather than merely providing information (Squire, 2010)
Attitude and beliefs	**Willingness to learn and use AR technology, and to incorporate it into curricula** • Positive attitude toward AR technologies (Marín-Díaz et al., 2022)

	• Willingness to invest time in creating AR content and lessons (Ilona-Elefteryja et al., 2020). • Willingness to incorporate AR into curriculum (Buchner & Hofmann, 2022), • Willingness to modify task structures when implementing AR (Mitchell, 2011). **Beliefs in the educational benefits that AR can offer** • Believing that AR technology will be genuinely useful for teaching (Tillman et al., 2019) and will lead to positive learning outcomes (Marín-Díaz et al., 2022). **Confidence of implementing AR activities** • Confidence in engaging students in AR class activities (Meletiou-Mavrotheris et al., 2020).
Context	
Leadership and culture	**Alignment of leaders' version with teacher's objective** • The alignment of leaders' vision for integrating AR into the educational environment with the objectives set by teachers. (Huang et al., 2016). • Deciding on the areas and levels of using AR in education (Nikou et al., 2023) **Culture of collaboration and professional learning communities** • Establishing a culture that fosters collaborative efforts among teachers, administrators, and instructional designers (Perifanou et al., 2022) • Creating a community that encourages the exchange of ideas, materials, expertise, feedback, and best practices related to AR (Meletiou-Mavrotheris et al., 2020; Perifanou et al., 2022)
Support and Professional development	**Technical and financial support** • Leadership's active support for AR integration, involving the provision of resources, equipment (Squire, 2010), training programs, and expertise to facilitate AR adoption (Ilona-Elefteryja et al., 2020).

- Allocating the necessary time for preparing and implementing AR activities, (Huang et al., 2016), along with providing technical and financial support (Huang et al., 2016)

Flexible and adaptive curricula

- Adaptive curricula enabling teachers to customize materials to local needs. (Squire, 2010).

Practice-centered collaboration

- Empowering teachers to gain confidence and competence in AR usage. (Nikou et al., 2023)
- Encouraging exchange of lesson plans, expertise and codesign educational activities based on specific AR-enabled teaching approach (Meletiou-Mavrotheris et al., 2020)

6. Discussion and Conclusion

The results suggest that few studies pay attention to the specific teaching strategies or mechanisms that can be used to ensure the effects of AR-based learning. This finding is consistent with the claim by Garzón et al. (2020) in their review study that minimal guidance during instruction was not sufficient in existing AR studies. Meanwhile, the results of the present review demonstrate that only a small number of studies concentrated on AR-related PD for teachers. Based on the existing research, the prerequisites for teachers' abilities and attitudes towards integrating AR into classroom teaching are like those of using other ICT tools. Teachers need to be familiar with the tools, integrate the tools with teaching methods and curriculum content, and know how to manage classroom activities. In terms of attitude, teachers are willing to actively understand and learn to use the tools, believe in their teaching value, and can confidently use the tools.

However, the uniqueness of using AR lies in its emphasis on the integration of tools with curriculum content. This is because the use of AR involves the visualization of specific knowledge points, enabling learners to have a better understanding of abstract concepts, thus requiring consideration of specific course needs for students of different grade levels. The flexibility of the curriculum has been proposed as an important factor for the effective implementation of AR activities. Additionally, the importance of technology and financial support is underscored, given the relatively high development costs associated with AR activities. The willingness of school leaders, alignment of teachers' goals, and a collaborative culture align with prerequisites observed in other effective curriculum reforms.

Practice-based collaborative teacher training is highlighted as an effective approach to teachers' PD for designing and implementing AR activities. Studies have indicated that PD should provide regular opportunities for teachers to be involved in active learning and reflection on it with their colleagues (Garet et al., 2001). Furthermore, effective PD should be situated within an authentic and contextualised learning community and allows educators to learn practical solutions from their peers (Webster-Wright, 2009). However, the findings of this review suggest that existing AR studies related to teacher's roles only focused on small-scale PD initiatives, despite the emphasis on collaboration among teachers. Our results encourage future studies on large-scale and longitudinal AR-related PD at the community level.

This review study has certain limitations as well. First, some relevant studies might not have been included due to the search terms and databases considered in this review. Second, the studies published before 2011 and after August 2023 were not included. Third, as articles specifically focusing on teacher education in AR environments are limited, in some selected studies, teachers' role was merely investigated in one of the research questions rather than the central focus of the entire study.

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A Proposed Framework for Promoting Metaverse Literacy

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Abstract: *This study aims to propose a framework for promoting metaverse literacy. With the development of technologies such as Real-time 3D Rendering and Extended Reality (XR), the social impact of metaverses has increased tremendously. Metaverse literacy should be promoted to the general public, particularly students, to enable them to benefit from its development and avoid being trapped by its potential risks. To acquire metaverse literacy, we propose that people should learn from three aspects: the engagement in metaverses, the understanding of metaverses, and the social impact of metaverses. To verify this proposed framework, we designed a survey and collected data from 359 university students. The results of the exploratory factor analysis suggested four factors, with the first two aligning with the engagement and understanding dimensions. The social impact dimension was separated into the current influence and future impact of metaverses. Therefore, the last two factors can be treated as two subdimensions and the results support our current framework.*

Keywords: exploratory factor analysis, framework, metaverse literacy, survey, university students

1. Introduction

On the one side, metaverses accompanying the physical world have great potential for benefiting people in many fields such as the sports economy (Huang et al., 2022). On the other side, metaverses may have a negative impact if issues such as cybersickness, privacy and security are not dealt with properly (Calogiuri et al., 2018). As metaverses may have wide-ranging influences covering all aspects of people's lives, including economy, health, and education (Almarzouqi et al., 2022, Calogiuri et al., 2018; Huang et al., 2022), people must learn about the potential advantages and risks associated with metaverses. The ability to understand and efficiently engage in metaverses is essential for people in the digitalized world and thus we intend to introduce metaverse literacy in this study and advocate it to the general public.

2. Literature Review

2.1 Technologies Related to Metaverse

Since the term "metaverse" was first introduced by Neal Stephenson (1992) in his science fiction Snow Crash, it has continuously been redefined through the decades (Ritterbusch & Teichmann, 2023). Metaverse is also considered a part of the broader Web 3.0, which is a semantic web of the next generation (Ritterbusch & Teichmann, 2023). Park and Kim reviewed the literature and gave a lengthy definition "Metaverse is a compound word of transcendence meta and universe and refers to a three-dimensional virtual world where digital avatars engage in political, economic, social, and cultural activities" (Park & Kim, 2022, p. 4211). In this study, we define metaverse as a 3D virtual environment for real-time interaction for the sake of simplicity for the general public to understand.

Metaverse draws upon numerous technologies to support its functions. The related technologies among those are real-time 3D rendering, extended reality (XR), blockchain, digital twin (DT), artificial intelligence (AI), Internet of things (IoT) and 5G/6G (Huynh-The et al., 2023). Real-time 3D is a computer graphics technology that generates three-dimensional interactive content faster than human perception (Fadzli et al., 2023), which is the core to enable synchronous communications between users through avatars, the representations of users in the virtual worlds (Huynh-The et al., 2023). Another set of technologies crucial to metaverse development is XR technologies, where XR is the umbrella term for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) technologies (Akyildiz & Guo, 2022). VR creates a purely virtual environment, AR overlays digital objects into the real world, and MR merges the virtual and the real world (Akyildiz & Guo, 2022). Meanwhile, DT technologies create digital equivalents of physical objects in metaverses (Park & Kim, 2022). Moreover, transactions within virtual worlds are supported by non-fungible tokens (NFTs), which are blockchain-based digital assets (Ali et al., 2023). Therefore, blockchain, a shared digital record for keeping track of transactions with cryptographic technologies, supports transactions in metaverses (Huynh-The et al., 2023). Apart from those foundational technologies, other existing technologies can also support metaverses. For instance, AI technology can improve 3D image processing (Huynh-The et al., 2023) while IoT technology can help create immersive experiences in metaverses (Asif & Hassan, 2023). The 5G/6G network technologies with high data rates and low latency will enable wireless XR technologies (Akyildiz & Guo, 2022).

2.2 A Proposed Framework of Metaverse Literacy

With recent advancements in technologies such as VR and AR (Huang et al., 2022), metaverses have been created and applied for many different purposes, such as medical education and sports economy (Almarzouqi et al., 2022; Huang et al., 2022). In the future, metaverses will have a widespread impact on the economy, health, education, and many other fields (Almarzouqi et al., 2022, Calogiuri et al., 2018; Huang et al., 2022). For instance, proper use of metaverses such as metaverse sporting experiences can have a positive influence on athlete's mental health and endurance performance (Huang et al., 2022). Nevertheless, potential risks produced by metaverses should be dealt with to prevent loss. For instance, cybersickness, where users experience dizziness after experiencing virtual environments, may occur when engaging in immersive virtual worlds created using VR and AR technologies (Calogiuri et al., 2018). Meanwhile, the security and privacy issues associated with NFTs remain to be solved (Ali et al., 2023). Consequently, learning about metaverses and relevant technologies is crucial for benefiting from metaverses and minimizing harm. With knowledge regarding metaverses' advantages and risks, people still need to engage within the metaverses to improve their performances. Engagement in metaverses has been investigated these years, with many researchers studying people's performances within immersive environments and outcomes after the immersive experiences (Calogiuri et al., 2018, Huang et al., 2022). The willingness of students to be engaged in metaverses is influenced by lots of factors and personalized metaverses should be designed to enhance students' willingness (Almarzouqi et al., 2022).

To sum up, engagement in metaverses, understanding technologies related to metaverses, and the social impact of metaverses are the three most important components of metaverse literacy, and we introduced this metaverse literacy framework with three dimensions, engagement, understanding, and social impact. In the next section, we will focus on examining the suitability of our framework by analyzing the results from the metaverse literacy survey.

3. Methods: Participants, Instruments, Procedure and Analyses

To verify the proposed model, a convenience sample of 359 students was recruited from two universities in Hong Kong (n = 359). There were 317 undergraduate students and 42 postgraduate students, with 207 female students and 152 male students. 60 students had programming experience while 208 students claimed that they had experience with metaverses. The students' ages ranged from 17 to 43 (M = 21.00, SD = 2.76). To study the three dimensions of metaverse literacy, the survey included 22 questions measuring engagement in metaverses (e.g., I want to use metaverses for interacting with people or digital artifacts), understanding of technologies related to metaverses (e.g., Virtual Reality (VR) technology creates purely virtual environments. I understand the concept of VR), and social impact of metaverses (e.g., I will be engaged in various social activities in metaverses, such as making friends, entertainment, education, tourism, etc.) The 5-point Likert scale was used in this survey, ranging from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree to 5 = strongly agree. Cronbach's alpha measures for internal consistency were calculated (Shrestha, 2021).

The surveys were carried out online through the Qualtrics platform, and duplicate responses were removed. The expected time for completing the survey was 10-15 minutes. If a respondent finishes it in an unusually short time (i.e., 180 seconds), this may suggest that they did not engage with the questions thoughtfully and the response was excluded. The descriptive statistics and Exploratory Factor Analysis (EFA) were conducted using SPSS. The correlations between all 22 items were obtained to check if any values were too high and if the two items could be merged. Bartlett's test of sphericity and Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) statistics were obtained to ensure suitability for EFA (Shrestha, 2021). Factors were extracted using the maximum likelihood method with an oblique promax rotation based on Kaiser's criteria and the Scree Test, while the communalities of all items were also calculated (Shrestha, 2021).

4. Results and Discussion

Bartlett's test of sphericity ($\chi^2(231) = 4302.07$, $p < 0.001$) and KMO statistics (0.917) showed that the data was suitable for EFA. Both Kaiser's criteria and the Scree Test suggested four factors and the factors extracted explained 54.97% of the variances. The Cronbach's alphas were greater than 0.8 for all three constructs engagement, understanding and social impact, showing good internal consistency. The skewness was generally close to 0, suggesting that the distributions for all items were symmetric. As there were no items with communalities close to 0, we proceeded to interpret the EFA results. Factor 1 was associated with Engagement 1

(λ = 0.62, M = 3.67, SD = 0.99), Engagement 2 (λ = 0.58, M = 3.59, SD = 0.96), Engagement 3 (λ = 0.65, M = 3.42, SD = 0.95), Engagement 4 (λ = 1.03, M = 3.70, SD = 0.94), Engagement 5 (λ = 0.96, M = 3.59, SD = 0.95), Engagement 6 (λ = 0.61, M = 3.42, SD = 1.04). Factor 2 were associated with questions regarding the understanding of VR (loading λ = 0.45, M = 3.69, SD = 0.90), AR & MR (λ = 0.64, M = 3.33, SD = 0.99), Real-time 3D (λ = 0.57, M = 3.53, SD = 0.96), AI (λ = 0.54, M = 3.66, SD = 0.92), IoT (λ = 0.80, M = 3.13, SD = 1.08), NFT (λ = 0.65, M = 3.25, SD = 1.05), DT (λ = 0.74, M = 2.78, SD = 1.08), Web 3.0 (λ = 0.75, M = 2.96, SD = 1.07) and 5G/6G (λ = 0.72, M = 3.48, SD = 1.01). Factor 3 were associated with Social Impact 2 (λ = 0.82, M = 3.83, SD = 0.95), Social Impact 3 (λ = 0.87, M = 3.87, SD = 0.87) and Social Impact 4 (λ = 0.56, M = 3.85, SD = 0.85), while Factor 4 were associated with Social Impact 1 (λ = 0.43, M = 3.37, SD = 1.10), Social Impact 5 (λ = 0.79, M = 3.29, SD = 0.98), Social Impact 6 (λ = 0.42, M = 3.87, SD = 0.85), and Social Impact 7 (λ = 0.57, M = 3.48, SD = 0.88).

In general, EFA results align with our three dimensions and show evidence for our framework to be appropriate, while confirmatory factor analysis should be carried out on future data to finally validate the model. Factor 1 is associated with all the engagement questions, with the questions regarding students' willingness to learn about the application of AI and IoT in metaverses being strongly related to it, with loadings higher than 0.9. Apart from that, all engagement questions have mean scores greater than 3, suggesting that students are willing to engage in metaverses in general. Factor 2 is associated with those questions concerning students' understanding of metaverses, where most questions have averages greater than 3 but lower than 4, suggesting that students generally have some understanding of Real-time 3D, VR, AR, MR, AI, IoT, NFT and 5G/6G technologies. Two questions that have mean scores lower than 3 are regarding the concepts of DT and Web 3.0, suggesting that the understanding of these two concepts is limited among students. Meanwhile, these two questions have loadings greater than 0.7, closely related to the first factor extracted. Understanding regarding concepts of IoT and 5G/6G is also strongly related to Factor 2 with loadings greater than 0.7. Introducing the core technologies to students with a focus on these four questions may help enhance their metaverse literacy, while further research is needed. While the first two factors exactly align with our understanding and engagement dimensions, the social impact dimension has been separated into two factors, with questions related to future attitudes towards metaverses being combined into one factor, and questions related to current views being merged into another. Questions related to Factor 3 investigate students' awareness of the potential risks and influences of metaverses, with the two covering potential risks having loadings greater than 0.85. As both are related to the social impact of metaverses at different time points, we choose to keep the social impact dimension and put questions regarding current views and future views together.

5. Conclusion

To sum up, a metaverse literacy framework was proposed in this study to guide educators in enhancing students' metaverse literacy. It was supported by the EFA analysis with three dimensions of engagement in metaverses, understanding of metaverses and social impact of metaverses in current and future views, with the former two dimensions completely aligned with the extracted factors and the social impact dimension separated into two subdimensions. To prepare students for the age of metaverses, students should learn about the related technologies and their potential risks, engage in metaverse activities, as well as learn about the social impact of metaverses. Teachers should have technology readiness and explicate the concepts to students. Students should have opportunities to effectively engage in metaverses, which is an important part of metaverse literacy where many current studies are being conducted. Further studies should be done investigating whether the social impact dimension is separated by current and future views. A limitation of this study is that we used convenience samples from two universities, making the results possible to be not generalizable. Confirmatory analyses should be conducted on new samples from diverse backgrounds to fully establish the framework. Future research should explore further the social impact dimension and the interrelationships among the three dimensions.

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STEAM 教育結合元宇宙遊程體驗及文創商品之研究-

以台灣磚雕工藝文化為例

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【摘要】 本研究計畫以 STEAM 教育結合元宇宙遊程體驗及文創商品開發之研究從符號學和工藝工法的角度切入，探討磚雕工藝特色與其文化元素,並以苗栗金良興磚廠為研究標的進行 VR 數位教材製作、數位體驗遊程規劃以及文創商品設計製作研究。本研究第一階段為「探討磚雕工藝特色與其文化元素」，透過相關史料、文獻和田野調查探討台灣磚雕的歷史背景。分析歷史背景對磚雕藝術的影響，包括技術的演進和風格的演變。接著從符號學的角度出發，透過評價構造法、隱喻抽取技術，探討台灣磚雕中常見的符號和意象，並解釋這些符號的文化意義，這些符號如何反映當地文化價值。透過訪談磚雕藝術家，找出台灣磚雕與當地文化之間的相互影響，歸納台灣磚雕在各領域應用之文化元素，並以此作為數位教材編寫之參考。第二階段為「遊程體驗設計及文創商品開發」，主要將前階段的成果彙整後，開發 VR 數位教材，以設計思考設計法進行金良興磚廠之遊程體驗設計及文化商品體驗，藉此提高參與者文化學習興趣，強化與苗栗歷史鏈結，進而推廣台灣磚雕工藝文化。

【關鍵字】 STEAM 教育；元宇宙遊程體驗；文創商品；VR 數位教材

Abstract: *This research project combines STEAM education with meta-universe tour experience and cultural and creative product development and explores the characteristics of brick carving and its cultural elements from the perspectives of semiotics and craftsmanship, using the Jinliangxing Brick Factory in Miaoli as the research target for the production of VR digital teaching materials, the planning of digital experiential tours, and the design of cultural and creative products. The first stage of this study is to explore the characteristics of brick carving and its cultural elements, and to explore the historical background of brick carving in Taiwan through relevant historical materials, literature, and field surveys. The impact of the historical background on the art of brick carving, including the evolution of techniques and styles, is analyzed. Then, from the perspective of symbolism, we will explore the symbols and imagery commonly found in Taiwanese brick carvings by evaluating the methods of construction and metaphorical extraction and explain the cultural significance of these symbols and how they reflect the local cultural values. Through interviews with brick carvers, we will find out the mutual influence between Taiwanese brick carving and local culture, summarize the cultural elements of Taiwanese brick carving in various fields, and use this as a reference for the development of digital teaching materials. In the second phase, 'Tour Experience Design and Cultural Commodity Development,' the results of the previous phase were compiled and used to develop VR digital teaching materials, and the design thinking method was used to conduct the tour experience design and cultural commodity experience at the Jinliangxing Brickworks, in order to increase the interest of the participants in cultural learning, to* *strengthen the link with Miaoli's history, and to further promote the culture of brick carving and artisanal craftsmanship in Taiwan.*

Keywords: STEAM Education; Metaverse Tour Experience; Cultural and Creative Products; VR Digital Teaching Materials

1. 研究目標

1. 磚雕文化研究:探討台灣磚雕的歷史背景，歷史事件對磚雕藝術的影響，例如新技術應用和工藝風格皆納入考量。接著分析台灣磚雕常見的符號和意象並解釋這些符號的文化意義，這些符號如何反映當地文化價值觀、宗教信仰和歷史事件等。根據上述研究結果分析台灣磚雕與當地文化之間的相互影響，並探討磚雕作品如何反映台灣文化。

2. VR 數位教材製作:透過訪談磚雕藝術家並錄製訪談紀錄影片，介紹台灣磚雕與當地文化之間的相互影響，以及說明台灣磚雕在各領域應用之文化元素。除訪談影片外，另根據磚雕文化研究成果發展一 VR 數位互動遊戲，以數位技術讓使用者體驗雕磚藝術與苗栗工藝文化之美，藉此達到台灣文化推廣及教學成效。

3. 遊程體驗設計:透過服務設計分析方法找出遊客需求，以教育性、娛樂性為遊程體驗重點，結合苗栗磚雕工藝特色，規劃符合遊客期待的參訪行程。VR 遊程體驗設計的目標是讓遊客在參訪過程中獲得愉快的體驗，並對地方文化產生深刻的印象。

4. 文創商品開發:通過符號學轉化和傳統工藝應用的角度，以台灣磚雕的藝術價值和文化背景，將其發展為文化創意商品。文化創意商品的開發方向分為體驗型商品及提供收藏之精緻型商品。

2. 背景分析

2.1. 藝術文化與數位科技研究

近年來文化傳播的普及率與數位教材與新媒體呈現正相關，有研究者從傳統文化模式中提取元素，結合數位科技從新設計運用於建築中(Xu、 Huang 與 Dewancker，2020)，另外利用數位虛擬技術中的網路多媒體、動畫和虛擬實境技術建立的資料庫也在傳承中佔有一席之地，Yu 與 Dai(2020)認為文化數位教材在傳承人培訓中發揮了即時互動、反覆演示、重點訓練的功能，提升學習成效與訓練品質。Wang 與 Zhu (2020)指出有必要從「 非物質文化遺產 」的角度探索如何將數位化創新與這文化瑰寶的傳承相結合。

2.2.以體驗設計提升觀光工廠遊程服務價值

近年來許多文化展覽以及觀光工廠行銷已從傳統的視覺展覽方式轉變為引導消費者進行各項特色體驗的形式，相較於傳統視覺展示，觀光工廠採取體驗式活動將參觀行程焦點放在顧客互動體驗過程，提供了感官、情感、思考、行動及相關互動體驗所產生的無形價值。Pine & Gilmore (1998)提出了體驗式經濟的觀點，說明顧客所追求的不只是有形商品與服務，而是參與其中所獲得的獨一無二的體驗感受。

2.3.以文創商品作為文化意象表徵

磚雕文化已在台灣及苗栗地區發展多年並存在許多在地文化特色，在地文化所蘊含之豐富內涵乃成為商品設計的創作靈感，設計師可以從中擷取文化元素，並透過設計方法轉化符號或表徵融入商品以傳達文化價值 (Moalosi，Popovic and Hickling，2010)。

3. 研究執行方法與內容

3.1.研究設計

第一階段研究設計以文獻分析法、訪談法研究第一手資料，爬梳磚雕文化歷史脈絡，作為主題文化內涵的基本知識，並參考分析資料用以製作數位教材的依據。第二階段根據第一研究階段之成果，開發 VR 數位互動教材並以設計思考方法規劃遊程體驗設計和文創商品體驗；在 VR 數位教材應用於互動數位體驗效益方面，係針對磚廠參與者進行問卷調查，所獲得之數據以相關係數分析和羅吉斯迴歸分析量化結果。

3.2.研究對象

數位教材為遊程體驗設計和文創商品體驗的研究母體以金良興觀光磚廠參與者為基礎，目標族群約 200 人，受測者身分為在學大專學生及一般參觀民眾為主。

4. 研究結果

研究結果顯示 VR 數位教材採用苗栗磚雕文化為主題領域，將其應用於數位學習與文創商品體驗對於提升使用者經驗有顯著性效益，對於文化與華語學習者而言能提升學習成效與學習動機；數位互動性磚雕文化的活動亦能提升磚廠參觀者對台灣地方文化的理解。在問卷調查數據顯示出數位教材之磚雕體驗與遊客滿意度呈正相關，且磚雕文創商品能提高公眾對文化的關注度及支持程度，有助文化資產保存。

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The Impact of Different Devices on the Effectiveness of Metaverse Learning

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Abstract: *This study attempts to develop learning content for a metaverse learning environment on the HTC VIVERSE World platform, aiming to understand students' learning experiences using different devices. After involving 75 students and a total of 174 instances of viewing and responding, the students showed high satisfaction in three aspects: easy to use, enhance interest, and improve understanding, with a score of 8.47. Through a t-test, it was found that students using VR headsets scored significantly higher in these three aspects compared to those using a Pad. These results indicate that students have a certain level of learning effectiveness in a metaverse context.*

Keywords: metaverse, virtual reality, learning effectiveness, VIVERSE

1. Introduction

Since the development of metaverse technology, the application of Virtual Reality (VR) has become more promising. Increasingly, research is exploring the impact of metaverse learning on students. However, in education, there are relatively few studies investigating students' perceptions of cross-platform learning and its effect on learning outcomes. Therefore, this study will utilize a platform based on WebXR technology in conjunction with teacher-made courses to facilitate student learning. This approach aims to understand the current state and differences in aspects of easy to use, enhance interest, and improve understanding.

2. Learning Environment Introduction

The metaverse platform used in this study is the VIVERSE World platform developed by HTC Corporation. This platform is based on WebXR technology and allows content to be viewed on VR headsets or tablets via a web link. During viewing, each teacher and student can choose an avatar with different appearances. Depending on the device used, they can navigate using a controller, mouse, or keyboard.

In this study, the metaverse space is designed as a classroom setting for unit courses. Besides 30-minute 3D video teachings based on different themes, the platform also provides photos and texts to establish a context-based learning environment. Teachers can not only guide students to watch videos but also invite them to specific arrangements in the metaverse space for teaching and explanation (as shown in Figure 1). Below is the link to the metaverse space for Leopard Cat Ecology Conservation and Environment: https://world.viverse.com/sZcGnXn.

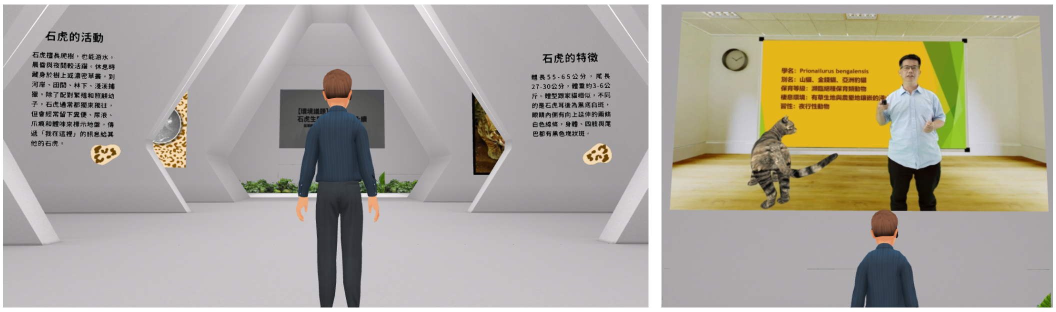

Figure1. HTC VIVERSE World platform

3. Research Design

This study was conducted from September to December 2023. The participants were students from the third grade and above from four elementary schools in Taiwan, with 75 students participating, amounting to 174 viewing instances.

Regarding the course implementation, school teachers arranged for students to view courses, including Leopard Cat Ecology Conservation and Environment, Personal Information Protection and Fraud Prevention, Let's SDGs, and Safe Practices for Online Shopping – a total of four courses. Depending on the number of headsets available in schools, some students used VR headsets, while others used tablets for viewing.

In the questionnaire, the researchers, referencing studies by Eraslan Yalcin & Kutlu (2019) and Hasanati & Purwaningsih (2021), designed three variables: easy to use, enhance interest, and improve understanding. Each variable consisted of three questions, using a 10-point scale. The questionnaire was completed online by students after finishing the metaverse course. Finally, the data were analyzed using descriptive statistics and an independent sample t-test.

4. Results and Conclusion

Through descriptive analysis of the 174 responses, it was found that tablets were used 125 times (71.8%), while VR headsets were used 49 times (28.2%). The mean and standard deviation for easy to use, enhance interest, and improve understanding are as shown in Table 1. The study showed a high satisfaction rating of 8.47 in all three aspects. Subsequent independent sample t-tests revealed, as indicated in Table 1, that in the three aspects of easy to use, enhance interest, and improve understanding, the performance of those using VR headsets was significantly higher than those using Pads.

Table 1. Results of descriptive statistics and t-test

	N	Mean	SD	t-test for Equality of Means				
	Pad VR	Pad VR	Pad VR	t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference
Easy to use	125 49	8.47 9.65	2.35 .66	-3.461	172	0.001	-1.184	0.342

Enhance interest	125 49	8.91 9.86	1.91 .56	-3.396	172	0.001	-0.942	0.278
Improve understanding	125 49	8.76 9.82	2.14 .73	-3.373	172	0.001	-1.054	0.312

The metaverse learning environment allows students to engage in immersive learning across different devices. In this environment, students enter a virtual space as avatars, watching 3D contextual designs and 360-degree videos. Generally, students rated the three aspects affecting learning - easy to use, enhance interest, and improve understanding - highly. Moreover, the scores of students who used VR headsets were significantly higher than those who used tablets, indicating that a realistic, immersive, and presence-enhancing learning environment is more helpful for learning.

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支持虛實混合學習的英語智慧雲平台

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【摘要】 本研究探討了運用虛實混合技術的資訊教學結合混成式學習的教學策略在台灣中小學的應用，特別是在英語學習領域。本研究發展了一套「英語智慧雲平台」的系統，整合了不同終端異質性學習載具，包括電腦、平板、VR 頭盔和機器人，以及對於學習教材、學習歷程、適性化學習的各種後端支援。該系統提供適合各載具的英語學習內容，並支持適性化診斷和推薦。目前此系統已在台灣桃園市某國小實際應用，研究成果可作為未來資訊教育跨平台整合系統開發的參考。
【關鍵字】 英語學習；虛擬實境；擴增實境；教育機器人；混成式學習。

Abstract: *This research explores the application of virtual-real hybrid technology in information instruction combined with blended learning strategies in Taiwanese primary and secondary schools, particularly in the field of English language learning. The study developed a system called the "English AI Cloud Platform," which integrates various heterogeneous learning devices for different clients, including computers, tablets, VR headsets, and robots. The system also provides backend support for learning materials, learning processes, and adaptive learning. Currently, this system has been implemented in an elementary school in Taoyuan City, Taiwan, and the research findings can serve as a reference for future cross-platform integration system development in information education.*

Keywords: English Learning, Virtual Reality, Augmented Reality, Educational Robot, Blended Learning

1. 研究背景與動機

因應後疫情時代，混成式學習（Blended Learning）愈來愈重要，混成式學習指的是線上與線下、實體教學與網路教學的混合。在台灣，近年來大力地推動資訊教育與數位學習以支持混成式學習與自主學習，從中央政府到地方政府都有各項計畫補助 12 年國民教育的學校各項資訊教學的設備，例如：大屏幕、平板、筆電、機器人、VR 頭盔、與 5G/無線網路。然而，對於適用於上述各種異質性載具的教學內容整合發展與相關研究仍然十分欠缺。在台灣中小學的資訊教育環境下，普遍存在以下三個問題與挑戰：(1) 許多學校有了平板、VR 頭盔、機器人，但是卻苦於沒有適合的軟體或教學內容，而導

致獲得補助的資訊設備因為缺少了好的內容就廢棄而無用。(2)有些學校就算有額外的經費能夠請廠商開發適用的軟體內容，通常也多數是訂製 A 教學軟體支援 VR 教學，訂製 B 教學軟體支援機器人教學，但其實學生在這些異質性載具之間學習的資料與歷程除了無法互通，學習內容也不易擴充；這代表著這些寶貴的學生學習歷程資料都無法被用於更重要的大規模資料分析、提供進一步的學習診斷與適性化學習推薦。(3)不同的學習載具對於學習的效果並不相同，例如：機器人可以在情感上支持學習，VR 可以提升學習樂趣與動機、平板的移動性可以支持適境化的學習、電腦/筆電則適合用於評量與診斷，若是沒有針對載具特性設計適合的學習內容也可能無法達到預期的學習效果。

在本研究中，我們提出了「虛實混合沉浸式智慧學習平台」的設計理念，「虛擬」，為運用 AR/VR 的虛擬科技增強學習沉浸感受、實現虛擬線上學習、促成自主學習動機的形式。「實體」，為學習平台或環境支援教師課堂中實體課程的學習活動，例如：即時投票、學習記錄與點名。「虛實混合」，為教師將實體線下課程與線上學習內容交互融合使用，以達到混成式學習的成效。所謂的「智慧」，則實踐在機器人輔助學習、智慧雲跨載具的遊戲化學習、雲端化歷程記錄、個人化學習推薦機制。在上述的設計理念下，本研究團隊與台灣桃園市的某一所國小以及系統開發廠商一同組成聯合開發團隊，花費歷時三年的時間完成開發一套系統，稱之為「英語智慧雲平台」。在本研究中主要介紹關於本系統的設計架構、系統研發成果，以提供資訊教育相關主管、系統開發者作為參考，並指出未來可能的相關研究議題。

2. 系統設計與研究成果

英語智慧雲平台的系統由於涉及到多種完全異質性的學習載具，包含了電腦、iPad 平板、HTC VR Focus 頭盔、凱比機器人，各種載具特性不同、開發程式環境不同、互動控制性不同，因此各終端載具的互動介面與功能僅能採用不同的開發工具與程式語言開發方能達到最佳的互動式效果。本系統以英語教學為目標，整合電腦、iPad 平板、HTC VR Focus 頭盔、凱比機器人等四種異質性學習載具，建立適合各載具的學習內容，以及跨載具間可共享的英語學習教材包含單字(2215 字)、例句(2206 句)、對話(125 個)、閱讀(82 篇)、題庫(24655 題)、測驗(302 個)，以及適性化診斷與推薦的後端支援系統。在英語教材內容的資料格式上，針對單字、例句、對話、閱讀、題庫、測驗制定標準的一套 JSON 格式的資料交換標準，並以 Web 服務的形式提供各載具與後端資料庫進行資料存取以達到學習教材共享的目的。英語智慧雲平台之各功能模組架構圖如圖 1 所示。本研究提出之「虛實混合沉浸式智慧學習平台」的設計理念，曾獲桃園市政府教育局邀請並於 2021 智慧城市展展出。2022 年-2024 年間，合作之對象學校持續推廣虛實混合教學、成為桃園市雙語智慧小學、代表桃園市與日本築波市進行中日交流、獲得台灣教育部 5G 新科技學校示範計畫補助以及肯定獎，亦為本研究成果對於台灣教育界之實務貢獻與影響。

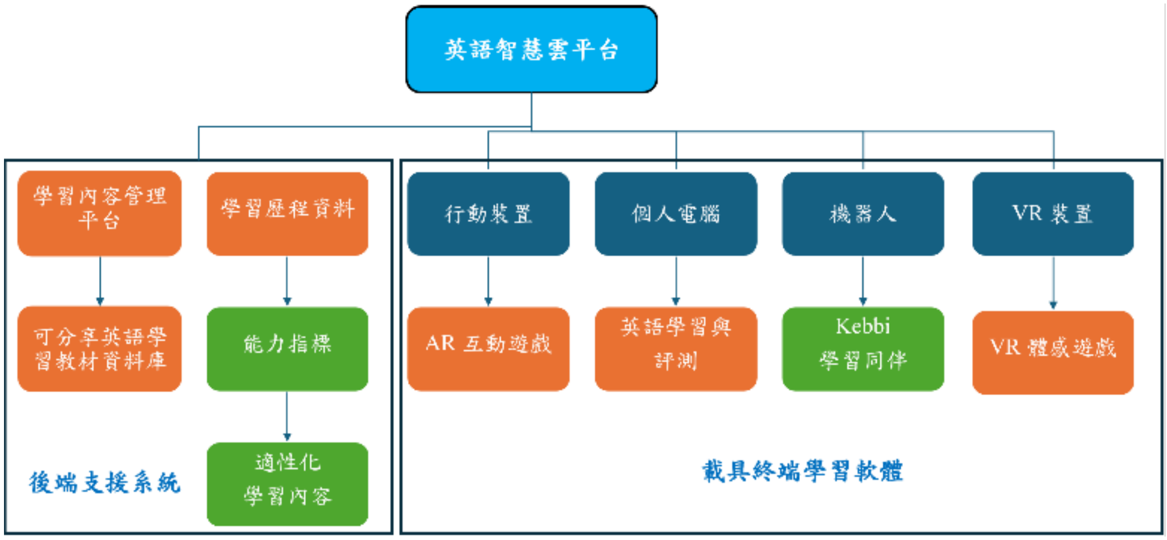

圖 1 英語智慧雲平台功能模組架構圖

3. 結論與未來研究

近年來在政府大力補助學校軟、硬體設備推動資訊教育的當下，仍需注意是否學校之管理人員、教師具有能力整合應用新科技於輔助教學上，否則可能無法達到提升教學的成效。本研究從整合異質載具、可共享教材內容的技術觀點為核心出發，提出虛實混合沉浸式智慧學習平台的概念並實際完成英語智慧雲平台，提供於台灣桃園市國小進行使用，驗證了本研究系統設計架構的可行性、推廣價值與實務貢獻。在學術部份，本研究未來仍有待規劃更多的實證研究深入地探討其對於教學成效的影響，以及探究在多種沉浸式裝置與智慧型載具的綜合教學應用上可能施行的教學策略。

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虛擬實境教學對學習障礙學生國語文學習動機和成效提升之前導研究

Effects of Applying Virtual Reality in Teaching Chinese Language Arts on Learning Achievement and Motivation for Students with Learning Disability: A Pilot Study

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【摘要】 本研究旨在探討虛擬實境教學對國小學習障礙學生提升國語文之學習成效。對一名國小四年級學習障礙學生進行 4 週 8 節課之國語文教學，傳統講述教學及虛擬實境教學分別各 4 節課，並於課程結束時進行評量。本研究採用改編之學習動機量表與自編的教師訪談問卷，並錄影蒐集研究對象學習參與狀況，探究研究對象在兩種不同教學下的學習成效及動機。結果顯示，該名學習障礙學生在實施虛擬實境教學之學習動機與成效皆優於傳統講述教學。根據研究結果提出建議，以供進行虛擬實境教學時的參考。

【關鍵字】 虛擬實境；學習障礙；學習成效；學習動機

Abstract: *This study aims to explore the effectiveness of virtual reality (VR) teaching in improving Chinese language arts learning for a fourth grader with learning disability. The participant was taught Chinese language arts in 8 sessions over 4 weeks, with 4 sessions of traditional teaching and 4 sessions of virtual reality teaching. The adapted learning motivation scale, and the self-developed teacher interview questions were used to collect the data of the learning effectiveness and motivation of the participant under two different instructions. The results show that the learning effectiveness and motivation of the student when virtual reality teaching is implemented has better performance than traditional teaching. Suggestions are made based on the research results for conducting virtual reality teaching.*

Keywords: virtual reality, learning disability, learning achievement, learning motivation

1. 研究動機與目的

特殊教育強調多感官學習，透過各種感官(視、聽、觸和動覺等)，輔以互動性高的學習環境，讓學生在訊息的接收和理解更為暢通與完整(楊雅婷、陳奕樺，2014)。故本研究透過將國小國語文文本結合虛擬實境(VR)技術，製作出較具互動性、吸引力的教材，以提升學習障礙學生的語文理解能力，更希望能夠打破傳統語文教學的框架，藉由虛擬實境(VR)技術，透過多感官、沉浸式的創新教學方法，提升學生在閱讀理解方面的學習成效與動機。據上述動機，本研究之研究目的為：比較虛擬實境(VR)和傳統講述教學運用在學習障礙學生之國語文學習動機及學習成效之差異。

2. 研究方法

本研究採個案研究法，探討兩種不同教學對一名國小四年級學習障礙女童之學習動機與成效之差異。本研究之研究對象之國語文能力，除理解文章大意困難外，歸納閱讀重點亦有困難。上國語課時，受限於識字量較低且書寫速度較慢，在抄寫語詞、語句時，跟不上課堂速度，甚至於課堂中頻繁出現搓手行為，學習動機低落。故本研究欲以不同之教學教導個案國語文，了解個案之學習動機及成效差異。本研究共進行八次教學，第一、二週進行四次傳統講述教學，每次 40 分鐘，並於教學後實施學習動機及成效評量；第三、四週進行四次虛擬實境教學，每次 40 分鐘(使用虛擬實境眼鏡前，先說明使用規則約 8-10 分鐘，接著引導學生使用虛擬實境眼鏡學習課文內容約 8-10 分鐘，之後教師解說學生於過程中所觀看之內容並實施評量約 20 分鐘)，之後實施學習動機評量，並訪談研究對象之教師，以了解研究對象在進行兩種教學後的學習表現及參與度。

本研究之研究工具分為教學工具及評量工具。教學工具包括 AR2VR、虛擬實境頭戴式裝置、以及同步投影虛擬實境教學畫面軟體-易投屏。研究者將國小四年級課文「請到我的家鄉來」透過 AR2VR 軟體，融入 360°全景照片及虛擬實境場景、課文語句以電腦語音播放，並輔以語詞解釋與圖像，研究對象可以透過手機及虛擬實境頭戴式裝置自行操作軟體。使用易投屏可將研究對象操作的手機畫面投影到筆電上，以便教師掌握學生的學習進度，並適時給予建議與指引。評量工具則包括學習動機量表(改編自劉政宏、黃博聖、蘇嘉鈴、陳學志、吳有城(2010)編制的「國中小學習動機量表」)，及自編教師訪談問卷以及教學時之錄影影片觀察。自編教師訪談問卷蒐集班級教師觀察研究對象之描述性資料，以了解研究對象學習動機及成效是否因虛擬實境教學而有所改變。為了觀察研究對象在上課時的學習表現，每一次教學都會進行錄影，透過觀察影片深入了解個案的學習表現。

3. 研究結果與討論

本研究之研究結果如下：在學習動機方面，本研究於進行兩種教學後實施學習動機量表評量，研究結果發現個案在虛擬實境教學中，學習動機評量得分較傳統講述教學為高。教師亦反應研究對象在傳統講述教學時較容易分心，把玩與課程無關的東西，無法

充分吸收課堂授課內容，而在虛擬實境教學時，課程內容畫面不斷呈現在個案眼前，且有旁白、音效及圖片，透過多感官學習，讓學生更專心，亦能正確回答課堂中教師對文本內容之提問。

本研究為個案研究之前導研究，主要目的是在於初探虛擬實境教學法對於學習障礙學生國語文之教學成效和學習動機是否提升。在初探過程中，研究團隊發現學生不管在學生課程的參與狀況，以及後續學習動機評量上，對於虛擬實境教學都產生高度興趣，而從教師的訪談中也能發現學生課堂參與度和學習動機的確提高。惟本研究只有一個樣本，期待未來能進行更大量樣本的實驗研究，並且設計標準化的學習成效測驗工具，更能實證性證明虛擬實境教學的有效性。

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Exploring the effects of integrating XR mode to support teaching and learning

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Abstract: *This study aims to provide insights into how teachers collaborated to develop a practical instructional design for a course integrating XR into the learning scenario. Pilot evaluations from the students' perspectives and teachers' feedback are conducted and summarized to offer suggestions for future research in this area. Four teachers and fifty-two students from three elementary schools participated in the study, and interviews and questionnaires were conducted for data collection. The results demonstrate a possible model for integrating XR techniques into educational scenarios. Teachers' practical experiences and suggestions for conducting XR-based courses, as well as students' feedback, are presented and discussed.*

Keywords: Evalution, eXtended Reality, Virtual reality, Teaching practice

1. Introduction

The applications of eXtended Reality (XR) technology include virtual reality (VR), augmented reality (AR), and mixed reality (MR). Integrating XR techniques into teaching and learning helps transform abstract concepts into visual information (Simon-Liedtke & Baraas, 2022; Aguayoa & Eamesb, 2023). This integration also creates virtual hands-on opportunities to enhance the learning experience. Additionally, the term "metaverse" has gained attention from research scholars in recent years (Chen, 2022). Hwang & Chien (2024) broadly define the metaverse as an environment where learners can share and interact through augmented or virtual reality, immersing themselves in virtual contexts and interacting with peers or instructors. The characteristics of the metaverse make it a valuable facilitator for supporting XR applications in educational scenarios, creating a space for students to learn, interact, and achieve unique learning experiences. Several studies in the past decade have experimented with XR in primary and secondary education (Simon-Liedtke & Baraas, 2022). Findings indicated that integrating XR applications into educational scenarios can positively influence learning outcomes, increasing students' motivation, engagement, and interest (Simon-Liedtke & Baraas, 2022). However, certain issues need further exploration, such as establishing best-practice guidelines for XR applications and examining the accessibility and usability of XR technology (Simon-Liedtke & Baraas, 2022).

The research purposes of the study aim to provide insights into how teachers collaborated to develop a practical instructional design for a course integrating XR into the learning scenario. Additionally, pilot evaluations from the students' perspectives and teachers' feedback are conducted and summarized to offer suggestions for future research in this area.

2. Research Methods and Data collection

The study invited four teachers to participate in personal interviews and asked them to share their experiences regarding their practical implementation of XR courses and instructional design. The four teachers were from different elementary schools, with one serving as an instructor delivering the course in a live broadcast room, and the other three acting as o broadcasting end instructors in three different schools. The interview questions covered topics such as how they collaborated with teachers from different schools to construct the course design, how they integrated XR into their courses, and their suggestions for future XR course activities. According to the ways of participating in XR course activities, the researcher categorized teachers into Live Broadcast (LB) and Receiver (R) for interviews. An example of the qualitative coding method is as follows: 1-LB represents the serial number where 1 denotes the live broadcast teacher, 2-R, represents serial number 2, corresponding to the teacher at the broadcasting end. Fifty-two fifth- and sixth-grade students from three elementary schools participated in the XR courses and were required to complete questionnaires before and after the XR courses. The questionnaire items focused on learning motivation, interest, satisfaction, and their feedback regarding the use of XR techniques for learning.

3. Results

3.1 XR course design

The XR course is designed for local cultural learning in the field of art, covering topics such as learning about local famous temples, worship practices, and features of god statues. The course aims to provide students located far from the target temples with the opportunity to closely observe statues, an experience that may not be feasible in reality. The teachers leverage XR to motivate students' learning interest and create virtual learning scenarios for cultural exploration. The XR course consists of six classes, each lasting 40 minutes. One teacher delivers the course in a live broadcast room equipped with a 3D director and a green screen to integrate virtual scenarios and 3D objects. The learning content is broadcasted to three different schools. Three teachers guide their students to participate in the course at different locations, using VR helmets and tablets to assist students in learning and receiving information. Each 40-minute course follows this structure: first, the teacher in the live broadcast room utilizes virtual objects and content for a warm-up activity lasting approximately 10 minutes. Next, students have time to explore the content on their own in groups using learning devices in the remote classroom for about 10-15 minutes. During this period, the VR contents offer students opportunities for self-directed practice, while the metaverse allows students to engage in discussions with peers from different schools. The three broadcasting end teachers move around the classroom, providing assistance as necessary. Finally, the teacher in the live broadcast room utilizes interactive response systems (IRS), such as Slido or Kahoot, to facilitate cross-school learning activities and assess students' learning outcomes. Additionally, students are expected to complete learning sheets to demonstrate their learning performance.

3.2 Instructor interview feedback

Some valuable suggestions for XR course and practical implementation were collected from interviews (Table 1).

In summary, before conducting an XR course, instructors should familiarize themselves with hardware and software, including the operation of 3D direction, VR helmets, and VR contents. Forming a cross-school instructor group via social networking services, such as a Line group, helped teachers from various schools collaborate in preparing the course. Additionally, having a pre-course rundown is crucial. The rundown follows the lesson plan but details every single step between teachers in the live broadcast room and broadcasting end classrooms.

During the XR course, teachers can adopt strategies such as teacher guidance, student self-study, joint learning within groups, and mutual learning between groups using VR devices and the metaverse. Lastly, teachers reported that students showed high interest and motivation during the course. The variety of learning methods motivated students to concentrate on learning. It is worth noting that one teacher mentioned that during XR learning, students not only learned the subjects but also interpersonal interaction as they engaged with each other in the metaverse. Teachers also emphasized the importance of the stability of web connections and hardware use during XR courses. It is suggested that more than one teacher should run the broadcasting end course to handle potential emergencies from students. Teacher collaboration can help overcome these challenges.

Table 1. Summary of teacher’s interview

Preparation	Course design and practical issues	Student’ leaning
• Coordinate courses within the group through a Line group; understand the course details and procedures for each class, and communicate about equipment issues (1-R). • After the group training, we designed the lesson plan. We review the lesson plan design and teaching material design as well as the Rounding down for live broadcast and broadcasting end classroom (1-LB).	• Integrating the strategies into teaching with VR, students are allowed to explore and discover in self-study situations within the context of topic inquiry. Group tasks promote shared learning within the group, and mutual sharing and comparison between groups encourage reflection on life. (3-R). • The broadcasting end eacher collaborated with each other to address equipment connection issues, ensuring an uninterrupted teaching course (1-R). • The ideal situation is to have an additional teacher in each class to assist with the course, and the host should have good control over the network connection (1-R). • The broadcasting end teacher should give real-time assistance during the	• Children find that completing tasks with their partners gives them a sense of accomplishment while they interact with learning partners in a metaverse (3-R). • Students learn not only at the subject content but also develop attitudes and interpersonal relationships (3-R) • Technology that students have never been exposed and Immersive learning experience, to motivates them to learn (2-R) .

	courses which can enhance students' learning stimulation (1-R) .

3.3 Students' questionnaire results

Regarding interest, the descriptive results from the questionnaire indicated that learners increased their interest in local cultural learning after the XR course. Specifically, the question item "If I were a teacher, I would want to teach this course" showed a significant difference before and after the XR course, as determined by paired samples t-tests (Before average: 3.27; After average 3.62, $p=0.04 < 0.05$).

In terms of motivation, satisfaction, and feedback on using XR techniques for learning, the descriptive results showed positive feedback (Table 2). The mean values for items such as "Through XR courses, I had more realistic experiences (Q19)," "I am confident in completing the learning missions (Q24)," "I am happy to participate in XR courses (Q27)," and "I am satisfied with learning through XR (Q30)" were all above 4.5, indicating learners' overwhelmingly positive feedback on learning through XR techniques.

Table 2. Descriptive Results of Students' reported score *(N=52)*

	motivation	**satisfaction**	**feedback of using XR for learning**
M	4.38	4.40	4.40
SD	1.37	1.40	1.35

4. Discussions and Results

The study explored how to use XR technology for teaching and learning, focusing on XR course design and collecting data from instructors and students to understand the practical issues of using XR-based learning. The techniques adopted in the study include XR courses with a specific focus on local culture learning. Teachers and students from three schools co-learned with the assistance of XR techniques. Teachers utilized not only VR devices and the metaverse to support the course but also learning technologies such as IRS tools to facilitate immediate interaction for learners in different spaces. From the pilot evaluation, students expressed positive feedback toward participating in XR-based learning.

The current study presents a possible model for integrating XR techniques into educational scenarios, and future research could explore the learning modes and strategies adopted in XR course design, as well as further tracking the long-term learning performance of students. Findings from this series of research will be shared in the near future.

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