香港教育大學
The Education University of Hong Kong

MetaACES 2023

The 1st International Conference on Metaverse and Artificial Companions in Education and Society

14 - 16 June 2023

THEMED-BASED INTERNATIONAL CONFERENCE SERIES
APSCE
TBICS

Conference Proceedings

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MetaACES 2023

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The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2023)

Conference Proceedings

Editors:

Maiga CHANG, Athabasca University, Canada

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Shirley YAU Shuk Yi, The Education University of Hong Kong

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MESSAGE FROM THE CONFERENCE CHAIR

Conference Chair
Weiqin Chen
Oslo Metropolitan University, Norway

The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2022) 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 2023 comprises keynote speech, panels, 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 2023 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 2023 include but not limit to the followings (in alphabetical order):

- Artificial Companion in Education
- Artificial Companion in Society
- Artificial Intelligence (AI)
- Assessment in Games and Virtual Worlds
- Authentic Environments and Worlds
- Automated Feedback
- Avatars or Player Characters for Learning
- Behaviour and/or Interaction Modeling, Detection and Visualization
- Big Data Analyzed and Processed by Computers
- Bridging Informal and Formal Learning Outcome
- Chatbot
- Computational Models of Knowledge and Expertise
- Computer Supported Discussion Analysis and Assessment
- Educational Applications of Metaverses
- Educational Robots and Toys
- Emotion (Affective State) Modeling, Recognition and Detection

- Emotive Agents
- Enhancing Grading, Scoring and Feedback
- Game Analytics
- Human Computer Interaction (HCI)
- Human Robot Interaction (HRI)
- Intelligent Agents
- Intelligent Tutors and Mentors
- Internet of Things (IoT), Internet of Everything (IoE), and/or Sensors
- Learning Companion Robots (Robotic Learning Companions)
- Languages, Thinking Skills, Meta-cognitive Skills, Cognitive Skills, and STE(A)M
- Learning Analytics in Educational Games
- Learning Companions
- Metaverse in Education
- Metaverse in Society
- Motivational and Affective Factors on Learning with Technology
- Natural Language Processing supported Tools, Systems, Applications, Mobile Apps, and Chatbots
- Non-Player Characters for Learning
- Personal Learning Environments (PLE)
- Roles of Artificial Companions in Metaverse
- Role Playing Games for Learning
- Security and Privacy Issues
- Sentiment Analysis
- Simulation and Training (Skill, Competence, Vocational Learning)
- Social Network Analysis (SNA)
- Speech Recognition and Synthesis
- Stealth Assessment
- Unstructured and Semi-structured Data for Computer to Read and Learn
- User Experience (UX) Evaluation
- Virtual and Augmented Learning Environments
- Virtual Animal Learning Companions
- Virtual Characters in Learning and Life
- Virtual Companions in Learning and Life
- VR, AR and Simulation Technology

We look forward to your participation.

Weiqin Chen
MetaACES 2023 Conference Chair
Oslo Metropolitan University, Norway

MESSAGE FROM THE INTERNATIONAL PROGRAM COORDINATING CHAIR

Program Coordinating Chair
Maiga CHANG
Athabasca University, Canada

The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2023) hosted by the Asia-Pacific Society for Computers in Education (APSCE) and organized by The Education University of Hong Kong, will be held on 14 - 16 June 2023 in a hybrid mode. I am honored to serve as the International Program Coordinating Chair of the first MetaACES conference.

The International Program Committee is led by a strong and dedicated team, which includes the Conference Chair, Prof. Weiqin Chen, International Program Coordinating Chair and three International Program Track Chairs, Prof Chee-Kit Looi, Prof Gautam Biswas and Prof John Erni, Local Organizing Chair, Prof Siu-Cheung Kong and Co-Chair Dr Yanjie Song, and 69 Senior PC members and PC members in the field of metaverse and artificial companions in education and society as well as related fields.

MetaACES 2023 calls for full papers, work-in-progress, extended summary, extended abstract from scholars around the world, this year, the Conference received a total of 29 submissions by 76 authors from 13 countries/economies include Austria, Canada, China, Croatia, Ecuador, Hong Kong, India, Malaysia, Pakistan, Singapore, Spain, Taiwan, and Thailand. Table 1 shows the statistics of regions of origin of the authors.

Table 1. Author statistics by country or economy of MetaACES 2023

Country or Economy			
Hong Kong	22	Ecuador	2
Taiwan	14	Pakistan	2
India	9	Spain	2
Singapore	8	Australia	1
China	7	Canada	1
Croatia	4	Thailand	1
Malaysia	3	Total	76

Two (2) of the 29 submissions were pre-screen rejected due to not following author guidelines format and/or not meeting the page limit requirements. The remaining 27 manuscripts were subjected to a rigorous review process by at least three reviewers from the conference international program committee. In total, 115 reviews were received. This resulted in 18 accepted manuscripts and the overall acceptance rate is 62.07%, which reflects our efforts to the maintenance of the quality of presentations at MetaACES 2023. The complete statistics of paper acceptance is shown in Table 2a-2b.

Table 2a. Statistics of paper acceptance in MetaACES 2023

Submissions	Accepted	Rejected	Pre-Screen Reject	Acceptance Rate
29	18	9	2	62.07%

Table 2a. Statistics of categories of accepted manuscripts in MetaACES 2023

Full Paper	Work-in-Progress	Extended Summary	Extended Abstract	Total
2	9	1	6	18

We are grateful to all who contributed to MetaACES 2023's success. We thank all the authors for choosing MetaACES 2023 as the venue to present their research. We would also like to thank the PC chairs and members, who undertook the responsibility of reviewing and selecting abstract that represent research of high quality. We want to thank the local organizing committee of members from The Education University of Hong Kong to make MetaACES 2023 happen. Specially thanks to our keynote speakers, panelists and session chairs for accepting our invitations and sharing their insights in the world of MetaACES.

Thank you for your participation and unfailing support.

See you in the next MetaACES!

Maiga CHANG
MetaACES 2023 Program Coordinating Chair
Athabasca University, Canada

MESSAGE FROM THE LOCAL ORGANIZING COMMITTEE CHAIR

Local Organizing Committee Chair
Siu-Cheung Kong
The Education University of Hong Kong

Enhancing Learning with Artificial Intelligence Companions

In the digital era, technology has transformed the way we learn and acquire knowledge. Artificial intelligence (AI) has emerged as a powerful tool to enhance the learning experience, and the development of AI companions has revolutionized the way we interact with technology. This conference explores the potential of AI companions to transform the way we learn, providing learners with personalized support and guidance that can make the learning process more efficient, effective, and engaging. These companions are designed to provide support to learners, using technology such as natural language processing to understand and respond to their queries. There are different types of AI companions, including chatbots, virtual assistants, and intelligent tutors. The benefits of AI companions include immediate feedback, access to a wide range of learning resources, and 24 hours accessibility. In this conference, there are also opportunities to discuss the challenges and ethical concerns associated with the use of AI companions in education, and how these can be addressed. Finally, this conference will look at the future of AI companions in education, and how advances in AI technology will continue to enhance the learning experience.

Siu-Cheung Kong
Local Organizing Committee Chair
The Education University of Hong Kong

ABOUT THE CONFERENCE

The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2023), organized by The Education University of Hong Kong, will be held on 14 - 16 June 2023 in a hybrid mode. MetaACES is one of the APSCE Theme-based International Conference Series.

MetaACES 2023 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 2023 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.

MetaACES 2023

THEMED-BASED INTERNATIONAL CONFERENCE SERIES
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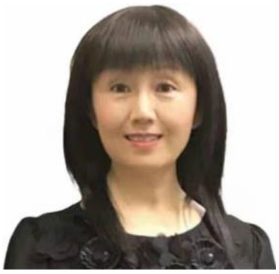

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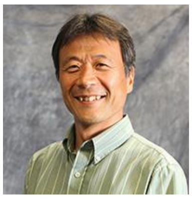

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PROGRAM AT A GLANCE

14 – 16 June, 2023 (Hybrid)
Hong Kong Time (GMT+8)

Physical Venue: Creative Arts Room, C-1/F-01F, MMW Library, EdUHK
Virtual Venue: Zoom

Date/Time	14 June 2023 (Wed)	15 June 2023 (Thu)	16 June 2023 (Fri)
9:00 – 9:30	Registration (Onsite / Zoom)	Registration (Onsite / Zoom)	Registration (Onsite / Zoom)
9:30 – 10:30	**Opening Ceremony** **Keynote 1 by Prof Chan Tak-Wai**	**Keynote 2 by Prof Chris Dede**	Paper Presentation
10:30 – 12:00	10:30 – 12:00 **Panel 1: What are the impacts of Seamless IDC theory and practice towards future learning in Asia and beyond?** **Chaired by Prof Looi Chee-Kit and Prof Kong Siu-Cheung**	10:30 – 12:00 **Panel 2: Artificial companions of 2040: Imagination and conjectures triggered by the current ChatGPT and their roles in the Seamless AI World** **Chaired by Prof Chan Tak-Wai**	10:30 – 11:30 **Symposium Chaired by Prof Maiga Chang** 11:30 – 12:00 **Closing Ceremony and Best Paper Award Presentation**
12:00 – 12:45	Paper Presentation	Paper Presentation	
12:45 – 2:00	Lunch Break	Lunch Break	
2:00 – 3:30	Paper Presentation	Paper Presentation	
3:15 – 3:45	Coffee/Tea Break	Coffee/Tea Break	
3:45 – 4:45	Paper Presentation	Paper Presentation	

KEYNOTE

Title: Invitation to Establish Seamless Interest-Driven Creator Theory — and its possible roles in achieving the Global 'Harwell' Goal in the Seamless AI World

Date: 14 June 2023 (Wednesday)

Time: 9:30 – 10:30

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

This talk is based on an ongoing discussion by a small group of international researchers who are exploring how to integrate IDC Theory and the Seamless Learning concept to form Seamless IDC Theory (SIDC Theory). It will cover what the global educational goal is, and how this goal can be achieved through SIDC learning in the era of AI and the metaverse.

Abstract:

More than 160 years ago, Dickens wrote in the first sentence of his A Tale of Two Cities: "It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair...". Now, the human lifespan is extended, but COVID-19 global death toll has exceeded 8 million (Our World in Data, 2023). Digitization enables all of us to connect and communicate, but we constantly quarrel over different beliefs; online games immerse players, but children's addiction may become a disaster; artificial intelligence can improve human life, but it can also do stupid things to human beings; the advent of metaverse may represent a bright future world, but it may also signal a dark abyss to come; we cheer for technological advancement, but worry about climate change, natural resource depletion, environmental pollution, wealth disparity and other problems.The world is on the brink of peril. Shall we live in harmony with the world around us? What is the future of human wellbeing? What role can education play? Mandela said: "Education is the most powerful weapon which you can use to change the world." Education is the hope of the future. The destiny of all human beings in the future is decided by today's education. In 2040, in their 30s, the current primary and secondary school students will be the pillars of our society.

The world is on the brink of peril. Shall we live in harmony with the world around us? What is the future of human well-being? What role can education play? Mandela once said: "Education is the most powerful weapon you can use to change the world." Indeed, education is the beacon of hope for the future. Today's education decides the destiny of all human beings in the future. In 2040, the current primary and secondary school students in their 30s will become our society's pillars.

Yet, progress and impacts of digital technology accelerate. Designing future education is creating the future world.

In 2006, 17 international researchers, from Asia, Europe, and North America, published a paper on seamless learning that holistically describes future technology-supported learning environments (Chan et al., 2006). Seamless learning is based on three other concepts: (1) one-to-one (1:1) technology-enhanced learning, (2) learning scenarios, and (3) seamless learning space. Seamless learning spells out the continuity of the learning experience while students switch from one scenario to another easily and quickly. Subsequently, the concept triggered abundant research (Looi et al., 2010; Wong & Looi, 2011).

In 2018, 23 Asian researchers collaborated and published the first paper on Interest-Driven Creator Theory (IDC Theory) (Chan et al., 2018) and a series of related conceptual papers (Chan et al., 2019; Wong et al., 2020; Chen et al., 2020). This effort stemmed from the fact that a considerable part of Asian education remains ‘examination-driven’. The overemphasis on examination outcomes distorts learning and teaching processes, ruining students' interest in learning, undermining the need to develop twenty-first century competencies, and failing to prepare our next generation to face the unpredictable future. Nevertheless, high-stakes examinations will still be with us in the foreseeable future. IDC Theory aims to lessen the drawbacks of examination-driven education and provides direction for future learning design in Asia and beyond.

Seamless learning speaks of a future technology-supported learning environment, while IDC Theory focuses on learning activity design. The integration will form a Seamless IDC Theory (or SIDC Theory) about the continuity of IDC-based learning in the future seamless learning space.

This talk invites interested researchers worldwide to establish SIDC Theory through the collective endeavor. In building the theory, the following questions may need to be addressed:

1. How to develop a broad framework of SIDC Theory to capture critical elements of the theory?

2. Will there be an extension of seamless learning per se and that of IDC Theory per se in view of SIDC Theory in the digital future?

3. If “global harmony and well-being” is an educational goal from the global perspective (or Global ‘Harwell’ Goal) that educators worldwide should strive for, will SIDC-based learning (or SIDC learning) contribute to this global educational goal?

4. In the ‘Seamless AI World’ of the digital future, extended from SIDC learning, will there be SIDC work, SIDC exercise, SIDC entertainment, SIDC family life, and so forth? In short, will there be SIDC life? Is SIDC life our aspiration?

Biography:

Professor Tak-Wai Chan is a trailblazer in digital learning and a global leader in the field. Almost 40 years ago, at a time when computers and the internet were not yet mainstream in the mid-eighties, he began researching on AI supported learning for his doctoral dissertation, proposing a new genus of AI in education system called learning companion system in 1988. This virtual companion system, called Integration-Kid, was the first artificial companion in the world. In 1989, he and his students started to build the world's first dedicated networked learning system for collaborative learning and learning through competition games, called Distributed West (1992). In early 2000s, he and his colleagues built the largest online learning community called EduCity (1.5 million learners with 1,700 schools involved in 2003), which was also referred as the first learning society in the world. In the same time period, his team conducted frontier research on mobile learning, intelligent classroom, future classroom, interactive clicker, e-schoolbag, one-to-one technology enhanced learning, and so forth. After this series of research, in 2006, working together with a large group of international researchers mainly from the Western countries, he proposed the concept of Seamless Learning. In 2010s, after some long-term experiments on reading (MSSR) and writing in one-to-one technology enhanced classroom, in collaboration with a group of Asian scholars, he proposed the Interest-Driven Creator (IDC) Theory. Again, he is now calling for an international researcher team to build the Seamless Interest-Driven Creator (SIDC) Theory.

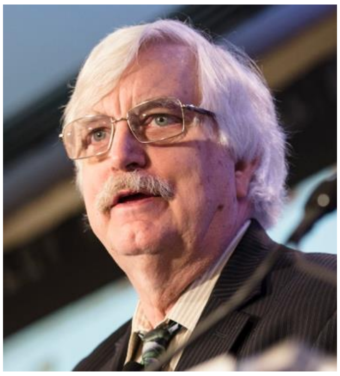
In addition to his research, Professor Chan has also been a major founder of two societies: the Asia-Pacific Society for Computers in Education (APSCE) and the Global Chinese Society for Computers in Education (GCSCE). These two societies respectively host annual conference series ICCEs and GCCCEs, as well as the journals RPTEL and JLCE. Moreover, to cope with the expanding research community of the field, he has been assisting the establishment of APSCE Theme-Based International Conference Series (TBICS), including CTE-STEM, ICFULL, MetaACES.

Throughout his career, Professor Chan has received numerous recognitions and academic awards, including the National Chair Professorship Award in 2020, the Executive Yuan Award for Outstanding Science and Technology Contribution in 2019, the Fellow of APSCE in 2019, the Academic Award of the Ministry of Education in 2013, the Pan Wen Yuan Foundation Outstanding Research Award in 2009, and the Chinese Foundation Award from the National Science Council in 2003. Besides being National Chair Professor, he has also held several distinguished positions, including Chair Professor at NCU since 2008, Distinguished Professor at NCU from 2004 to 2008, Excellent Appointed Researcher at the National Science Council in 2008, and Appointed Researcher at the National Science Council from 2000 to 2007. Additionally, he has received Excellent Research Awards from the National Science Council for the years 1995-1996, 1997-1998, and 1999-2000.

Throughout his career, Professor Chan has received numerous recognitions and academic awards: the National Chair Professorship Award in 2020, the Executive Yuan Award for Excellent Science and Technology Contribution in 2019, the Fellow of APSCE in 2019, the Pan Wen Yuan Foundation Excellent Researcher Award in 2009, among others.

KEYNOTE

Title: If the Metaverse is the Answer, What is the Question?



Date: 15 June 2023 (Thursday)

Time: 9:30 – 10:30

Speaker: Professor Christopher Dede
Senior Research Fellow,
Graduate School of Education,
Harvard University

Abstract:

We live at a time of rapid advances in both the capabilities and the cost of virtual reality (VR), multi-user virtual environments (MUVEs), and various forms of mixed reality (e.g., augmented reality (AR), digital puppeteering). These emerging media potentially offer extraordinary opportunities for enhancing both motivation and learning across a range of subject areas, student developmental levels, and educational settings.

Immersive media have affordances that enhance experiential learning based on a plan/act/reflect cycle. Psychological immersion is the mental state of being completely absorbed or engaged with something. For example, a well-designed game in a MUVE draws viewers into the metaverse portrayed on the screen, and they feel caught up in that virtual environment. The use of narrative and symbolism creates credible, engaging situations; each participant can influence what happens through their actions and can interact with others. Via richer stimuli, head-mounted or room-sized displays can create sensory immersion to deepen the effect of psychological immersion, as well as induce embodied virtual presence (place illusion), the feeling that you are at a location in the virtual world.

This talk will describe how the metaverse is powerful for “situated” learning: Experiences take place in the same or a similar virtual context to the real world setting in which skills and knowledge are later applied, and the virtual context itself fosters tacit learning through experience and modeling. However, learning in the metaverse faces challenges of simulator sickness, access by learners with limited vision, and limited bandwidth for non-verbal human interaction.

Biography:

Professor Chris Dede is a Senior Research Fellow at the Harvard Graduate School of Education and was for 22 years its Timothy E. Wirth Professor in Learning Technologies. His fields of scholarship include emerging technologies, policy, and leadership. He is a Co-Principal Investigator of the NSF-funded National Artificial Intelligence Institute in Adult Learning and Online Education.

PANEL

Title: What are the impacts of Seamless IDC theory & practice towards future learning in Asia and beyond?

Date: 14 June 2023 (Wednesday)

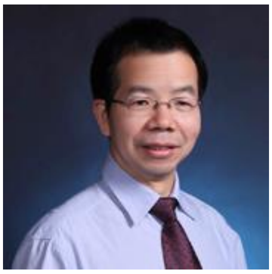
Time: 10:30 – 12:00

Chairs:

Professor Chee-Kit LOOI
Research Chair Professor of Learning Sciences, EdUHK

Professor KONG Siu-Cheung
Research Chair Professor of E-Learning and Digital Competency
Director, Centre for Learning, Teaching and Technology, EdUHK

Panellists:



Professor Ronghuai Huang, Beijing Normal University, China

Professor Hiroaki Ogata, Kyoto University, Japan

Professor Kinshuk, University of North Texas, US

Professor Juling Shih, National Central University, Taiwan

Professor Su-Luan Wong, Universiti Putra Malaysia, Malaysia

Abstract:

Seamless Interest-Driven Creator Theory (SIDC Theory) is an extension of the Interest-Driven Creator Theory (IDC Theory). In the IDC Theory, based on the three anchored concepts of “interests”, “creation” and “habit”, students are nurtured to be interest-driven creators who successfully demonstrate learning interest, creative mind-set, and habitual behaviour in the learning and application of subject knowledge. The SIDC Theory expands the IDC Theory to add the “seamless” element for connecting students’ interest-driven learning process between the school learning environment and the home learning environment. The successful implementation of the SIDC Theory needs the collaborative efforts from schools, families, and communities to provide students with a stable and cohesive support in terms of seamless infrastructure, online platforms, digital resources, and learning guidance in their SIDC learning process. The ultimate goal of implementing SIDC Theory is to promote the positive development of students for a global culture conscious of harmony and well-being among one another.

PANEL

Title: Artificial companions of 2040: Imagination and conjectures triggered by the current ChatGPT and their roles in the Seamless AI World

Date: 15 June 2023 (Thursday)

Time: 10:30 – 12:00

Chair:

Professor Tak-Wai Chan
Chair Professor, National Central University, Taiwan

Panellists:

Professor Chee-Kit LOOI
Research Chair Professor of Learning Sciences, EdUHK

Panellists:

Professor Gautam Biswas, Vanderbilt University, US

Professor Art Grasser, University of Memphis, US

Professor Ulrich Hoppe, University of Duisburg-Essen, Germany

Professor James Lester, North Carolina State University, US

Professor Maggie Wang, The University of Hong Kong

Professor Shengquan Yu, Beijing Normal University, China

Abstract:

Rapid development in artificial intelligence (AI) have led to the creation of advanced systems that are getting more capable of serving as companions for humans. In this panel discussion, we will explore the potential for AI companions in the seamless AI world of 2040, where learners move seamlessly between learning spaces. We will examine how AI companions can enhance learning experiences, provide personalized support, and create new opportunities for collaboration and engagement. Drawing on the latest research and insights in AI, education, and other fields, we will explore the ethical and practical implications of AI companions in education, including issues related to privacy, autonomy, and bias. We will also consider the ways in which AI companions might evolve over time, including the potential for these systems to support living and learning in different spaces such as in and between physical and virtual spaces. Through this panel discussion, we hope to stimulate further thinking and dialogue about the exciting possibilities and challenges of AI companions in education and the seamless AI world.

SYMPOSIUM

Title: Generative Artificial Intelligence Tools and School Education: Impact of ChatGPT and the Likes 人工智能生成工具對學校教育的影響：從 ChatGPT 說起

Date: 16 June 2023 (Friday)

Time: 10:30 – 11:30

Chair:

Professor Maiga CHANG
Full Professor, School of Computing and Information Systems, Athabasca University, Canada

Speakers:

Professor KONG Siu-Cheung
Research Chair Professor of E-Learning and Digital Competency, Director, Centre for Learning, Teaching and Technology, EdUHK

Mr HA Chi Hung
True Light Middle School of Hong Kong, Chairman, FlippEducators@HK

Mr CHU Tsz Wing
Chief Headmaster of St. Hilary's Kindergarten and Primary Section

Abstract:

Generative Artificial Intelligence (AI) tools, such as ChatGPT, have the potential to revolutionize the way students learn and teachers teach in schools. ChatGPT is an AI learning companion that students can use to access learning materials at any time and from anywhere, making education more accessible and convenient. However, educators may have concerns of using GPT in school education. This symposium will explore the impact about ChatGPT and other generative AI tools on school education, highlighting how they can transform the learning experience for students and the teaching experience for educators.

PROCEEDINGS

Table of Content

* Chinese papers

Chang, M., Looi, C. K., Biswas, G., Erni, J. N. (2023). Proceedings of The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2023).
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Exploring the Impact of Pedagogy and Group Dynamics in Metaverse Learning

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Abstract: *This study aimed to examine the effect of social learning on student intent to use a metaverse learning platform. With limited empirical evidence of social learning in a metaverse, the study sought to investigate the potential impact of group activities and pedagogy on student perception of the platform. Results from a linear regression showed that pedagogy was significant in students' intent to use the platform, while technology was not. The impact of group activities on student intent to use was not significant. However, the study showed that students who participated in group activities engaged in more reflective learning, leading to a deeper understanding of the material and the development of critical thinking skills. The study highlights the need for further research to understand the complexity of social learning and pedagogy in metaverse-based learning, particularly the features that would support collective intelligence. The results suggest that incorporating reflective activities into metaverse-based learning can enhance the social learning experience and promote meaningful and relevant learning.*

Keywords: metaverse, social learning, collective intelligence, reflection, pedagogy

1. Introduction

The virtual world known as the metaverse has long been a mainstay of science fiction. Despite varying definitions, it can be largely characterized as a virtual environment where users can communicate with one another's avatars (Ng et al., 2022). The metaverse is described as a virtual environment that is immersive and interactive (Dwivedi et al., 2022). It creates a special opportunity for education as it provides a dynamic way of teaching and learning, especially due to rising popularity of virtual and augmented reality technology (Hwang & Chien, 2022). A key component of the metaverse is social learning, where one learns something new or improves one's abilities while seeing or interacting with others. In a metaverse environment, group learning is enhanced by presence and reflection to promote a cooperative learning environment (Dwivedi et al., 2022; Oh et al., 2023), thus applying social learning. Students apply their lessons in real-world situations by interacting with classmates or virtual agents in a virtual setting.

This paper aims to assess how group activities affect students' opinions of the metaverse and their desire to use the metaverse system. We investigated how group activities affect students' perceptions of the technology and pedagogy employed in the metaverse through a study conducted on language acquisition, economics, and sustainability tasks assigned in groups or separately.

2. Social learning with the metaverse

Social learning in the classroom has been shown in research to boost learning motivation (P.P.Y. Wong et al., 2022). However, limited participation in online social learning through the usage of social media may be attributable to a lack of perceived value, particularly when compared to platforms with high levels of engagement like TikTok (Akcaoglu & Lee, 2018). Group activities improve social learning experiences in the metaverse. This can be done by using varying learning experiences, realistic settings, and applying classroom knowledge to real-world situations (Farrell, 2020). Social learning can also invoked by the presence of others in the metaverse, as even just being aware of peers can encourage participation (Oh et al., 2023). Discussions or assessments that combine online and offline group activities can improve the social learning environment in the metaverse (Ng et al., 2022). The flipped classroom method, which involves switching from online to offline activities, can be utilized to control cognitive demands of learning (Chen et al., 2021).

Recent research on the use of the metaverse in education has demonstrated that it can be especially helpful in fields like the humanities, where virtual field trips can take students to remote locations difficult to do in real-life. The usage of virtual agents can simulate social interactions, fostering real-world application of learning and inspiring students to take on challenges (Hwang & Chien, 2022; Nah et al., 2022).

3. Theoretical Background

The process of acquiring knowledge, abilities, and attitudes through observation, imitation, and interaction with others is known as social learning (Bandura, 2008). Social learning is a crucial component of education since it fosters collaboration, increases motivation and engagement, and improves the learning process (P.P.Y. Wong et al., 2022; G.W.C Wong, 2022). In topics like humanities and social sciences, where the capacity to comprehend and engage with the perspectives of others is crucial, social learning is crucial (G.W.C Wong, 2022). Authentic learning—which encourages students to apply what they have learned in real-world situations—can be promoted through social learning (Farrell, 2020).

By offering a fully immersive and engaging experience that enables users to explore new worlds and interact with other users in real-time, the metaverse can alter the way we study, work, and interact with others (Dwivedi et al., 2022). The metaverse allows users to engage with each other in a shared digital area and can be accessed by a range of devices, including laptops, cell phones, and tablets (Dwivedi et al., 2022). A metaverse can be transformed into a virtual learning environment enabling students to interact, communicate, and work together using digital identities (Ng, 2022).

The metaverse is based on theories like presence, reflection, and narrative transportation (de Regt et al., 2021). Presence in a virtual environment can increase a user's sense of immersion and engagement in the metaverse (Makransky & Peterson, 2021; Sartaş & Topraklkolu, 2022). In the metaverse, reflection can be used to improve learning and problem-solving. Reflection is the process of thinking about and judging one's own experiences (Hamby et al., 2017). These theories explain how the metaverse can be used to create a compelling and immersive experience and facilitate social and collaborative learning. Metaverses have been used in language, tourism, and science, among other fields (Sartaş & Topraklkolu, 2022), but more can be done for interactions and creating narratives.

Collective intelligence is a result of social learning in communities (Bandura, 2000). The term "collective intelligence" describes a group's capacity to cooperate and pool information in order to achieve a common objective or address a challenge. This can be done in a metaverse by using group activities or a quest system where students work together and share knowledge (Jovanovi & Milosavljevi, 2022). The knowledge shared or created by one individual in the metaverse, or knowledge produced offline using pedagogies like flipped classrooms, can influence the knowledge of others in a group and foster a sense of understanding and problem-solving skills among them.

4. Research question development

As metaverse technology is increasingly used in education, it's important to understand how students view its utility and pedagogy (Fussell & Truong, 2022). Studying students' perceptions of group activities can help improve social learning and collective intelligence (Glassman et al., 2021). Understanding the factors that influence students' perception of the platform's utility and pedagogy can inform the development and implementation of metaverse-based educational activities and programs (Wang & Shin, 2022). Wang and Shin (2022) claim that situational environments and personalized metaverse pedagogy can increase intent to use more than technology maturity.

RQ1: How does participation in group activities within a metaverse affect students' perception of the platform's utility and pedagogy?

It is important to understand how the unique features of a metaverse, such as presence, reflection, and narrative transportation, can enhance social learning. Additionally, there is limited research on how group activities within a metaverse can impact the social learning experience and how online and offline activities can be integrated to enhance this experience (Oh et al., 2023). In light of these gaps in knowledge, the following research question was developed:

RQ1: How does the integration of online and offline activities, such as discussions or assessments, impact the social learning experience within a metaverse?

5. Hypothesis development

Social learning can be used in a metaverse platform through concepts of presence and reflection. For example, avatars can replace the lack of physical bodies in the virtual world, thus invoking social presence (Oh et al., 2023). Reflection can be added by technical features for users to think about their experiences and share what they've learned. These can improve collective intelligence and make social learning work better (Dwivedi et al., 2022). Presence in a metaverse lets students feel like they are physically present in the virtual environment (Bos et al., 2022), which can make the experience more immersive and interesting. Also, reflection, which is the ability to think about one's own learning (Farrell, 2020), can be supported through the use of non-player characters in the metaverse.

Hypothesis 1: Participation in group activities within a metaverse will positively affect students' perception of the platform's utility and pedagogy.

Adding both online and offline activities to a metaverse can help students learn more about social learning. It is expected that combining online and offline activities, for example through flipped classroom can give students an all-around experience (Farrell., 2020), which can make them more interested in the material and help them understand it better. Online activities like looking at NPCs in a scene to get information can give students a sense of being there and enable them follow the story (de Regt et al., 2021), while offline activities like discussions or assessments can give students a chance to reflect about the material and get a deeper understanding of it. By combining different types of activities, students can have a better experience learning together and possibly create collective intelligence.

Hypothesis 2: The integration of online and offline activities, such as discussions or assessments, will positively impact the social learning experience within a metaverse.

Individuals in a group can bring diverse perspectives and experiences to the table, enhancing the social learning experience and leading to a more diverse and robust understanding of the material being studied. When one person shares their knowledge, it can act as a catalyst for others to reflect on their own understanding and potentially lead to new insights

(Glassman et al., 2021). Additionally, when individuals feel that they have contributed to the group's understanding, they may be more engaged in the learning process and have a more positive attitude towards the material and the group.

Hypothesis 3: The knowledge shared or produced by one person in the metaverse, or generated outside the metaverse through pedagogies like flipped classroom, will positively affect the knowledge of others in a group.

Our research model (Figure 1) examines the relationship between technical capabilities and pedagogical use on student intent to use the metaverse, where pedagogy can be implemented in both group and non-group settings.

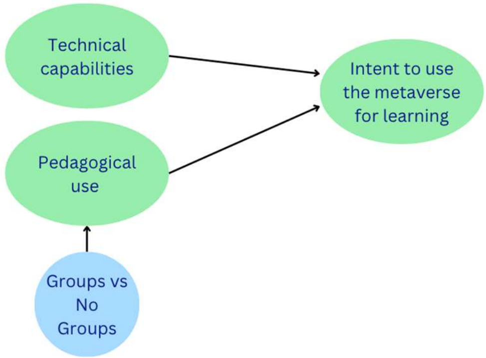

Figure 1. Research model.

6. Method

In this study, we recruited a total of 184 number of students from Malaysia, Hong Kong, and Thailand to participate in our research. All students were of higher education (17-19) and lived in urban areas with stable internet connections. These students were divided into two groups, with one group participating in group activities and discussions within the metaverse, while the other group completed the tasks individually. More details are provided in Table 1.

Table 1. Participants.

Class	Group	Topic	Country	Participants	Education Level
1	No	Sustainability	Hong Kong	35	Undergraduate
2	No	Finance	Hong Kong	34	Undergraduate
3	No	English conversation	Malaysia	33	Community college
4	Yes	Sustainability	Hong Kong	20	Undergraduate
5	Yes	Communication	Malaysia	35	Undergraduate
6	Yes	Sustainability	Thailand	27	Undergraduate

The selection of topics in each group was based on a variety of factors, including the relevance to the current curriculum, availability of classes, and suitability of the topics for the study. Additionally, the teacher's comfort with the chosen teaching method, such as dialogic pedagogy, was also taken into consideration. It is important to note that this study was designed as a pilot and thus may not be representative of all possible topic selections.

Students explored sustainability, finance, and communication metaverse scenarios in this study. For sustainability, students participated in a Hong Kong traffic pollution scene and a waste pollution restaurant (Class 1 and 4). Finance students "time traveled" to the 1930s to study the Great Depression (Class2). In English conversation, students roleplayed someone who lost their memory and had to remember vocabulary (Class 3). For communication class (Class 5) exhibited their social media findings in an exhibition hall. Class 6 sustainability students used metaverse data to discuss and present their findings. Class 4 discussed restaurant waste, while Class 5 used videos and multiple-choice questions to present in the metaverse. For classes with a group component, they were required to discuss and present offline. As students navigated the virtual scenes in different ways, other students got to hear different perspectives and information, making learning more collaborative and diverse.

The study was conducted using the platform, Classlet, an educational metaverse designed to support simulations and scenarios in a virtual 3D world. The students were asked to join 30-minute learning sessions to complete at least 10 NPCs (non-player characters) within the metaverse. The 30-minute duration was selected as the smallest minimum content that could still provide meaningful learning experiences. 10 NPCs were chosen as it was estimated that each NPC would require a minimum of 2 minutes to process, which included reading and making decisions through multiple-choice questions. Furthermore, the study design aimed to encourage online-to-offline learning activities, where the teacher could review MCQ results from the online metaverse session and facilitate deeper conversations in the offline setting. These NPCs acted as 'real people' in the scenes and provided information for the students to learn from.

Participants answered ten 5-point Likert questions after the metaverse session. The survey measured technology (like ease of use and functionality with questions such as “the platform was easy to use”), pedagogy (like usefulness, ability to improve performance with questions such as “the metaverse is helpful for my learning” and “the metaverse is useful”), and intent to use. Intent was a dependent variable, while technology and pedagogy were independent variables. This helped us assess how technology and pedagogy affected students' intent to use the platform. Linear regression was used to determine the relationship between group participation and students' platform perception. Our data was verified with Cronbach's alpha and assumption checks. We adapted Fussell & Truong (2022)'s virtual reality intent model and included it in our study's method. The original model underwent a rigorous process to assess reliability and validity, including normality, outliers, and model fit. As we only made slight adaptations to the questions, we evaluated internal consistency using Cronbach's alpha. To learn more about students' perceptions and experiences, we also qualitatively analyzed metaverse reflections, entered in an additional text field in the survey. Data analysis was conducted using JASP.

7. Results

In this study, all classes were conducted within one semester and student participants either downloaded Classlet from the Apple or Play store, or joined the metaverse platform from a browser using a passcode to enter the associated scenes. The requirements for each class varied due to the cross-disciplinary nature of the study, but were judged similar enough in nature to allow for a following analysis. For example, in the economics session, students were required to identify three differences between the content in the metaverse platform and that delivered in offline lectures. Meanwhile, in the communication class, students produced content in groups and uploaded it to the metaverse platform. In other cases, like sustainability, students discussed the content offline in groups after browsing the content in the metaverse scenes.

Screenshots of the metaverse scenes are shared below on Figure 1. It should be noted that reflection was the most seen in offline group discussions and presentations. It was observed that all presentations were vastly different from others and provided various opinions. In some cases, an inquiry-based learning approach was seen where students would present questions about the information retrieved from the metaverse and ways to further understanding. Reflection was also observed when students had to compare metaverse content to classroom content, traditionally delivered on slides. For example, students were asked to reflect on their own learning experience within the virtual environment by finding three differences between the virtual game and real life slides during a lesson on the Great Depression.

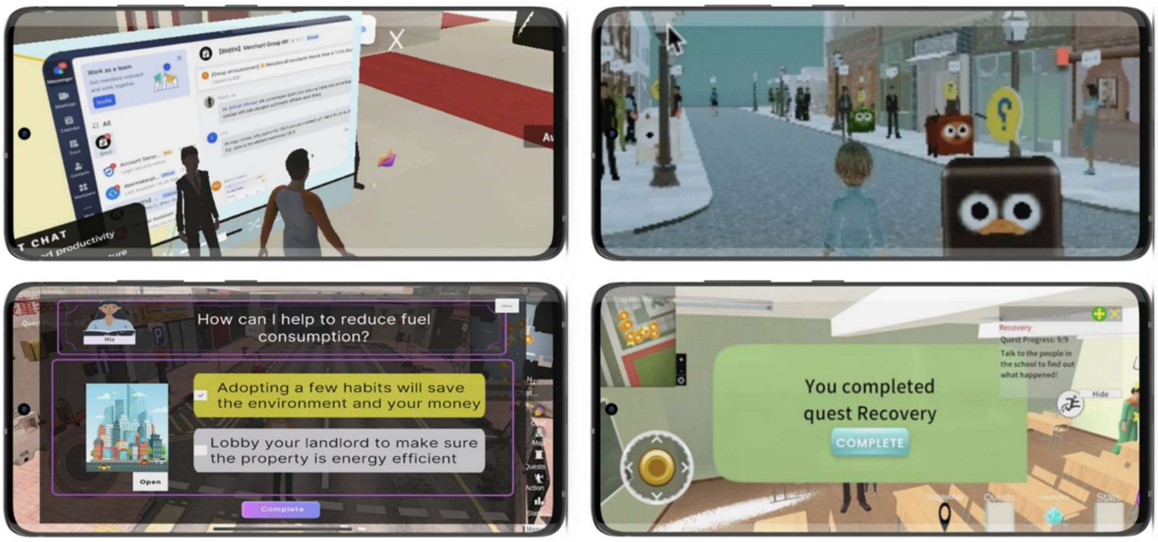

Figure 2. Screenshots of the Classlet metaverse learning platform.

At the end of each metaverse learning session, an online survey was distributed. A total of 76 responses were received for non-group participants while 69 responses was received for group participants. The data were entered into JASP for analysis. The results of our study indicate that the reliability of the survey data was high, with a Cronbach's alpha of 0.935. T-T plots showed that the normality of the data was normalized. However, the Shapiro-Wilk test was significant with a p-value of <0.001, indicating that the data did not follow a normal distribution. The Pearson's correlation coefficients of all the factors in the survey were significant, with the factor of "interesting" having the highest correlation ($r=0.805$, $p<0.001$) and "improvement to learning" having a correlation of ($r=0.701$, $p<0.001$). Spearman's correlation coefficients, consisting of "interesting" ($\rho = 0.774$, $p<0.001$) and "improvement" ($\rho = 0.677$, $p<0.001$) ,were also significant.

In the linear regression analysis, the root mean squared error (RMSE) was 0.723, with a standard deviation of 1.171. This suggests that the model is still accurate ($F(3,141) = 78.724$, $p < .001$) despite not having normalized data. Pedagogy was a significant predictor of students' intent to continue using the platform in the future ($\beta=0.932$, $p<0.001$) while technology was not ($\beta=0.070$, $p=0.52$). Whether the activities were done in a group or not was not a significant predictor ($\beta=-0.037$, $p=0.779$). The R-squared value of 0.626 indicates that 62.6% of the variance in intent to use the metaverse can be explained by pedagogy. Overall, these results suggest that pedagogy plays a significant role in shaping students' perceptions and intentions towards using the metaverse learning platform, while technology and group participation do not have a significant impact.

The survey also allowed students to key in open-ended feedback, for which an independent rater evaluated, coded and classified the responses into keywords. 33.1% comments were provided linked to ‘Perceived enjoyment’, with keywords like: “Interesting (funny), More interactive, Beautiful and eye-catching”, followed by Ease of use (27.8%) with keywords like: “Technical issues (lag), easier to use and learn, easy to access”. Performance expectancy and Behavioural control were scored at 13.1% and 12.8% respectively. Illustrative quotes are provided at Table 2:

Table 2. Illustrative quotes.

Class	Keywords
Communication / Conversation	“Public comments and posts, multiple approaches to access resources like posting video, pictures, easy to access”

	"I kept getting distracted because it feels like I'm playing a game rather than learning. So rather than visiting the booth, I wander around a lot most of the time."
	"It was fun talking to the peoples, it has so many places to explore and it is not boring at all and I think learning while playing is such a nice learning method."
Sustainability	"-I appreciate the activities that have to be done in groups because they can help each other plan the event."
	"Easy to control, NPCs are easy to find and kind of a fun way to learn"
	"Creating a character to talk with people who are at restaurant, makes it more realistic. You can go around and find different NPC to answer questions, it can make the learning more interesting."
Finance	"Not interesting/beneficial to study since phone's monitor is smaller, also not interesting by reaching the NPC and to receive information (although not boring than sit in classroom)"
	"The idea of new york city decoration 2. Could be an interesting ways of learning with visuals 3. can close the relationship gap between each other"

8. Discussion

8.1. The importance of presence in a metaverse.

The results of the study suggest that, while the use of group activities may not have a significant impact on student's intent to use the metaverse for learning, the use of pedagogy and the incorporation of presence into the metaverse-based learning platform can enhance the effectiveness of social learning, fostering a more dynamic and effective learning experience. The results of the linear regression indicate that technical factors alone ($\beta=0.070$, $p=0.52$) may not make up students' perception of the virtual environment, and that pedagogy plays a more crucial role ($\beta=0.932$, $p<0.001$) in terms of student engagement. This is also in line with Wang & Shin (2022)'s conclusion that technology maturity does not have significance on usage intent of the metaverse. This further highlights the need for learning activities and quests that promote engagement and foster deeper understanding of the material.

The metaverse has the potential to address limitations of traditional online learning, such as lack of social interaction and isolation. Through presence, the metaverse can foster meaningful and engaging social interactions, leading to more positive learning experiences. Furthermore, the ability to switch between online and offline activities can give students opportunities for face-to-face interactions, which are important for 21st-century learning. It was also observed that students had fun when they were following or watching others in the metaverse. However, it should be noted that a few students highlighted distractions that may be a result of the laughter or noise generated in the class, which suggests that instructors must more closely guide students in the learning activity, for example through incorporating of flipped classrooms (Chen et al., 2021).

Referring to Bandura's (2008, 2010) theories of observational learning and collective efficacy, our study focused on the implementation of group activities to facilitate collective learning in both online metaverse experiences and online-to-offline experiences. Through the observation of other individuals' actions, students were able to learn and engage more effectively with the learning content. The presence of peers in the form of their avatars, as well as the use of non-player characters or virtual agents, contributed to their heightened attention and motivation to continue with the learning activity. According to Sinatra et al. (2021), other features of virtual agents, or non-player characters (NPCs) that exhibit social behaviour, such as emotions, voice and facial expressions can increase the feeling of social presence and thus increase engagement and buy-in of using the virtual environment. NPCs were found to be crucial in fostering engagement and encouraging students to engage in various modes of learning, such as visual, auditory, and kinaesthetic. This is consistent with Hwang & Chien (2022)'s recommendations to use smart NPCs to deliver personalized learning material.

Since conducting metaverse learning in groups or no groups was not identified as a significant predictor in this study for student's intent of using the metaverse for learning, H1 could not be supported. However, it should be noted that pedagogy overall is a significant predictor. The use of social learning pedagogy, whether it is through peers or social presence, may have contributed to the results. Further studies may focus on exploring the effects of different types of social learning pedagogy in the metaverse and examine their contributions to student engagement and learning outcomes.

8.2. The role of reflection in metaverse-based learning.

The study found that reflection played a significant role in metaverse-based learning, with students engaging in two forms of reflection: reflection of the virtual scene to self and offline reflection. The reflection of the virtual scene to self was particularly evident in virtual field trips, where students were transported to different time periods to learn about historical events, such as the Great Depression. This demonstrates the use of virtual reality reflection that helps to internalize material as described by Hamby (2017), which led to a more positive perception of the platform. In contrast, offline reflection was prominent in group sessions, where the combination of individual and group learning, as well as the diverse perspectives and opinions shared by classmates, created a dynamic learning experience that was different from traditional classroom settings. Through group reflection, students were able to analyze and evaluate their learning, leading to a deeper understanding of the material and the development of critical thinking skills. According to Farrell (2020), having varying experiences is a factor to promote authentic learning. In the context of student perceptions, the results demonstrates that the metaverse can help students appreciate new situations and complexities in various scenarios (Ng, 2022; Wang and Shin, 2022), thus gaining the perception that they have learnt more.

Even though the study didn't directly measure how reflection changed how students used the metaverse platform, it did find that reflection helped students learn better. Reflection is a crucial component of authentic learning in a metaverse and provides a valuable opportunity for learners to connect their experiences in the virtual environment to their own lives (Farrell., 2020).

H2 is supported by the study's findings, which demonstrate that reflection plays a significant role in metaverse-based learning. Both reflection of the virtual scene to self and offline reflection were found to be important for student engagement and learning outcomes. This suggests that reflection should be a core consideration when designing learning experiences for the metaverse, in order to promote authentic learning and deeper understanding of the material. Further studies could explore the specific types and methods of reflection that are most effective in the metaverse context.

8.3. The significance of knowledge sharing in metaverse-based learning.

The results of the study highlight the importance of knowledge sharing and collective intelligence in a metaverse platform. For example, in the context of sustainability education, as students browsed the virtual restaurant to learn about different aspects of waste, such as food, packaging, and disposal, they picked up different pieces of information. The information allowed them to contribute in different ways to the group discussion, resulting in comprehensive understanding of the topic and positive perceptions of the platform. However, it should be noted that the regression analysis did not find group activity to be a significant predictor of students' perception of the platform. This suggests that more needs to be evaluated to understand group activities in a metaverse. For example, the implementation of a flipped classroom requires careful handling of time management, instruction, and facilitation (Chen et al., 2021).

It was unclear what features could support knowledge sharing and collective intelligence. For example, comment boards are available, but they would need more planning around learning goals or they might not be beneficial for learning (Akcaoglu & Lee, 2018). According to Glassman et al. (2021), collective intelligence is made when individuals participate to the wider community and in turn cycle back to the individual. Features that support this may include chat rooms, discussion boards, and collaboration tools for real-time interactions and knowledge sharing.

8.4. The significance of metaverse on social learning

Metaverse has the potential to revolutionize the way we learn and interact in virtual spaces. Social learning, in particular, benefits from the immersive and interactive features of a metaverse. Students can engage in hands-on activities, explore real-world scenarios, and collaborate with one another in a way that traditional learning environments cannot provide. The use of presence, reflection, amongst other features can enhance the effects of social learning, leading to a more effective and engaging learning experience. However, it is important to note that while the metaverse has great potential for social learning, there are still challenges that need to be addressed. For example, it was unclear what technical features or tasks were suitable to fully support knowledge sharing and collective intelligence. One suggestion mentioned by participants in the survey was the potential for user-generated content in the metaverse. Allowing students to author their own spaces, perhaps in an exhibition format, may encourage collective intelligence. By showcasing their work, students are encouraged to learn from one another, build on each other's ideas, and engage in meaningful collaboration.

Another idea floated by participants was the importance of collective action in addressing sustainability issues, such as reducing waste in a restaurant setting. Group quests that involve working together to achieve a common goal may provide an engaging and immersive learning experience. The introduction of roles for peer-to-peer engagements, such as playing the role of restaurant owners, non-profits, and customers, could further enhance the social learning experience within the metaverse. This could help students develop understanding of different stakeholders in sustainability issues and boost collaborative problem-solving. Overall, it is important to note that both pedagogy and technical features can contribute to the development of collective intelligence in a metaverse platform and should be considered when designing metaverse learning experiences for knowledge sharing and collective intelligence.

H3 is only partially supported as the study showed promising signs of the use of pedagogical and technical factors for knowledge sharing and collective intelligence in metaverse-based learning, but results were not conclusive. More research is needed to understand the impact of group activities in a metaverse and how to effectively conduct them offline.

Based on the discussions, we propose the following model that can be explored in future studies. This model can guide future studies in exploring the complex relationships between these factors and their impact on student engagement, learning outcomes, and perceptions of the metaverse platform. The proposed model (Figure 3) includes: pedagogy, technical features, social learning – peers, social learning – virtual agents, reflection, and collective intelligence.

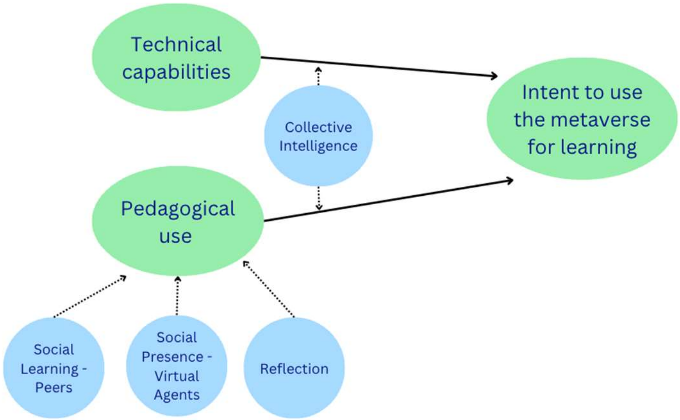

Figure 3. Proposed research model.

Limitations: The sample size of our study was small (n=184) and data was not normally distributed according to the Shapiro-Wilk test (p<0.001). However, reliability of the survey data was high (α=0.935) and correlation and regression analyses were significant and able to provide insights. Therefore, caution should be taken in generalizing our findings.

9. Conclusion

In conclusion, the study aimed to evaluate the impact of group activities and pedagogy on student's intent to use a metaverse learning platform. Results showed that pedagogy was a significant factor in determining student's intent to use the platform, suggesting that incorporating effective pedagogical strategies, such as social learning and flipped classrooms, is crucial in the design and implementation of metaverse learning environments. However, technology was not found to be a significant factor in determining student's intent to use the platform, indicating that technical features alone are not enough to drive student engagement and learning. The results of the study suggest that there is a complex relationship between group-based learning and pedagogy, even though group activities were not found to have a statistical significance. Future research should explore this relationship further, in order to better understand the potential of metaverse learning environments for social learning and collective intelligence. Group activities and role-playing, for instance, may support the development of collective intelligence and enhance the effectiveness of pedagogical strategies like social learning.

It is important to note that this is a preliminary study and more research is needed to fully understand the potential benefits and limitations of social learning in a metaverse. The potential for user-generated content and group quests to enhance social learning and collective intelligence is exciting and warrants further exploration. By better understanding the impact of pedagogy, technology, and group activities on social learning in a metaverse, educators and researchers can help to maximize the benefits of this innovative learning platform for students.

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Metaverse Literacy in Primary to 12th-Grade and Higher Education

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Abstract: *Metaverse is a major attention in the fourth industrial revolution in the 21st century. With the rapid growth of digital technologies and Internet infrastructure for merging the physical world and virtual world, citizens in the digital era are increasingly exposed to metaverse-related initiatives for their daily pursuits in the digitalized society. Students in primary to 12th-grade (P-12) education and higher education nowadays face a pressing need to build a solid know-what and know-how foundation for their use of metaverse technologies; as well as develop a strong self-identity with proper attitudes for their participation in metaverse environments to complete daily endeavors and make interpersonal interactions in a safe and productive manner in metaverse environments. This study proposes the cultivation of metaverse literacy for students in P-12 and higher education. The notion of metaverse literacy covers four dimensions: (i) the cognitive dimension about the understanding of latest development of and knowledge about related core technologies solving in metaverse environments; (ii) the meta-cognitive dimension about the engagement in collaboration, inquiry, creation and problem-solving in metaverse environments; (iii) the affective dimension about the empowerment and identity-building for participation in and contribution to metaverse environments; and (iv) the social dimension about the experience of social interactions in metaverse environments with safety and ethical concerns. This study discusses the crucial elements of metaverse literacy and talks about how to promote them in P-12 and higher education.*

Keywords: higher education, metaverse literacy, metaverse, primary to 12th-grade education, students

1. Introduction and Background of Study

Metaverse, firstly coined in Stephenson's science-fiction novel *Snow Crash* in 1992, gains a growing attention in recent years after the rebranding of Meta Platforms, the parent company of many internationally popular online social media and social networking services (e.g., Facebook, Instagram, WhatsApp, etc.) for a vision of connecting human communities to interact, learn, work and create without the boundaries of physical world and virtual world (Hwang & Chien, 2022; Tlili et al., 2022). In the digital era in the 21st century, an important goal across primary education to higher education is to develop students to be future-ready learners who are able to interactively use diverse tools and resources offline and online for solving problems flexibly and creatively in both individual and collaborative contexts (Hwang & Chien, 2022; Mistretta, 2022). The wave of metaverse development in the coming decade creates opportunities for primary to 12th-grade (P-12) education and higher education sectors to realize this educational goal in a learning environment which organically combines offline classrooms in physical campus sites and online learning spaces in 3D virtual environments (Pimentel et al., 2022; Suh & Ahn, 2022). This study aims to discuss the promotion of metaverse literacy for students in P-12 and higher education, with a goal of preparing new generation to ride on the wave of metaverse for a success in the digitalized society.

2. Core Technologies for Metaverse Development

Metaverse combines the real world with the virtual world for a fusion of both virtually-enhanced physical reality and physical-persisted virtual space (Tlili et al., 2022; Zhang et al., 2022). Metaverse could be fully or partially virtual. It provides the multiple participants inside with a persistent world in which they make "virtual presence" (such as through avatars) for engaging in a variety of daily-life activities and interacting with other people and objects interoperable between the physical world and virtual world; while their works and logs in the virtual spaces inside are continuously recorded and securely kept (Huggett, 2020; Hwang & Chien, 2022). We suggest that there are four types of technologies core for the development of metaverse, as shown in Figure 1 (Kong, 2022).

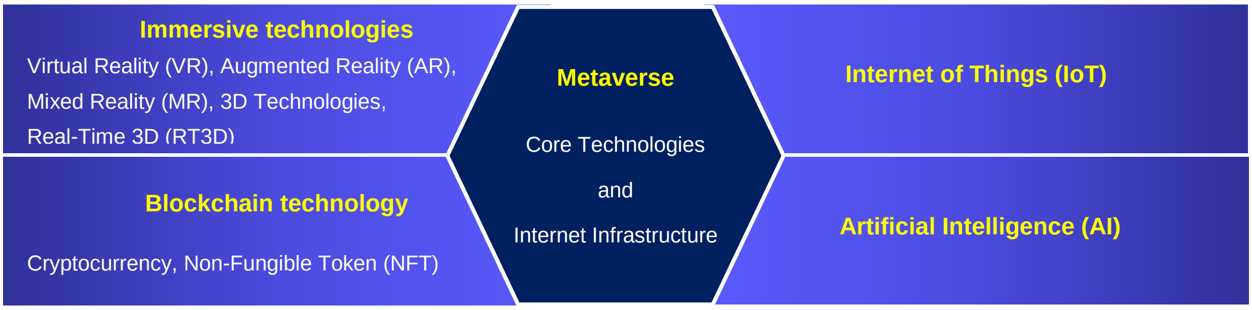

Figure 1. Core technologies for metaverse development.

The first type of core technology is immersive technologies, which cover virtual reality (VR), augmented reality (AR), mixed reality (MR), 3D technologies, and Real-Time 3D. Immersive technologies are necessary for the creation of immersive environments for the virtual world to enable participants in metaverse to have authentic, multimodal, and personalized experiences as if they are in the physical world. VR refers to a technology for creating a fully immersive virtual environment; AR refers to a technology for overlaying virtual elements onto physical objects in the real-world environment; and MR refers to a technology for interacting with physical objects existed and virtual elements overlaid in the real-world environment (Pimentel et al., 2022; Tlili et al., 2022). MR is the next wave in computing. 3D technologies and Real-Time 3D are the foundation of VR, AR and MR for achieving immersive experiences in real-time virtual environments – with the support from high-resolution 3D display technology, high-precision 3D interactive technology, and high-quality low-delay remote rendering (Fan et al., 2022; Tlili et al., 2022). These immersive technologies are key to model vivid and colorful scenes in the 3D digital environments of which mirror the physical contexts into the virtual platforms; and to enable participants in metaverse to interact with digital representations of people and objects in the 3D digital environments.

The second type of core technology is Internet of Things (IoT). The technology of IoT refers to physical objects with sensors and actuators that connect wirelessly to the Internet or other communications networks for transmitting data to move and manipulate the networked objects in a real-time manner (Jean et al., 2022; Tlili et al., 2022). IoT is necessary for the creation of immersive experience in the digitally-created 3D environments in metaverse, as this technology uses different sensors and devices to merge both the physical world and the virtual world for participants to manipulate virtual objects and creations, navigate movements of own avatars, and interact with other participants real-time in metaverse (Tlili et al., 2022; Zhang et al., 2022).

The third type of core technology is artificial intelligence (AI). AI refers to the technology of making decisions which mimic human intelligence. It is a computational capacity demonstrated by computing machines to process certain kinds of information for solving problems; and some of the AI systems make decisions by training through large sets of data (Chaka, 2023; Porayska-Pomsta, 2016). AI technology is necessary to enable IoT-supported actions in metaverse to work in an ordered manner – as it supports IoT devices in metaverse environments for an automatic signal detection in the sensing stage, response decision in the reasoning and/or computational stage, and action implementation, adjustment and/or refinement in the reacting stage – for instant feedback to achieve the same effect as in real-world environments (Hwang & Chien, 2022; Khan et al., 2022).

The fourth type of core technology is blockchain technology, together with the related digital items of cryptocurrency and non-fungible token (NFT). The nature of blockchain is a secure distributed ledger in the technology-mediated socioeconomic system. Blockchain technology enables its users to control and secure digital data only by themselves; and it is therefore recognized to be useful for business transactions in virtual environments in a decentralized, secured, reliable and transparent manner (Bhaskar et al., 2020; Park, 2021). Blockchain is the backbone technology of cryptocurrency and NFT. Cryptocurrency refers to a digital currency that uses encryption technology for a transparent and verifiable record-keeping of transactions and payments through a virtual accounting system (Afrashtehfar & Abu-Fanas, 2022; Bhaskar et al., 2020). NFT refers to a digital creation (commonly in the form of artwork, image, music, or video) which is a unique cryptographic token certified by blockchain technology for its ownership and authenticity in the virtual word (Afrashtehfar & Abu-Fanas, 2022; Hwang, 2023). Blockchain technology is necessary for participants in metaverse to carry out their daily endeavors in the virtual environments – whenever a need to share and/or acquire digital items and/or services with the authentic and unchangeable recording of the relevant exchange and transaction activities in the virtual world in metaverse (Chaka, 2023; Zhang et al., 2022).

The development of metaverse is impacting how people learn, work, and communicate in the digitalized society. It is therefore important for our next generation to get an understanding of these four types of core technologies for metaverse development; and know how to capably and properly use these four types of core technologies for the purposes of learning and other daily pursuits in the increasingly complex world in the digital era.

3. Metaverse Literacy in P-12 and Higher Education

This study makes an advocacy of nurturing metaverse literacy among students in P-12 and higher education to prepare them to be familiar with the metaverse technologies, engage in the metaverse environment for immersive learning and problem-solving, participate in and contribute to the metaverse environments, and aware of the goal of participating in the metaverse environments for the benefits of all participants in the digitalized society. We propose metaverse literacy to cover four dimensions, namely cognitive, meta-cognitive, affective and social dimensions (see Figure 2).

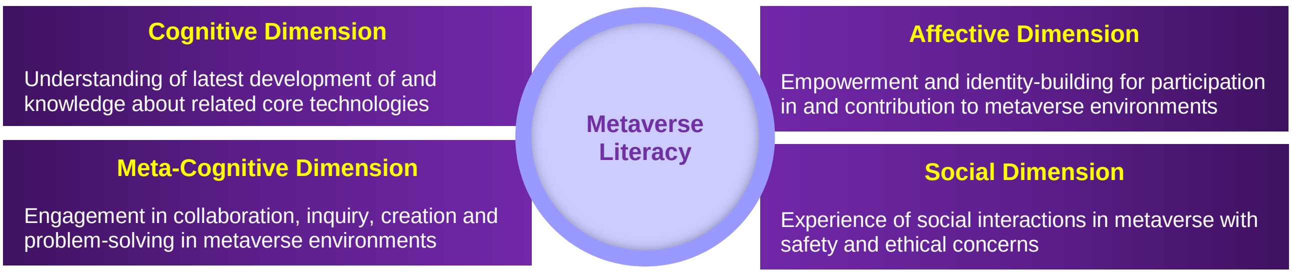

Figure 2. Metaverse literacy in P-12 and higher education.

3.1 Cognitive Dimension

The cognitive dimension of metaverse literacy focuses on students' understanding of the latest development of and knowledge about related core technologies. Students are expected to master the know-what and know-how about metaverse technologies and metaverse development in terms of five aspects (Akour et al., 2022; Hwang & Chien, 2022; Pimentel et al., 2022). The five aspects are that (a) metaverse is an organic combination of the physical world and virtual world; (b) there are already many occasions for them to experience, learn and create in virtual environments in their daily-life contexts, like playing popular online games Minecraft and Roblox; (c) the setup of a virtual environment in metaverse needs to use immersive technologies (involving VR, AR, MR, 3D technologies and Real-Time 3D); (d) each participant in metaverse has a "virtual presence" (such as an avatar) for the interoperable actions between the physical world and virtual world, with the support of IoT and AI technologies; and (e) the use of blockchain technology can support transactions in metaverse in which participants use cryptocurrency and/or NFT for the exchange of artifacts and/or services inside the virtual world.

3.2 Meta-Cognitive Dimension

The meta-cognitive dimension of metaverse literacy focuses on students' engagement in collaboration, inquiry, creation and problem-solving in metaverse environments. Students are expected to demonstrate the capability and willingness to participate in metaverse for daily endeavors (Hwang & Chien, 2022; Mistretta, 2022; Tlili et al., 2022). There are increasing efforts made by the academic communities to integrate the elements of metaverse into day-to-day curriculum delivery and formative assessment in different school sectors for students to experience the use of immersive technologies and the process of learning in various virtual environments in metaverse. These educational efforts reveal that metaverse-related initiatives particularly motivate students to collaborate with peers to explore domain knowledge and co-create project works on addressing subject-related problems. This brings chances for students to apply and consolidate their collaboration skills and inquiry skills for their better collaboration with other peers and inquiry about interested topics when learning in metaverse. There are also chances for students to foster creativity for problem-solving, as students need to tailor and/or produce graphical representations for their "virtual presence" in the virtual environments when learning in metaverse.

3.3 Affective Dimension

The affective dimension of metaverse literacy focuses on students' empowerment and identity-building for participation in and contribution to metaverse environments. Students are expected to demonstrate the self-efficacy and self-identity of a responsible and willing participator and contributor in metaverse environments (Mistretta, 2022; Pimentel et al., 2022; Zhang et al., 2022). When students participate in metaverse, they need to have a "virtual presence" for the interoperable actions between the physical world and virtual world. For example, students are requested to customize and/or build their own avatars for joining a group discussion about a subject-specific concept in a virtual classroom set in an immersive space at Spatial App. This drives a process of empowerment and identity-building in metaverse – students are empowered with an autonomy to name and outfit their graphical representation in the virtual world for a feasible reflection of their facial motion and body movement made in the real world. Students in this process need to demonstrate creativity, as they need to produce their "virtual presence" which uniquely blends the real-person and make-believe characteristics according to own preference. When students are introduced to multiple virtual environments in the metaverse, they are required to realize how to create their appropriate identities in different virtual environments and how to accordingly fortify their own physical identity in the real world when participating in metaverse. This awareness is important for students to contribute to the positive and sustainable development of metaverse, with a concern on the equity and inclusiveness for participation in metaverse.

3.4 Social Dimension

The social dimension of metaverse literacy focuses on students' experience of social interactions in metaverse with safety and ethical concerns. Students are expected to make interpersonal communication safely and productively in metaverse for daily endeavors (Pimentel et al., 2022; Tlili et al., 2022; Zhang et al., 2022). For learning in metaverse, students have to make "virtual presence" and interact with the parties (teachers and peers) inside the virtual environments in metaverse. It is foreseeable that students very often extend their interpersonal communication virtually in metaverse for learning purposes after school hours – as like their practice in the physical world – via the use of online social media and social networking services (such as Facebook, Instagram, Messenger run by Meta Platforms). In this circumstance, the problems of cyber-bullying and privacy-infringement may extend from the human-to-human context in physical world to the avatar-to-avatar context in metaverse. This drives the need to cultivate students with a culture of positive social connection in virtual environments for confidently interacting and helpfully supporting peers in metaverse; and an awareness to safe virtual communication to avoid unnecessary communication with untrusted avatars with unverified identities behind.

4. Conclusions and Future Work

The recent digitalized society has a growing attention to metaverse and a promising trend for integrating educational initiatives in metaverse. This drives the need to prepare our next generation in the digital era for their readiness to learn, work, and interact in metaverse in a safe and productive manner. We propose to cultivate metaverse literacy among students in P-12 and higher education for a readiness to participate in metaverse with benefits, not harms, in their daily pursuits interoperable between the physical world and virtual world – students build cognitive understanding of metaverse technologies; make meta-cognitive engagement in metaverse environments; build affective empowerment for participation in metaverse; and gain social experience of participation in metaverse.

It is anticipated that in the coming five to ten years, there will be a fast development and widespread use of metaverse in varying aspects of daily pursuits. The possession of metaverse literacy is a key for students in P-12 and higher education to succeed in this coming wave of MR and metaverse. The promotion of metaverse literacy, therefore, should be prioritized as an area of concern in P-12 and higher education sectors shortly. We are interested to put efforts to formulate a comprehensive framework of metaverse literacy across different learning stages in P-12 and higher education sectors. Such framework should be built through an extensive and in-depth review of worldwide policy documents and research publications related to metaverse in education – taking students' stage-specific developmental needs and learning characteristics into consideration – for an informed articulation of literacy-dimensions, concise standards of literacy-proficiency, and precise indicators of literacy-demonstration specific for metaverse literacy. We recommend policy makers to collaborate with academic researchers for an informed planning and implementation of governmental initiatives specific for metaverse literacy education – in line with a comprehensive framework of metaverse literacy – across different learning stages in P-12 and higher education sectors. We recommend school practitioners to take the relevant policy plans and/or initiatives into consideration for integrating elements of metaverse literacy into curriculum delivery, and building readiness for metaverse literacy education through professional development. We recommend parents to support school-based initiatives on metaverse literacy education for guiding the next generation to participate in metaverse after school hours safely and productively. It is believed that the joint efforts from these important stakeholder parties in education sectors can drive a successful launch of metaverse literacy education in the near future.

We are pursuing the first attempt to develop and validate a research instrument on assessing students' understanding of metaverse literacy and their self-identity in metaverse. This research attempt will address the interrelations among the four dimensions of metaverse literacy – students' better know-what (cognitively) and know-how (meta-cognitively) for the use of metaverse technologies; their stronger self-identity with proper attitudes (affectively) and responsible behaviors (socially) for participating in the metaverse. Its goal is to enable students to create appropriate identities in different virtual environments and to fortify own physical identity in the real world – with benefits to their own selves, their peers, their family and the larger society. An extensive literature review on metaverse in education will be conducted for setting indicators of literacy-demonstration specific for students' metaverse literacy and their self-identity in the metaverse.

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Research Issues for Minority Students by AI and Metaverse-empowered in Inclusive Education

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Abstract: *This paper presents AI and Metaverse-empowered in inclusive education which aims to help educators or teachers know what trends, issues, and learning scenarios are for minority students in realizing the mission of educational institutions that are equity and quality in terms of interacting teaching and learning activities with pedagogical transformation towards AI technology and metaverse. We believe it is necessary to fill this with strong encouragement and motivation from students to show that minority students have a place in inclusive education. The results that we obtain metaverse and artificial intelligence focus on virtual-based environmental learning systems such as mixed reality, virtual reality, augmented reality, e-learning, and digital tools by innovating from year to year can be seen very clearly in the progress of 2019-2022, without intending to skip physical learning but it is trending in that direction so this is a great potential for researchers as well as research issues on health, social, and ethnic minority. In the context of AI and the metaverse as a platform that contributes to convenience in carrying out learning activities with no partition between students, so that adaptive learning is suitable to fill the place of inclusive education which shows encouraging trends for a number of minority students.*

Keywords: artificial intelligence, metaverse, minority students, inclusive education

1. Introduction

By leveraging virtual reality and augmented reality technologies, the metaverse can expand the physical world by interacting in real-time with simulations using virtual environments, immersive games, and avatars (Dwivedi et al., 2022). Because of that, companies, consortiums, and institutions are starting to look at the potential of the metaverse to be integrated into their existing business models, especially artificial intelligence. With the existence of real technology that makes it smooth for someone to interact without boundaries, many researchers have researched from various multidimensional and its implementation, by looking at literature from various perspectives (Fernandez & Hui, 2022), inclusive education is very interesting issues related to minority students which also highlights the challenges of technology in providing what users want.

Inclusive education is a mandatory thing in educational institutions in equitable service to students, by implementing a fair system on the principle of equity for minority students, so it is not only attracting quantity but the mission of realizing quality and equity of education for students who joined the institution, researchers have highlighted this group for attention (De Bruin, 2019; Engelbrecht, 2020; & Cucio et al., 2020). There is an effective use of technology from a concept where there is teacher and student readiness. By not skipping the digital age, technology with its design, and without seeing the background of students from the same context, the same packaging, both culture, sex, race, disability, and others.

We analyze several literature of the inclusive education such as minority students including those with special needs, autism, disabilities, and race in the inclusive education literature or figure out to metaverse only for student in general (Chiu, 2019; Perez et al. al., 2022; Lee, 2021; & Tlili et al., 2022) however researchers discuss on it exclude bibliometric analysis with AI and metaverse, here we fill that gap. The following research questions to be proposed:

1. What are the most keywords for minority students in inclusive education that empowers AI and Metaverse from 2010-2022?
2. What are the research issues and learning scenarios regarding minority students empowered by AI and Metaverse with inclusive education?

2. Methodology

The Scopus, Web of Science, and IEEE Xplore databases were taken to analyze research articles on inclusive education of minority students in the AI and Metaverse platforms. Bibliometrics helps analyze for the period of 2010-2016; 2017-2018; 2019-2022 which aims to see trends, issues and also what learning scenarios with technologies will implement inclusive education. The query string of (TITLE-ABS-KEY (minority) OR TITLE-ABS-KEY (underrepresented) OR TITLE-ABS-KEY (diversity)) AND (TITLE-ABS-KEY (inclusion) OR TITLE-ABS-KEY (inclusive)) AND (TITLE-ABS-KEY (artificial AND intelligence) OR TITLE-ABS-KEY (metaverse)). Referring to the PRISMA flow diagram search the keyword analysis of titles and abstracts obtained 212 articles, then collected 185 articles connected to inclusion for minority students using the AI and Metaverse platforms. Finally, we screened the focus on education only, eliminating uncorrelated documents like book series, book, non-English, and excluded education fields, so only 28 selected articles need to analyze and discuss in the next section.

3. Findings and Conclusions

Minority students by AI and Metaverse who are empowered in inclusive education starting from 2010-2022, for the first research question used VOSviewer software in 2010-2016, where encountered experiments with the keywords second life, virtual world, learning environment, distance technology, distance education, knowledge base system that leads to virtual technology, therefore in 2017-2018 that at this time researchers solved research problems on how education can be achieved and minority students can obtain equity in education by using communication of virtual technology, whereas in 2019-2022 namely metaverse and artificial intelligence, the study is more about learning systems within the framework of innovation in education, it can be seen from the results of keywords with virtual reality, augmented reality, mixed reality, e-learning, emerging technology, roblox, learning environment and digital tools. Here we also found the targets of survey from level of elementary school to higher education which each of them discuss on the minority students.

In Table 1, the second research question concerns minority students in empowering AI and Metaverse that there has been progress from 2019-2022 with research issues of health, social, and ethnic minority. Teaching and learning activities for both students and teachers concentrate on dealing with virtual reality, augmented reality, mixed reality learners that are integrated with artificial intelligence. Meanwhile, related to the learning scenarios from 2019-2022 researchers put right formula on VR learning, game-based learning, e-learning, and adaptive learning. However, VR learning are exist in each year 2010-2016, 2017-2018 and 2019-2022 with focus on health, social interaction and behavior learning environments such second life, virtual world, adaptive behavior, and face recognition skills in technology development as well as pedagogical transformation that students do not use technology effectively to support learning which is considered by researchers to be beneficial (Margaryan & Littlejohn, 2008). Adaptive learning has great potential for future challenges by looking at the progress of the last period 2019-2022 which is integrated with AI and Metaverse platforms by accommodating social issues and ethnic minorities. In the learning scenarios, adaptive learning systems are a consideration in recognizing the characteristics and preferences of students (Yang, et al., 2013) which is the goal of providing personalized learning resources for students, in particular for virtual worlds with AI and Metaverse technology inside. Meantime, the limitation of this research does not have many documents for the context of AI and Metaverse, especially targeting minority students in inclusive education, hence from the databases of WoS, Scopus, and IEEE Xplore obtained twenty-eight in maximizing full-contain articles analysis which dominated in 2019-2022.

Table 1. Issues and Learning Scenario.

Issues	**Learning Scenario**	**First Period**	**Second Period**	**Third Period**
Health	E-learning			2019-2022 = 1
	VR Learning	2010-2016 = 2		2019-2022 = 3
Social	E-Learning	2010-2016 = 2		2019-2022 = 2
	VR Learning	2010-2016 = 3	2017-2018 = 2	
	Mobile learning	2010-2016 = 2		
	Game-based learning			2019-2022 = 3
	Adaptive learning			2019-2022 = 3
Etnic Minority	VR Learning			2019-2022 = 2
	Adaptive learning			2019-2022 = 3

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Foster Dialogue Between Students when Solving Calculus Problems in the Metaverse

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Abstract: *Using the Metaverse as a learning environment when working on Calculus problem-solving tasks allows students to engage in different ways of exploring mathematical thinking processes and fosters dialogue between them about emerging pedagogies and emerging online platforms. For this study, it was important to document the extent to which pedagogies were used and how our dynamic C3 (competition, cooperation, and communication)-based learning platform was strategically designed to promote more personalized, social, open and real time learning. To this end, the student-teacher-student communication interaction pattern sequences in online Calculus teaching and learning were used to foster dialogue between students. We will also discuss how these tasks take place in a dialog-to-action approach based on different questioning types. Three types of discourse interactions that are embedded in a communication pattern are turn-taking, sequential positioning and adjacency pairs, where students learn from, through and with others.*

Keywords: metaverse, mathematical thinking, triadic dialogue, calculus

1. Introduction

The Metaverse has been used in classroom teaching of Calculus to foster learners' mathematical thinking and problem solving pathways/experiences. It is used to help students communicate, share information, socialize, and develop their knowledge (Kung & Wong, 2022). In pursuing this goal, using multiple shared-screen modes from Spatial's virtual environment (https://spatial.io/), students use our real time online C3 (competition, cooperation, and communication)-based learning platform to learn from/through each other and with others while solving man-made and real-life first year calculus problems. In Spatial, teachers, students and peers create their own lifelike avatars to interact with each other in different shared spaces. The central goal of the C3 platform is to act as a teacher-led learning delivery system to build a reciprocal relationship between students and teachers, where students can interact with each other using online cooperation and/or competition learning modes and peers freely walk through different shared spaces to learn how these students solve math problems interactively and see what kinds of mathematical tools and techniques they use. Using a co-action model between students and a dynamic learning environment (Moreno-Armella & Hegedus, 2009; Salinas et al., 2016), we use communication interaction pattern sequences (Hodgen & Wiliam, 2006; Ingram, 2021) in online Calculus teaching and learning, where students guide the action occurring on the platform. To keep a synchronous and bidirectional conversation going, we use turn-taking (Sacks et al., 1974), sequential positioning (Schegloff, 1992; Heritage, 2001) and adjacency pairs (Levinson, 1983), which are embedded in the communication patterns.

The aim of this paper is to describe a triadic (student-teacher-student) dialogue experience that helps users learn Calculus using a communication interaction pattern and conversation approach built an online platform in Spatial. A sequence of activities using a set of bidirectional dialog-to-action tasks was designed to provide in-class and out-of-class learning. These tasks help students learn from, through and with others by switching their roles – teacher, peer and student. The rest of the paper is summarized as follows. In Section 2, as a turn-taking process, we describe how an e-learning platform in Calculus using an educational game strategy in the Metaverse is created. As a sequential positioning process, we first show how we used mathematical thinking processes in the calculus problem design and then describe the different questioning types embedded in the platform. Emphasis is placed upon the applications of the initiation-response-evaluation/feedback/follow-up sequences in online Calculus teaching and learning. In Section 3, using an adjacency pairs process, we demonstrate two examples of how the Metaverse and the C3-based learning platform can be used in both face-to-face and online teaching and in virtual discussion. Conclusions are presented in Section 4.

2. C3-based learning platform for fostering dialogue

The aim of the C3-based learning platform is to develop a social learning network to link with the Spatial Metaverse and foster dialogue between students using the conversation learning mode. **Turn-taking**: A turn-taking activity in educational games is used to ensure more measurable competitive and cooperative learning. Different simultaneous/sequential games for two students (players) (or two groups of students) from the applications of game theory (see e.g., Straffin, 1993) in strategic thinking are first embedded in the platform. After they play a game, the winner has the first choice of which of the two Calculus problems to solve, that is, a choice between solving the easy or the hard problem. Six sets of problems address the following first year Calculus topics: limits, continuity and differentiability, differentiation, indefinite integrals, definite integrals, applications of differentiation and integration. For each problem set, we use various types of two-person games, for example, the Three Boxes Game (Gardner, 1959), the Spoof Game (Schwartz, 1959), the Odd Even Game (Cohon, 1979), the Bluffing Game (Graham, 1997), the Fibonacci Nim Game (Whinihan, 1963) and Game of Dice (Prisner, 2014). After five problems are solved, the two players play the game again, and the winner gets to choose one of two problems. Every fifth problem they are required to play another game. Detailed descriptions of each two-person game with the rules of the game can be found via the html link: https://www.math.cuhk.edu.hk/~mathcal/mathgame/. **Sequential positioning:** To demonstrate how every aspect of turn-taking interaction is deployed systematically and helps shape how the conversation unfolds, two basic tenets of conversation analysis are used when solving online Calculus problems a) talk is a collaborative achievement (Schegloff, 1982, 1988), and b) it is sequentially organised (Sacks, Schegloff & Jefferson, 1974). For the first tenet, we use Mason's (Watson & Mason, 1998), Walsh and Satters' (Walsh & Sattes, 2011), and Sahin and Kulm's (Sahin & Kulm, 2008) questioning types, which are embedded in the platform not only to encourage students to interact and share experience, but also to improve mathematical thinking and orchestrate students' discourse before they respond to the questions. For example, as proposed by Sahin and Kulm's questioning types (Sahin & Kulm, 2008), we use probing, guiding and factual questioning types when designing Calculus problems. Typically, when solving each problem, students are required to solve a few sub-problems that may contain any combination of these questioning types. For the second tenet, we use a student-teacher-student communication pattern (see e.g., Sinclair & Coulthard, 1975; Swann et al., 2004; Walsh, 2011; Ingram, 2021), where there are two types of move sequences, either a two-move sequence, i.e., Initiation-Response (IR) (see e.g., Mehan, 1979) or three-move sequences, i.e., Initiation-Response-Evaluation/Feedback (IRE/IRF) (see e.g., Rustandi & Mubarok, 2017) or Initiation-Response-Follow-up (IRFo) (see e.g., Miao & Heining-Boynton, 2011; Park et al., 2020). The platform is treated as a teacher. The first move is the initiation, where the teacher (the platform) asks a question to initiate student interaction on a teacher-led online platform instead of face-to-face in a classroom. The second move is the response, where students interact in response to the teacher's stimuli. The last move is either the evaluation/feedback or the follow-up. With the first, the students' answers are evaluated by the online platform and it gives a reply such as right or wrong, which means that students get the correction or evaluation for their response immediately. With the second, the teacher invites students to answer extra problems after students have made the second move. Our main contribution is the combination of evaluation, feedback and follow-up together as a single move, namely the Initiation-Response-Evaluation/Feedback/Follow-up (IREFFo) pattern but we also contribute the embedding of these two-move and three-move sequences in six problem sets. As we shall see below, to provide an effective follow-up response, such as peer reviewing or comparing and contrasting students' activities rather than having a simple evaluation/feedback or follow-up, we use the IREFFo pattern:

Table 1. IREFFo Pattern.

1. [Game Play] Students play warm up game activities.
2. [Initiation]
   a) Both students solve the same problem by filling in the blanks.
   b) Click the Submit button
3. [Response] Students mark their opponent's answers via reciprocal marking,
   a) Opponent's answer is shown in the darker green region.
4. [Evaluation/Feedback]
   a) Students select items they think their opponent got wrong. If the students think their opponent got it all correct, none of the items has to be selected.
   b) Click the Approve button
   c) Each student's answer is shown in the darker green region.
   d) Both students can see what the other thinks of their answer.
   e) Both students can amend the answers that they think they did wrong.
   f) Click the final Submit button.
   g) The system will check the answers.
      - Correct answers are indicated in green.
      - Incorrect answers are indicated in red.
5. [Follow-up] Before working on the next problem, the platform will use a recommendation system to suggest other problems as follow-up questions students can use to improve their math drill skills.
   a) Both students will do the same follow-up questions and learn from them.
6. [Open-ended Question] To provide more than a short and fixed response, open-ended questions are also added in the platform. Students get a comprehensive review of the whole question and see how to get the answers and reinterpret the results.

Step 1 allows two players to join an educational game activity. Step 2 introduces the initial tasks for solving Calculus problems. Steps 3 and 4 are for making role changes between student and teacher, and letting peers participate in a learning process without pressure. Steps 5 and 6 provide an opportunity for users to do another learning activity whenever they want to return to the knowledge point and polish their skills. Adjacency pair: Adjacency pairs are used for starting and closing a conversation and moves in conversations. To this end, a case study is presented below.

3. Discussion

Figure 1. Inserting corresponding mathematical expressions and answers inside the Spatial Metaverse chat box.

Figure 1 shows a snapshot of May and Howard as players solving a calculus problem in the Metaverse. The left screen workspace is for May while the right screen workspace is for Howard. Using their own computers, they both inserted corresponding mathematical expressions and answers inside the Spatial Metaverse chat box, as shown by the text messages on the right-hand side of the snapshot.

Figure 2. Illustration of an effective follow-up response from Step 1 to Step 6.

Turn-taking and Sequential positioning: Figure 2 shows illustrations of sequences of the IREFFo pattern activities from Step 1 to Step 6 when a pair of students, "John and David", solved integration problems. In Figure 2, the questions provided assist students in clarifying or extending an understanding of the properties of the definite integral, e.g., 1. the value of a definite integral remains unchanged if its variable is replaced by any other symbol, 2. by the interchange in the limits of the definite integral, the sign of the integral is changed, 3. by decomposing the integration interval, the additive integral is formed. These questions are classified as types of factual questions. Steps 4c and 4g in both figures show that two students were taking turns checking their opponents and students learned from one other and through the IREFFo pattern activities. **Adjacency pair**: Table 1 lists some of John and David's dialogue, illustrating some adjacency pairs features, e.g., greeting/greeting, question/answer, offer/accept, and complaint/denial. These triadic (student-computer-student) dialogues between students and the C3 platform enhanced students' problem-solving skills as well as their dynamic discussion through the sequence of the activity.

4. Conclusion

The aim of this work has been to share the way the Spatial Metaverse as the mediator could be used in mathematical teaching and learning allowing a virtual display and classroom that could support students' mathematical thinking training and learning. In this regard, for online teaching and learning purposes, the triadic experience may be considered useful in various ways, such as by bringing a bidirectional element of design and creativity in the well-planned worked problems when different questioning types are considered and the IREFFo pattern is used. The experience using turn-taking, sequential positioning and adjacency pairs led to the opportunity to gauge the students' learning abilities when working with an online Calculus platform. Typically, the online C3 platform together with the Spatial Metaverse allows dynamic interaction and promotes an expansion of the mathematical thinking process in terms of numeric, algebraic and graphical representation at that time. Future studies are: 1. To collect more dialogue from students and classify what types of adjacency pairs often used and what kinds of Calculus problems they solve; 2. To arrange an online or offline direct teacher and student discussion after students have finished all the follow-up questions, e.g., teachers will review their correct and incorrect answers and guide them to improve their problem solving skills.

Table 2. Some of John and David's dialogue, which is classified as an adjacency pair process.

John	David	Adjacency pairs
Good afternoon!		Greeting/greeting!
	Good afternoon!	
Let's play the game with 6 coins.		Request/grant
	Good idea!	
I would like to give you the opportunity to start first. Is that ok?		Offer/accept
	Sure!	
	Arrr! I almost won.	
Good game!		
	Ok let's do the integration problem now.	Request/grant
Let's go!		
	Umm. How can we distinguish the upper limit and the lower limit?	Question/answer
The upper limit is on top and the lower limit is at the bottom.		
I've done my part. Please click your confirm button.		Instruct/reject
	I haven't done my part yet.	
	My question is longer than yours. Please be patient.	Complaint/Apology
Ohhhh sorry for being impatient.		
	It's fine!	
	Ok! I've done my part.	
I think you've made a mistake here.		Challenge/acceptance
	Really? Let me see…	
	Where is my mistake?	Question/answer
One pair of your upper limit and lower limit is switched.		
	Oh, that's true! You are a careful guy. Thanks!	Compliment/acceptance
It's my pleasure!		
	Playing with you is fun. See you next time!	Degreeting/degreeting
See you!		

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探索啟發式學習的無限可能：

結合教育元宇宙與實地考察的互動，共創可持續發展海洋生態未來

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【摘要】教育元宇宙是指在通過利用元宇宙技術而創建的虛實融合的場景中進行學生教育活動，實現悅趣化學習。透過虛擬和實際環境的整合，元宇宙可以為學生提供沉浸式的互動學習體驗，提供具有吸引力和意義的創新的教育體驗。本文總結校本元宇宙教育計劃「Discover²se—Metaverse in Education」，配合可持續發展生態課程，結合實地考察活動及運用 Minecraft Education 創建海洋虛擬場景為學生提供無法在實際世界中進行的教育體驗，如浮潛和實踐創意海洋生態保育方法等，增加學生合作和互動的 機會，促進教育的多樣性和包容性，並整理有關元宇宙的相關文獻，提供元宇宙與小學教育的規畫建議，期望能夠提升教育工作者對元宇宙應用於學與教的認知。

【關鍵字】元宇宙;教育創新; 可持續發展海洋生態;虛擬實境;實地考察

1. 「Discover2se – Metaverse in Education」計劃源起—及早認知，裝備未來

計劃的構思源自於香港教師、學者的討論，為了讓學生及早認知未來及作出準備，透過「元宇宙」的多元經歷，培養數碼素養及「元宇宙」價值觀。學生身處 Metaverse 的世代，學習在元宇宙自處，掌握在虛擬世界的溝通協作技能和應有態度、學習保護個人私隱同尊重知識產權。更進一步，擴闊學生視野，除了學習履行世界公民的責任，更要肩負數碼公民的身份，認識自己在「元宇宙」充當的角色，及早認知未來，裝備自己。

圖 1 「Discover2se – Metaverse in Education」計劃啟動禮

圖 2 學生展示元宇宙設計的作品

2. 計劃內容—關注可持續發展，培育負責任的世界公民

計劃由香港 6 間小學與科技、娛樂及教育企業合作，共同開發，運用 Minecraft Education Edition 進行沉浸式學習，培育學生的可持續發展思維。讓學生在學習海洋與保育知識的同時，體驗元宇宙的環境中創造和協作。第一期計劃應用了元宇宙 Metaverse 的互聯網特性及虛擬實體的概念，以聯合國 17 個可持續發展目標中的第 14 項—「保護和可持續利用海洋和海洋

資源以促進可持續發展」為主題，以問題導向學習法（problem-based learning）的方式引導學生探索議題，以問題導向學習法(Problem-based learning)為基礎，利用海洋生物瀕臨絕種的真實案例，引對學生搜尋及閱讀資料，以「評估知識」 (assess)、「獲得知識」 (acquire)找出海洋生物瀕臨絕種的原因，「分享知識」 (share)激發學生利用「元宇宙」Minecraft Education 建構、實現保育創意構想，解決問題，以提升學生的海洋保育意識及解難能力，宣揚保育意識，讓未來的主人翁意識到生態永續發展的重要性。

圖 3 VR 觀看海洋生物的美態及污染情況

圖 4 分享海洋生物瀕臨絕種的原因及解決方法

圖 5 計劃結合五年級課題，配合專家訪問，引導學生評估、修正解決方案

3. 未來教育的啟示—虛擬與現實的有機結合

經濟合作暨發展組織（OECD）發佈《回到教育的未來：經合組織關於學校教育的四種圖景》（Back to the Future of Education: Four OECD Scenarios for Schooling）報告中提出未來學校應具備學校教育擴展（schooling extended）、教育外包（education outsourced）、學校作為學習中心（schools as learning hubs）、無邊界學習（learn as you go）的元素。本計劃連繫了教育界的持分者及公司夥伴，匯聚了各範疇有志於教育的機構和專家，負責課程相關專業的範疇，一起運用他們的專業，共同於平台上創建知識和內容，當中產生協同效應絕不是傳統教育模式可比擬。計劃可以豐富學生學習經歷，揭開元宇宙神祕的面紗，讓學生善用科技於學習。由海洋公園規劃全方位實地考察，讓學生產生同理心；由海洋公園專家線上訪談，以掌握準確、專業的海洋知識；由老師引導學生建構學習內容、訓練訪問及匯報技巧等，讓學生了解各海洋生物面對的挑戰及困難，再以小組合作學習的形式，在科技公司技術人員的指導下利用 Minecraft Education 建構，實現保育創意構想；透過元宇宙分享交流，宣揚保育意識，培育具有原始創新能力的人才。

圖 6 實地考察活動

圖 7 參與淨灘活動，認識海洋垃圾來源

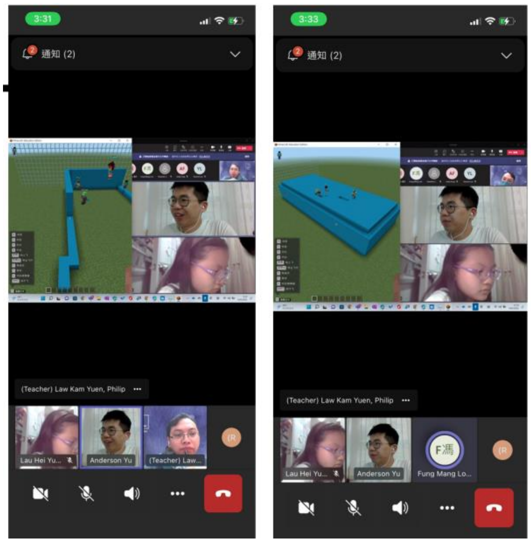

圖 8 科技公司指導學生在元宇宙進行創建

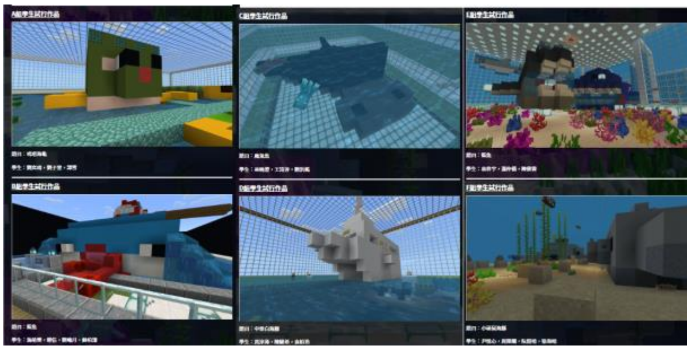

圖 9 學生元宇宙作品示例

4. 計劃推行的困難與展望

個別學生對數位平台非常熟悉，推行的過程中亦有家長反映子女過份投入於創建之中，有沉迷數位遊戲的情況，故教學過程中，如何提升學生的資訊素養和自我規範能是重要的命題。宜多作檢視，提示學生聚焦學習重點，巡視了解學習情況，讓家長知悉活動安排有其必要。計劃期望讓學生體驗在元宇宙的環境中創造和協作，唯在計劃推行過程中，因加上各校創建主題及進度的分歧、數位平台安全性限制更新，以致出現滯後。期望在第二期計劃得到改善。「創新重視勇於嘗試，但不能指望一蹴即就；創新也重視經驗共享，方能達至共同建構新知識，趨向完善。」科技發展日新月異，再加上全球一體化的趨勢，作為教育工作者更應致力推動創新教育，教育創新，從小讓學生數碼充權，為發展香港成為國際創新科技中心奠下穩健的基石，推動香港創科教育的前進。

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The Possibilities of Inquiry-based Learning
—— Integrating the Educational Metaverse Discover2se and Field Trips to Create a Sustainable Marine Ecological System

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Abstract: *Educational Metaverse is a three-dimensional virtual world that integrates aspects of online gaming, social media, virtual reality (VR), and augmented reality (AR) to create a space where students can interact virtually. Metaverse creates an enjoyable virtual learning environment that enables experimentation with hard-to-create phenomena. Through the integration of virtual and field experiences, Metaverse can provide students with an immersive and interactive learning experience, providing an innovative educational experience that is engaging and meaningful. This article summarizes the school-based metaverse education program "Discover²se—Metaverse in Education", which contains field trips and uses Minecraft Education to create a virtual world to promote safety in a way that real-world teaching simply cannot, such as scuba diving, etc. Educational Metaverse increases engagement in learning activities. The analysis of program provides planning suggestions for metaverse education in primary school. To improve Educators' understanding of metaverse as applied to learning and teaching.*

Keywords: *metaverse, innovation, cognition, virtual reality, field-based learning*

Metaverse as a Technological Innovation in the Educational Field

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Abstract: *The metaverse is a technology that pursues the emulation of the real world through the combination of technologies such as augmented reality, virtual reality, and artificial intelligence, among others. One of the most promising applications of the metaverse lies in the educational field, especially given the relevance of online education. To investigate current perspectives on the use of the metaverse for educational purposes, as well as the advantages and challenges affecting its application, we conducted a preliminary literature review of the most recent research on the topic. During this qualitative analysis, we found gamification to be a key paradigm that facilitates metaverse-based education. On the other hand, we identified two new key concerns regarding the implementation of this technology: (1) the interference between AI and the teacher, which may render the latter irrelevant or even unnecessary; and (2) privacy loss, as users may be subject to active monitoring without their consent. Altogether, the metaverse has great potential towards transforming educational paradigms, being it crucial to further study and address the challenges identified.*

Keywords: metaverse, education, gamification, online education, innovation

1. Introduction

The concept of the metaverse refers to a shared and immersive virtual world characterized by a three-dimensional space in which users can interact with each other and with the environment similarly as they would in the real world (Shen, 2022; Felip, 2023). There are three main characteristics to differentiate a metaverse from traditional AR or VR, they are: (1) shared (enables interaction in a virtual world in real-time); (2) persistent, (allows users to create, experiment, and save virtual experiences that remain online); and (3) decentralized (Hwang & Chien, 2022).

Metaverses have been identified as the next stage of social interaction, understood as constructed universes in which individuals can live following the rules set up by the creator, where virtuality and reality coexist and coevolve, and where social, economic, and cultural activities take place (Kye et al., 2021). Real individuals or virtual characters may be friends in the metaverse (Márquez et al., 2020; Kye et al., 2021), and individuals can interact socially by keeping conversations, working together on projects, playing games, and learning from their successes and mistakes (Jovanovic & Milosavljevic, 2022; Park & Kim, 2022). Like in the real world, there can be numerous types of events in the metaverse, such as political decisions, natural disasters, or economic activities (Márquez et al., 2020).

Given their characteristics, metaverses constitute a perfect example of how technology can expand human perspectives and create new opportunities for an infinity of applications, including educational purposes. When used as a tool in online education, metaverses enable students to experiment in an immersive 3D environment. This could include simulations, virtual field trips, and collaborative projects that require students to work together in a shared space (Chen, 2022). Another potential application of the metaverse in education is to create personalized learning environments that adapt to the needs and preferences of individual learners, in other words, an AI-powered virtual tutor can adapt the curriculum to match the student's learning pace, interests, and abilities (Hurtado, et al., 2022, Díaz et al.,2020).

There are also challenges associated with the metaverse in education, such as ensuring the security and privacy of user data, preventing cyberbullying and harassment, and ensuring that all learners have access to the necessary technology and digital literacy skills to fully participate (Codina, 2023). Additionally, it is important to consider how the metaverse can complement rather than replace traditional classroom-based learning, and how to ensure that learners are not isolated from real-world social interactions. Other authors have highlighted concerns regarding the scalability and interoperability of the metaverse due to the large amount of data this technology stores (Wang et al., 2022).

The present article aims to review the existing literature about the use of the metaverse as a technological innovation in the educational field, without focusing on criticism, but without disregarding this concern.

2. Materials and Methods

We performed an intensive search through the repositories Elsevier, SciELO, and Redalyc. The following keywords from DeCS were used: “metaverse” and “education”, and their equivalent in Spanish, “metaverso” and “educación”, respectively. Only results that included both terms were selected. Publication language was considered a non-delimiting criterion. To provide more clarity and quality assurance about the article selection process, we employed the PRISMA Flow Diagram. Article selection criteria were applied as follows:

Inclusion criteria:

- Original scientific articles published between 2017 and 2022 (new research area).
- Scientific articles that include perspectives about the metaverse and its educational use.
- Full open-access scientific articles.

Exclusion criteria:

- Articles published in non-indexed journals.
- Undergraduate, postgraduate, Master, or Ph.D. theses.
- Articles published in 2017 or prior, following the recommendations of the ISO 11620 for systematic reviews.
- Articles exclusively focused on the metaverse, without considering the educational field.

3. Results

The following PRISMA Flow Diagram *(Figure 1)* illustrates the article selection process followed for this review.

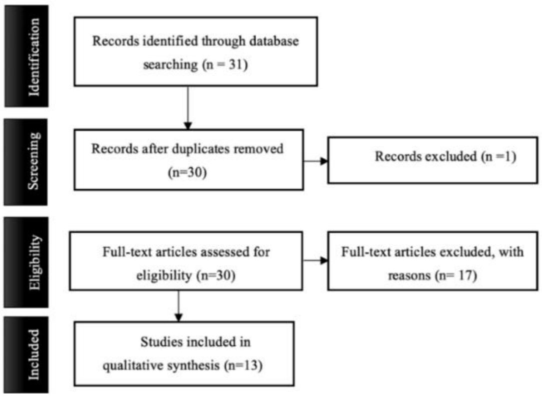

Figure 1. PRISMA Flow Diagram.

3.1. Gamification and the metaverse in the educational field

Some of the works reviewed (n=6) mention the concept of gamification, that is, the use of strategies oriented towards promoting learning thanks to the educational elements present in games, which has been implemented for a decade (Contreras Espinosa, 2016). Gamification increases the compromise and the interaction of the student during online courses (Jovanović & Milosavljević, 2022). However, gamification now seems to require immersion in the virtual world (Gallastegui, 2018; Hwang & Chien, 2022; Park & Kim, 2022).

Gamification can be exploited in any of the two immersive levels of the metaverse: (1) interaction, and (2) representation, and may be incorporated to improve student motivation, which may as well lead to more effective learning and better long-term knowledge retention (Gallastegui, 2018). Teachers may use VR and AR to combine game-based learning efforts, promoting learning through interactive simulations and the practice of skills in controlled environments. Classrooms (physical and virtual) become more vibrant when including games. This combination of technologies also awakens interest and curiosity and promotes learning (Chen, 2022; Park & Kim, 2022).

3.2. Advantages of the use of the metaverse in education

Several authors (n=7) mention the advantages of the use of the metaverse for educational purposes. In the metaverse, common standards are demolished, and individuals can create avatars that represent them as they are in the real world, but also depict them as any animal or creature they feel identified or represented (Abarca & Llamas, 2022; Da Silva, & Villamar, 2021). While students are in an immersive environment, they may experiment with different roles and characters (Hwang & Chien, 2022), which may improve their ability to empathize and understand different perspectives. It may also promote more freedom of expression and creativity in the learning process. The use of 3D images seems to promote immersion, previously reported in the fields of Anatomy (Menezes et al., 2019) and Engineering (Ochoa & Ortíz, 2018). Recent research by Dwivedi et al. (2022) highlights that the use of the metaverse in education can reduce costs and improve the efficiency of educational programs. Immersion in virtual spaces may be more attractive and accessible for the new generations, who grew up surrounded by technology and social network interactivity. This may open new opportunities for education and learning, as well as for new horizons in creating educational and economic models. Lastly, Garzón (2022) mentions that the interest in the use of the metaverse in the educational field is growing, as shown by the increasing amount of content creation and viewing in relation to this topic on other platforms, such as YouTube.

3.3. Limitations for the use of the metaverse in education

Some works (n=6) mention a certain set of limitations or characteristics that may affect the implementation of metaverse-based education. It is widely accepted that one of the general characteristics of the metaverse is that it breaks down the barrier between what is real and what is digital, theoretically leading to a unique and indivisible world (Inceoglu & Ciloglugil, 2022). Among the problems the use of the metaverse may encounter in the educational field, some authors highlight the interference between AI and the figure of the teacher (Dwivedi et al., 2022; Chen, 2022), progressively making the role of the latter somewhat irrelevant and unnecessary, as AI is updated with programming, evolving and learning by itself (Hwang & Chien, 2022; Mejía, et al., 2022), being able to update and produce content and activities in a faster and more efficient manner. Other authors (Falchuk et al., 2018) remark on the privacy loss issue, both due to the direct publication of user data and the mere individual presence in the virtual world.

4. Discussion

The perception of games and their relationship with learning have evolved with time (Contreras, 2016). Games now include certain characteristics, such as the type of content, and the personal and immersive experiences (Gallastegui, 2018), that contribute to a new view of gamification as an effective and immersive educational strategy (Dwivedi et al., 2022) that increases the compromise and interaction level of students (Jovanovic & Milosavljevic, 2022) and improves motivation, leading to more effective learning and knowledge retention (Gallastegui, 2018). In contrast, one potential disadvantage is that game-based learning may not always provide a fully realistic simulation of real-world scenarios (Álvarez et al., 2022). While games can simulate some aspects of a situation, they may not accurately capture all the variables or nuances of a real-world scenario (Hurtado, et al., 2022). This can limit the effectiveness of game-based learning in preparing students for real-life situations. By allowing students to participate in an active community and experience an enriching virtual culture, game-based learning may provide a unique and effective educational experience (Contreras, 2016), which creates a secure and low-risk setting for students to try new things and make errors, enabling them to learn from their mistakes without the worry of negative outcomes. As a result, it may boost their self-assurance and drive, leading to improved learning achievements (Codina, 2023). Immersion in the virtual world represents the natural next step of gamification in the educational field (Gallastegui, 2018; Hwang & Chien, 2022; Park & Kim, 2022) and the metaverse is a key tool to this end, favored by the current technological convergence (Park & Kim, 2022). This synergy would render the integration of knowledge and entertainment (Park & Kim, 2022) and lead to more vibrant learning environments that promote interest and curiosity (Chen, 2022).

Allowing individuals to interact and explore a virtual world in the first person through an avatar (Abarca & Llamas, 2022; Da Silva & Villamar, 2021) instead of merely looking at a screen creates a more immersive experience and allows experimentation with different roles (Hwang & Chien, 2022), which may translate into an increase in the ability to empathize and understand others that promotes freedom of expression and creativity while learning. The immersion level the metaverse offers in a conceptual and semiotic world beyond what is possible with any other technology, providing individuals with a feeling of presence and connection with other users in a real and exciting manner. When applied to education (Menezes et al., 2019; Ochoa & Ortíz, 2018; Garzón, 2022), this first-person experience has been shown to increase the comprehensive abilities of students (Dwivedi et al., 2022). Furthermore, it is important to note that game-based learning may not be suitable for all learning objectives and subjects. While it can be an effective tool for imparting certain skills and concepts, it may not be the most suitable approach for other subjects or learning objectives (Caicedo, 2022).

It should be noted that game-based learning may not be within reach or economical for all students, particularly those who come from low-income or underprivileged backgrounds (Hurtado, et al., 2022). Developing and implementing game-based learning programs can be very costly, and not all students may have access to the technology or equipment required to participate. Building a metaverse, regardless of whether for educational purposes or not, entails challenges (Falchuk et al., 2018). Besides the general ethical concerns regarding the metaverse highlighted by Molina (2022), implies current challenges in relation to sustainability, security, and safety (Dwivedi et al., 2022), and a lack of adequate technological support (Wiederhold, 2022). As it has been stated, for a metaverse to truly replicate the real world, existing technology would require significant upgrades in the areas of cloud computing, AI, and powerful networks, (Wiederhold, 2022).

This review has allowed us to identify two new key barriers affecting the use of the metaverse in the educational field: (1) the interference between the teacher and AI, and (2) privacy loss. AI may represent a threat to the role of the teacher due to its efficiency and the ability to autonomously learn and personalize content depending on the student´s needs, which may render the teacher´s role irrelevant or eventually even unnecessary (Dwivedi et al., 2022; Chen, 2022; Hwang & Chien, 2022; Mejía et al., 2022).

Nevertheless, from a constructivist point of view, the direct interaction of students 24/7 with an artificial agent may be valuable for the educational process. It may even surpass traditional teachers and improve the efficiency of learning, and mutual help among users through consistent interaction which may help them overcome their doubts while studying. On the other hand, loss of privacy is a significant concern about the metaverse, as users may be exposed to monitoring without their consent (Falchuk et al., 2018) as mentioned earlier by the owners of the platform or third parties. Therefore, as this technology advances, it would be crucial to study and evaluate its effect on society and put measures in place to avoid undesirable impacts.

5. Conclusions

The metaverse holds great potential for revolutionizing the way we approach education. It offers new ways of teaching and learning that are more immersive, engaging, and personalized. However, there are several crucial matters that need to be addressed before metaverse-based education can become a reality. Technological advances are needed to ensure that the metaverse is accessible to all learners and that it can provide a seamless and high-quality learning experience. Two key concerns regarding the implementation of metaverse technology for educational purposes are the potential interference between AI and the role of the teacher, and the risk of privacy loss, especially for under-age students. Further research is needed to better understand these issues and develop effective strategies to address them. An acceptability study among teachers and students can also provide valuable insights into the potential and utility of the metaverse within the educational field. In conclusion, while the metaverse holds great promise for the future of education, it is important to approach its development with caution and care, considering the potential risks and challenges as well as the opportunities for innovation and improvement.

However, we believe that the development of metaverse technology provides society with a new sense of imagination, and its possible applications in the educational field will revolutionize how education is delivered, improve the efficacy of both teaching and learning, and open a new world of opportunities and perspectives for students, educators, and the educational sector through more immersive experiences.

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聲音單元 VR 教材開發之使用者滿意度個案研究

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【摘要】 虛擬實境教材的設計與開發，是近年因應元宇宙議題與 5G 新科技潮流所備受矚目的領域。隨著政府推動 5G 新科技融入教學之策略，各教育領域對於使用數位學習優勢改善傳統教學之需求應運而生，也因此使虛擬實境教材內容設計與系統使用感受度顯得格外重要。本研究以 K-12 的教師端教學需求為基礎，依據 ADDIE 模式，設計開發一項自然領域的聲音單元教材，並使用準實驗研究法及問卷調查法，與國小端合作入校施測，進行使用者滿意度之研究，以此檢視本教材的製作適用於國小學習者，並確實能夠提升其學習意願。

【關鍵字】 虛擬實境；使用者滿意度；教材開發；聲音

1. 研究背景與動機

近年來 Web 3.0 與元宇宙的投資迅速增長（Kshetri, 2022），元宇宙議題及 5G 新科技潮流盛行，技術的發展改變了社會運作方式，以及消費者之間的互動模式（Mishra et al., 2020）。而數位學習領域的研究亦正快速發展，特別是 covid -19 大流行後，教育領域的應用成為目前極為重要的事情（Mastan, 2022）。有鑑於此，虛擬實境（Virtual Reality,VR）教材的設計與開發需求與日俱增，教材內容的設計與系統使用的感受度顯得愈發重要。而本研究依據此階段的教學現場所需，進入國小校園進行觀察與討論，以 108 課綱內自然科中的聲音學習單元為主題，根據「聲音傳播原理太抽象」、「各式聲音蒐集不易」等需求，開發能夠適用於小學各版本的 VR 教材，並於開發完成後進行使用者滿意度之研究，以檢測本研究開發之教材的優勢，與可供他人作為修改借鏡之處。

2. 研究方法與流程

本研究透過「深度訪談法（in-depth interview）」進入國小校園與教師對話，瞭解其真實之課堂需求。之後再以 Branch（2010）所提出之 ADDIE 模式進行 VR 教材設計與開發，待開發完成後透過「準實驗研究法（Experimental Research）」與「問卷調查法（Questionnaire Survey）」，將開發完成之聲音單元 VR 教材以問卷及測驗之方式，進行使用者滿意度問卷調查，並就分析資料提出結論與建議。

圖 1 進入國小校園與教師對話

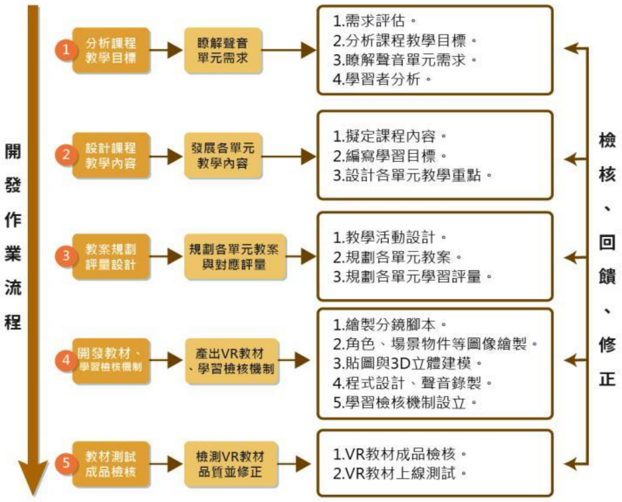

圖 2 以 ADDIE 模式進行本 VR 教材設計與開發

3. VR 教材開發與設計

本教材學習關卡的設置，透過森林、馬路與海邊場景的轉換，讓學習者在 VR 教材內身處不同環境、聆聽各式聲音，並且透過 VR 控制器把手的操作，一手收集聲音，一手能夠查詢資訊面板。因為學習歷程記錄具有很好的潛力，能夠提高學生對課程內容的興趣和參與度（Chris, 2010），因此本教材設計除了能就已收集之物件認識其發聲的原理，亦可透過資訊面板上的進度條機制，得知學生的學習體驗進度。

圖 3 聲音單元 VR 教材之森林、馬路與海邊場景的關卡操作畫面

本 VR 教材的開發製作透過 Unity 跨平台工具，創建虛擬實境，結合 C#程式來建構教材發展所需之互動設計內容。3D 立體模型則以 Blender 軟體製作，並透過 Substance Painter 進行模型的材質貼圖；2D 平面以 Adobe Photoshop 與 Clip Studio Paint 繪製圖像製作素材。並且利用 Adobe Illustrator 進行介面設計之排版。本教材在開發過程中經過多次測試與優化，搭配合作小學教師與相關專家評測，改善增加手部收音動作的直覺性引導、文字引導，以及設置路線限制等，力求系統操作體驗流暢。

4. 研究結果與分析

本研究使用教材滿意度量表，於 2022 年底進入國小校園進行本 VR 教材的實驗，在滿意度的部分，總共收回 37 份問卷，根據量表回饋數據分析，我們將各題分數加總並計算出每題的平均得分，並將結果繪製為長條圖（圖 4）。

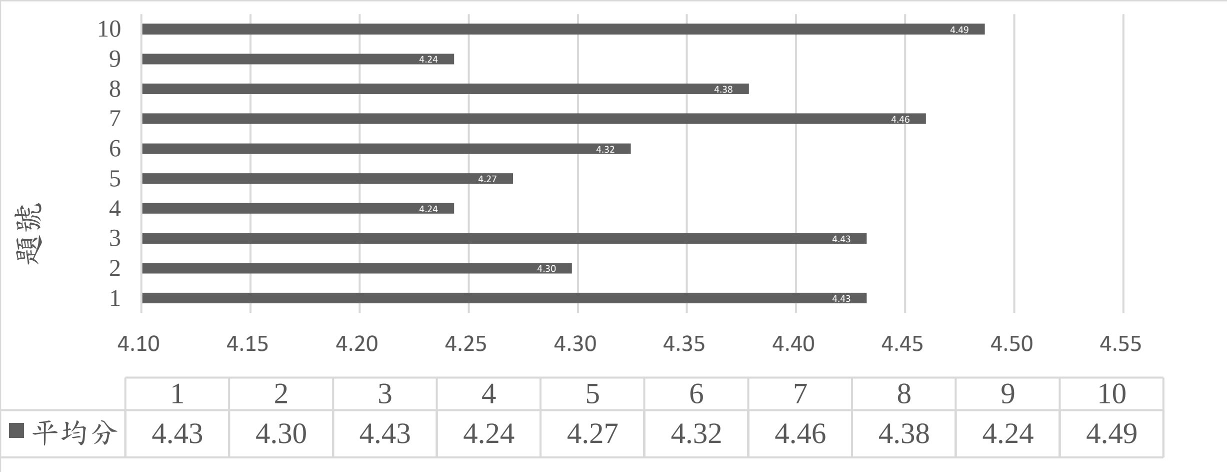

圖 4 教材滿意度調查長條圖

從圖 4 能夠發現，每一題的平均分都超過 4 分，顯示整體的滿意度是高於平均值的，而十項題目內平均最低分 4.24 分的部分落在第四題與第九題的「使用此份教材讓學習變得更有效率」與「此教材提供我具體情境進行學習互動」；最高分落在第十題平均分 4.49 的「我願意推薦此份教材給其他人使用」。經過觀察與事後訪談的結果，推測回饋分數較低之原因，為部分學童因不熟悉硬體使用，導致使用教材時花費較多時間處理設備問題，因而壓縮到學生操作教材學習的時間，亦造成部分學生體驗時程不足，從而沉浸感受不佳。但整體來說，本 VR 教材回饋滿意度是高的，國小學童們也願意推薦且繼續使用。

在質性回饋部分，我們將所有體驗對象的建議與反饋彙整於表 1，從內容面向來看，在介面與媒體部分的反應數量相對是較多的，而教學設計與內容部分多數是符合使用者需求的。

表 1 質性回饋內容彙整表

對象	質性回饋內容	內容面向
學習者	第一關的山豬好大跟我一樣高！突然衝出來好可怕！我來不及收集他的聲音。	介面與媒體
	我有收集到四個聲音了，還想繼續體驗，老師我還可以再玩嗎？	教學設計
	前面的說明講好慢。	介面與媒體
	字有點看不清楚耶！	介面與媒體
教學者	教材的內容很棒，小朋友充滿好奇心很願意體驗，對引起教學動機滿有幫助的。	教學設計
	建議後面題目可加入更多聽音辨識的題目，比起文字敘述的考題會更加活潑，且符合讓小朋友認識該關卡音色的學習目標。	教材內容
	每關卡的新手引導是否能新增「跳過」按鈕，這樣可節省第一次之後的教學時間。	介面與媒體
專家顧問	除了開頭遊戲說明，建議過程中若使用者頻繁出錯或沒有動作時可以增加提示引導。	教學設計
	教材內的旁白語速要再評估看看，目前測試感覺較慢，要觀察國小生對象是否會沒耐心聆聽學習。	介面與媒體
	關卡內移動方式需要調整，小朋友操作不易。	介面與媒體

5. 研究結論與建議

本研究開發透過 VR 將聲音的震動具體化，解決了聲音傳播原理太抽象之問題需求，並且透過 VR 的沉浸式體驗特性，模擬場景聲臨其境，解決各式聲音蒐集不易的困境。根據前章所蒐集之量化與質化資料，得知多數體驗者針對聲音單元 VR 教材的體驗都給與極高的評價，並且表示若未來還有機會的話，會想要體驗更多的課程主題。使用滿意度高之主因包括：虛擬教材學習方式新穎、有趣，且能夠不受限於場域與時間，隨時體驗生活中不常聽見之聲音。研究建議的部分，我們得出可進一步修正之處，為各關卡的資訊欄位（左手把面板）之辨識度，因本研究開發時為了將知識內容全部置入，因此教材內字體較小且壅擠，經多位使用者反應不好閱讀、尋找答案吃力。因此未來建議開發者在設計 VR 教材時，應多注意教材文字尺寸，以增加辨識度與閱讀舒適度，以此更加提升使用者之滿意度。

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A Case Study on User Satisfaction in the Development of VR Teaching Materials Related to Sound Units

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Abstract: *The development of VR teaching materials is an area that has attracted much attention in response to metaverse issues and the trend of 5G new technology in recent years. There is a demand in various education fields to use the advantages of digital learning to improve traditional teaching. This study is based on the teaching needs of K-12 teachers, and according to the ADDIE model, develops a sound unit teaching material in the natural field. Research on user satisfaction, in order to check that the production of VR teaching materials is suitable for elementary school learners.*

Keywords: virtual reality, user satisfaction, teaching material development, sound

Chang, M., Looi, C. K., Biswas, G., Erni, J. N. (2023). Proceedings of The 1st International Conference on Metaverse and Artificial Companions in Education and Society (MetaACES 2023).
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Investigating Students' Epistemic Beliefs in Augmented Reality-based Inquiry learning environment

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Abstract: *The effects of AR-supported science learning on the cognitive domain have been documented, but findings on the effect of AR on the improvement of students' academic performance are not conclusive. Additionally, though epistemic beliefs have been identified as a significant determinant of student learning outcomes, few AR-supported science learning studies have explored the effectiveness of AR activities on students' epistemic beliefs. This study examines the relationship between students' engagement in the AR-based inquiry learning environment and their epistemic beliefs, particularly, if students' engagement in the AR activities had an impact on their epistemic beliefs and academic performance and which aspects of students' epistemic beliefs might be impacted by the activities. A total of 159 primary 5 students participated in the AR activities for two months. Findings indicated that students' academic performance improved significantly as evidenced in the pre- and post-tests. Students' perceived engagement had no significant effect on their academic performance, but students' perceived engagement in the activities influenced their epistemic beliefs, particularly in the dimension of justification of knowledge in science. The findings can help AR learning designers better understand how the learning environment can be optimally designed to better engage students in argumentation and reflective learning.*

Keywords: Augmented reality, Inquiry-based learning, Science learning, Epistemic beliefs, Primary school

1. Introduction

Augmented reality (AR) is a technology where digital information is superimposed over a real-world environment. When AR is used in teaching and learning, it helps to add digital elements to real-world non- digital settings in a planned and synergistic way to support different forms of learning (Wen, 2021). The pedagogical affordances of AR for science learning have been evidenced, including increasing conceptual understanding by the visualisation of invisible or abstract concepts (e.g., Dunleavy, 2014) or encouraging scientific inquiry by manipulating and learning in 3D perspectives (e.g., Squire & Klopfer, 2007). Meanwhile, many studies have shown that AR helps to stimulate positive emotions in learning (e.g., Pedaste et al., 2020) because of its media characteristics, such as sensory immersion, navigation, and manipulation. The effects of AR-supported science learning on cognitive aspects also have been documented (e.g., Sahin & Yilmaz, 2020; Sırakaya et al., 2020). AR is also found to have potential effects on students' scientific epistemic beliefs. For instance, Cheng (2018) identified relationships between learners' conceptions of learning sciences with the aid of informal learning with AR books and their epistemic beliefs.

Epistemology of science can be conceptualised into different facets. Among them, epistemic beliefs refer to the beliefs that one holds regarding the nature of knowledge and knowing (Conley et al., 2004; Kampa et al., 2016). Researchers have documented the positive impact of epistemic beliefs on conceptual learning, science inquiry, or laboratory practices (Hofer & Pintrich, 2002). Epistemic beliefs are essential to inquiry-based learning, both determining students' learning outcomes (Khaleghinezhad et al., 2012) and potentially being shaped by the inquiry experience (Wang et al., 2022). However, research evidence in support of the latter remains inconsistent (Wang, et al., 2022). For example, Wu and Wu's study (2011) suggested that most fifth-grade students' epistemic beliefs remained at the naïve level after engaging in 5 weeks of inquiry activities. AR may help augment the potential link between inquiry-based learning and epistemic beliefs. However, despite a burgeoning body of literature that evidence how AR may boost the cognitive, metacognitive, motivational, emotional, and collaborative dimensions of inquiry-based learning (Pedaste et al., 2020), little research attention has examined the potential of AR-based inquiry learning activities in influencing learners' epistemic beliefs.

Given the paucity of research on the influence of AR activities on students' scientific epistemic beliefs, and the concomitant influence on students' academic performance (Khaleghinezhad et al., 2012; Wang et al., 2022), this study aims to fill the research gap by examining the relationships between students' perceived efficacy and engagement in the AR-based inquiry learning environment and their scientific epistemic beliefs and academic performance. This study seeks to answer the questions: (1) Do the designed AR-based inquiry learning activities help to promote students' academic performance? (2) What are the relationships among students' perceived efficacy and engagement in the AR-based inquiry activities, students' scientific epistemic beliefs, and their academic performance? The findings of the study may provide some insights into AR learning environment design in science education.

2. Theoretical Background

Research has reported that AR-based inquiry can help to promote student engagement (e.g., Hsu et al., 2017; Wang et al., 2014). For example, Hsu, Lin & Yang (2017) explored perceptions of high-school students' STEM interest through authentic AR-embedded inquiry lessons in the context of medical surgery exploration, and the results revealed that students' engagement in AR lessons was high. Engagement is associated with internal feelings of and cognitive perceptions of the learning environment (Xie et al., 2019), and it can positively impact learning performance (Hamari et al., 2016). It is also suggested that perceived efficacy of the technology-rich activities is positively related to student engagement (Kamarainen et al., 2013). As reported by Kamarainen et al (2013), the combination of AR and environmental probe ware on a field trip was very effective for sixth-grade students, as it invited more group discussion and interaction as students tried to figure things out together. As a result, teachers observed more student engagement and students also reported positive gains in their affective survey. Hence, we hypothesise:

H1: Students' perceived efficacy of AR-based inquiry learning activities (PAR) positively predicts their perceived learning engagement.

H2: Students' perceived learning engagement (PLE) positively predicts their learning outcomes.

Meanwhile, some studies indicated that mature epistemic beliefs can be shaped by learning environment design (Brownlee et al., 2001). Hofer and Pintrich (1997) identified epistemic beliefs in 4 dimensions: source of knowledge, justification for knowing, certainty of knowledge and simplicity of knowledge. These 4-dimensional epistemic beliefs have been widely used in science education studies to investigate the relationships between learners' epistemic beliefs and science learning (Lee et al., 2021). There are also studies investigating specific dimensions of learners' epistemic beliefs and their impacts (Tsai, 2011). As this study focused particularly on the impact of AR-based inquiry learning environment on students' epistemic beliefs in science, we took the sub- dimensions of epistemic beliefs into account and hypothesized that:

H3: Students' PLE is positively related to scientific epistemic beliefs (SEBs) about the "Source" of knowledge. H4: Students' PLE is positively related to SEBs about the "Certainty" of knowledge.

H5: Students' PLE is positively related to SEBs about the "Development" of knowledge. H6: Students' PLE is positively related to SEBs about the "Justification" of knowledge.

H7: Students' SEBs about the "Source" of knowledge are positively related to students' academic performance. H8: Students' SEBs about the "Certainty" of knowledge are positively related to academic performance.

H9: Students' SEBs about the "Development" of knowledge are positively related to academic performance. H10: Students' SEBs about the "Justification" of knowledge are positively related to academic performance.

3. Method

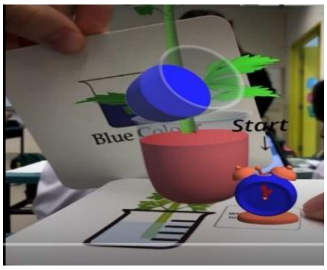
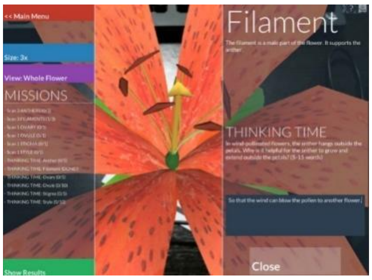
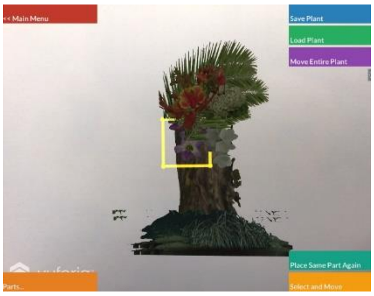
3.1 Research context and participants

The participants of this study were 159 primary 5 students (10 to 12 years old) from a government primary school in Singapore. The students from 4 classes experienced the AR-based inquiry learning activities. The study lasted for two months, and each lesson was between half hour to an hour, depending on the lesson objectives.

The lessons were conducted on the topic of Plants, comprising Plant Transport System and Plant Reproductive System. During the first lesson, the teacher introduced the overarching problem scenario to set the context of their learning – the planet of their alien friends' is dying as they cannot grow plants. Thus, students need to save them with their botanical knowledge. Accompanying these topics are five AR activities – two apps for Plant Transport System (Oil beaker puzzle and Celery lab) and two apps for Plant Reproductive System (Flower Anatomy and Seed dispersal), with the last app to consolidate the entire topic on Plants (Plant engineer). For the Oil Beaker puzzle, the aim is to retrieve treasure stuck in a beaker filled with oil, by applying the principles of capillary action. As for Celery Lab app, students conduct virtual experiments on celery plants to understand the function of food- and water-carrying tubes and observe the changes happening to the plants via real-time animations. In the Flower Anatomy app, students are to locate and scan the main parts of the virtual plant based on a "Mission list". Upon locating each part, students are presented with a textual description of the part, as well as a question for to check their understanding. For the seed dispersal app, students plant fictional plants on a virtual island and watch it grow and disperse. They are to observe the plants' dispersal patterns, and hypothesise which seed is dispersed by wind, water, or explosive action with evidence for their hypothesis. The last app, Plant engineer is meant to capture all previous learning in a single activity as a final consolidation. It provides a summation of students' botanical knowledge, built on a fictional narrative where students have to help aliens to "re-green" their planet, which has harsh weather conditions (e.g., drought; strong winds). As such, students need to apply what they have learnt in the two topics and design a plant to survive and reproduce in these conditions. Thereafter, the students need to present their creations and articulate their scientific explanations.

Table 1. AR-based inquiry learning activities.

Topic 1: Plant Transport System		
AR Apps & learning objectives	**AR-based Activities**	**Examples of the AR environment**
Oil Breaker: Identify food- and water-carrying tubes	• Retrieve treasure stuck in a beaker filled with oil.	

and their functions.		 Pouring the selected colour into the beaker by using a marker
Celery Lab: Apply understanding of capillary action in plants	• Conduct AR experiments with celery stems; • Observe movement of water and food particles in the celery; • Complete quiz	
Topic 2: Plant Reproduction System		
AR Apps & learning objectives	**AR-based Activities**	**Examples of the AR environment**
Flower Anatomy: Identify basic parts of a flower and their functions.	• AR parts of exploration of flower; • Complete quiz.	 Scanning a part of a flower.
Seed dispersal: Explain patterns of water dispersal, wind dispersal and explosive action in plants.	• Plant virtual seeds on an island and observe their dispersal patterns.	 Plants dispersed by wind in a characteristic pattern.
Plant engineer: Consolidate students' learning of all concepts in the two topics	• Create a virtual plant that can grow on the aliens' planet which has harsh weather conditions. • Presentation of plant with corresponding explanations.	 Example of a completed plan model.

3.2 Data sources and Instruments

3.2.1 Pre-and post-tests

Each student took pre-and post-tests measuring learning gains, and post-surveys measuring their perceptions towards the AR activities, learning engagement, as well as epistemological beliefs after experiencing the learning activities. Pre- and Post-tests comprised a total of 13 questions (6 MCQ and 8 open ended) which assessed students' knowledge on plant transport and plant reproduction, with a full score of 20 marks. The students completed the post-test after the intervention and the test questions were the same as the pre-test.

3.2.2 Questionnaires

The post-survey was developed based on existing questionnaires for learning engagement and epistemic beliefs. It consists of 6 scales and 21 items. Items were rated on a 5-point Likert Scale (1 = strongly disagree; 5 = strongly agree). The measurement items on AR activities were self-developed to investigate students' perceptions on the efficacy of the designed AR activities for understanding the topics. Examples are "the animations and pictures in the AR app made me want to explore more about the science topics on my own" and "the tasks in the AR app helped me to understand the given topics."

The measurement items for learning engagement were adapted from Fu et al.'s study (2020) by considering both emotional and cognitive engagement. Example questions are "I stayed with the app till I completed all the tasks" and "Using the AR app to learn science was very absorbing".

The measurement items on epistemic beliefs were adapted from the scientific epistemic beliefs' questionnaire developed by Conley et al. (2004). The questionnaire was used to measure 4 different facets of epistemic beliefs and it is the most frequently used questionnaire for epistemic beliefs (Lee et al., 2021). The four facets are "source of knowing" (e.g., knowledge is given by authority or can be tested); "certainty of knowledge" (e.g. knowledge is static or continuously developing); "simplicity or development of knowledge" (e.g. knowledge is absolute or relative); and "justification of knowing" (e.g. knowledge can be learned from critical thinking processes or from existing facts).

3.2.3 Post study interviews with teachers and students

The researchers conducted observations of the lessons and took notes of the interactions between the teachers and students; students and AR in order to collect data from lesson observations. Post study interviews were also conducted with the students and teachers. 4 teachers from the 4 participating classes were interviewed. The interview with each teacher lasted an hour. We asked about teachers' reflections using AR and perceptions of their teaching beliefs after using AR. We also selected 2 classes and interviewed 3 groups of students. Each group consists of 2 students according to how they were grouped during science lessons. The interview was centred around students' experiences using AR in science learning and lasted 20 mins for each group. All interviews were conducted via zoom due to COVID-19.

3.3 Data Analysis

Paired t-test of the pre- and post-scores were conducted in SPSS 29 to reveal whether the AR-based inquiry learning process contributed positively to learning. The questionnaire responses were analysed using structural equation modelling (SEM), using the learning gains as the endogenous variable and learners' perception of the AR experience, their learning engagement and epistemological beliefs as the exogenous variables, to reveal the working mechanism behind AR experience and the learning gains. CFA and SEM analysis were conducted in AMOS 28, using maximum Likelihood Estimation as the estimation method. The model fit was assessed using the following criteria: RMSEA <0.05, CFI and TLI value close to 0.95, and $\chi 2/df < 2$ (Hu & Bentler, 1999). Additionally, students' interview data was analysed thematically to explain the quantitative findings.

4. Findings

4.1 Students' perception and learning gains from the designed activities

As shown in Table 2, the descriptive analysis of the six constructs showed that the students had positive perceived efficacy of AR-based inquiry learning activities (M = 3.773, SD = .961). Students felt they were engaged in the learning activities (M = 4.062, SD = .832). The findings are consistent with our interview data and observations.

We used open-ended coding to analyse the transcribed interviews to explain the quantitative findings and students' responses revealed how students were engaged in the aspects of: (1) learner control, (2) affective processes. Students could conduct the virtual experiments instead of only seeing a teacher's demonstration and the opportunity to direct their own learning was effective in engaging students. One student explained that despite science not being her favourite subject, she felt more excited and motivated during science lessons while using the iPad with AR. She felt that with AR, learning was clearer as "all the information is already there, so, you can just read from the app, like the information needed". Likewise, her partner shared that with AR, she had the chance for self-exploration, which she preferred, "instead of everyone just giving the answers" as she could understand better. Her classmate said that his favourite app was making the hybrid plant because "It's quite cool, how I can make [what] I like, I can choose how I want my plant to be". Because students felt more motivated and engaged, it had an impact on their affective processes. One teacher felt that students were more excited and that it "generate[d] a lot of discussion, which is usually absent… it actually generate[d] a lot of sharing of ideas and affirmation by friends". She believed that AR improved communication generated between students, because of the AR, and was "the most valuable part". Generally, most students found using AR "fun and interesting". Researchers also observed that students found it "cool" when they could see the AR simulations of abstract science concepts. For instance, when students could see the food and water particles moving in the celery stem, students showed amazement and expressed that "it was so cool", acknowledging that it was something they would not be able to see with the naked eye when observing the actual celery specimens.

Table 2. Descriptive statistics.

	N	Mean	SD
PAR	141	3.773	0.961
PLE	141	4.062	0.832
SEB_ Source	141	3.076	0.857
SEB_ Certainty	141	3.496	0.898
SEB_ Development	141	4.106	0.807
SEB_ Justification	141	4.365	0.730

Statistical results of the pre-test (n = 139, M = 8.953) and the post-test (n = 139, M = 15.155) showed that students' academic performances were improved after intervention. A paired two-sample t-test for means indicated a statistically significant difference between performances on the pre- and post-tests ($t= 19.905$, $p<0.001$). Besides, students showed more sophisticated in their beliefs about the development (M = 4.106; SD = 0.807) and justification of knowledge in science (M = 4.365; SD = 0.730), and comparatively less sophisticated beliefs about the source (M = 3.076; SD = 0.857) and certification of knowledge in science (M = 3.496; SD = 0.898).

4.2 The Working Mechanisms behind the Learning Gains and the AR experience

Table 3. Factor loading and Cronbach's alpha.

	Items	Standardized factor loading	Cronbach's alpha	Composite reliability
PAR	PAR1	.849	.875	.916
	PAR2	.886		
	PAR3	.919		
PLE	PLE1	.789	.817	.83
	PLE2	.724		
	PLE3	.857		

	PLE4	.578		
SEB_ Source	SEBS1	.705	.843	.846
	SEBS2	.799		
	SEBS3	.718		
	SEBS4	.816		
SEB_ Certainty	SEBC1	.677	.707	.706
	SEBC2	.716		
	SEBC3	.606		
SEB_ Development	SEBD1	.749	.827	.828
	SEBD2	.765		
	SEBD3	.839		
SEB_ Justification	SEBJ1	.755	.879	.884
	SEBJ2	.894		
	SEBJ3	.807		
	SEBJ4	.776		

Confirmatory factor analysis (CFA) was conducted to validate the constructs and assess the quality of structural reliabilities. Results of CFA showed that the overall fit of the model is within the threshold ($\chi 2/df = 1.226$, $p <.022$; CFI = 0.975; RMSEA = 0.038; TLI = 0.966). Three to four items remained for each dimension. All the factor loadings of the measured items were statistically significant and higher than 0.60 (see Table 2). The reliability coefficients (Cronbach's alpha) for all the dimensions ranged from 0.707, to 0.879. The composite reliability (CR) coefficient exceeded 0.7 (ranged from 0.768 to 0.916), and the AVE exceeded 0.50. Discriminant validity was tested using the correlation matrix of the constructs and the results are shown in Table 4. The square root of AVE exceeded the bivariate correlations between structs, demonstrating adequate discriminant validity.

Table 4. Discriminant validity.

	PAR	PLE	SEB_Justification	SEB_Development	SEB_Certainty	SEB_Source
PAR	**0.885**					
PLE	0.828	**0.744**				
SEB_Justification	0.329	0.442	**0.810**			
SEB_Development	0.266	0.353	0.750	**0.785**		
SEB_Certainty	0.081	0.056	0.415	0.436	**0.668**	
SEB_Source	0.012	0.015	0.296	0.383	0.805	**0.761**

Structural equation modelling (SEM) was used to evaluate the conceptual model. The conceptual model was tested against the dataset. Then, the link between SEB_Justification and SEB_Development and the link between SEB_Source and SEB_Certainty were added based on modification indices. It has been widely acknowledged that justification and development were correlated to reflect students' sophisticated beliefs, and source and certainty were correlated to reflect students' beliefs about absolutist knowledge and knowledge (Tsai et al., 2011; Chen, 2018). The model yielded the following model fit indices: $\chi 2/df = 1.347$, CFI = 0.956, and RMSEA = 0.047, TLI = 0.944. The indices all met the recommended guidelines (Tabachnick & Fidell, 2013), which suggests that the conceptual model fit the survey data.

The structural model revealed that students' perceived AR-supported inquiry-based learning activities had a significant positive influence on students' perceived learning engagement ($\beta = 0.825$, $p<.001$). Perceived learning engagement positively influenced students' epistemic beliefs in the facet of justification of knowledge ($\beta = 0.440$, $p<.001$). Besides, students' epistemic beliefs in the facet of certainty of knowledge positive influence on students' learning gains (β = 0.702, p< .05). Contrary to the hypotheses, perceived learning engagement did not influence students' epistemic beliefs in the facet of source of knowing (β = 0.025, p> .05), certainty of knowledge (β = 0.062, p> .05) and development of knowledge (β = -0.025, p> .05). Moreover, perceived learning engagement did not influence students' learning gains (β = -0.075, p> .05). Table 5 summarizes the hypothesis testing results of the separate paths in the conceptual model.

Table 5. Hypothesis testing results.

Hypotheses	*β*	t-value	p-value	Decision
H1: PAR → PLE	.825	9.558	< .001	Supported
H2: PLE →Learning Gain	-.075	-.691	.489	Not supported
H3: PLE →SEB_Sources	.025	.259	.796	Not supported
H4: PLE →SEB_Certainty	.062	.774	.439	Not supported
H5: PLE →SEB_Development	-.025	-.322	.747	Not supported
H6: PLE→ SEB_Justification	.440	4.543	< .001	Supported
H7: SEB_Sources→ LearningGain	.443	1.652	.099	Not supported
H8: SEB_Certainty→ LearningGain	.702	2.400	< .05	Supported
H9: SEB_Development→ LearningGain	.115	.648	.517	Not supported
H10: SEB_Justification→ LearningGain	.025	.134	.894	Not supported

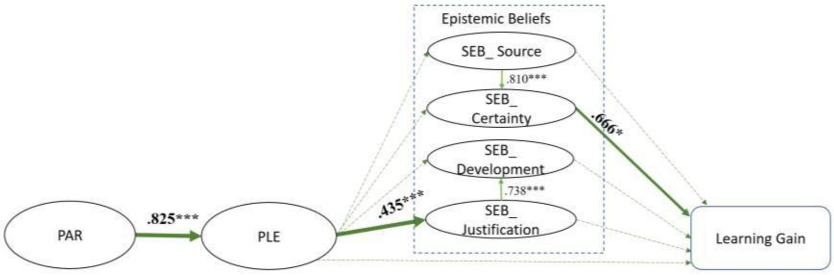


Figure 1. The structural model

5. Discussion

The findings of this study showed that students expressed positive perceptions of the AR-based inquiry learning activities, and they were engaged in the designed activities. Students' academic performance was significantly improved in the post-tests. The findings of the study suggested that the AR activities were generally well-designed. On this basis, we further explored why the designed activities helped to improve students' learning gains, and how the design should be further improved by focusing on students' epistemic beliefs.

The findings showed that students' perceived engagement in the AR-based inquiry activities predicted their epistemic beliefs, with a significant positive association with the dimensions of development and justification of knowledge in science. Conley et al. (2004) revealed that young children's epistemic beliefs about science changed over a few weeks when they were engaged in hands-on science classes (2004). It is worth noticing that, in Conley's study (2004) students did not show significant improvement in the development or justification dimensions of the epistemic beliefs. They argued that it might be caused by less emphasis on argumentation and reflection in the instructions, and an inquiry-based approach may lead to epistemological development in these two dimensions. The findings of our study confirm the assumptions in their study. When students engaged in the AR-based inquiry learning, their epistemic beliefs of justification would be improved, and their epistemic beliefs of development would be improved accordingly.

This study evidenced that students tended to have more sophisticated beliefs that scientific knowledge is contextual and continuously evolving (development) and verified through multiple sources (justification) than beliefs about absolute scientific knowledge (source) and knowledge (certainty) after the AR-based inquiry learning activities. The findings are consistent with Chen's (2018) study on investigating the relationships between students' epistemic beliefs and conceptions of learning science by AR books. On the one hand, this may be because the dimensions of source and certainty were measured by reverse questions in the survey. On the other hand, the findings suggest that the AR learning environment may help to provide learners with more contextual information and multiple sources in nature.

This study found that students' perceived engagement in the AR-based inquiry learning activities had no significant effect on their academic performance. As Radu & Schneider (2019) indicated in their study, AR visualization, regardless of any educational content, influences learner engagement, but the high engagement may be simply due to the exposure to new technology and irrespective of the presence of learning content. The findings of this study indicated that the epistemic beliefs of the dimension of justification did not significantly predict students' academic performance. The findings may reveal that though the designed AR-based inquiry learning activities can help to raise students' awareness that scientific knowledge can be learned from critical thinking processes, there is room for improvement in the design. As we observed, no sufficient questioning, explanations, and argumentation-related interactions took place when students were completing AR-based tasks. AR learning designers should pay more attention to engaging students in argumentation and reflections either individually or in groups, beyond exploration and observations. Instead, epistemic beliefs on certainty positively predicted academic performance. That means students who viewed scientific knowledge as uncertain tend to have better academic performance. This finding is consistent with most of existing studies that students who have sophisticated epistemic beliefs are likely to have better academic performance.

6. Conclusion

This study contributes to the relationships between students' perceived engagement in the AR-based inquiry learning and their epistemic beliefs. The findings suggest that the designed AR activities can help to engage learners, and the engagement is positively related to students' epistemic beliefs particularly in the dimensions of justification of scientific knowledge. Beyond providing learners with an immersive environment for observation, AR learning design should pay more attention to scaffold learners in argumentation and reflections to promote learners from hand-on activities to minds-on activities. There are some limitations of this study. First, we did not include the process data. Hamilton and Duschl (2017) have argued that researchers have turned their interest in personal epistemology to practical epistemology. Our following research will zoom into students' interactions in the AR activities to further expand the findings of this study. Second, the structural model could be improved with a large sample size. Epistemic beliefs have been evidenced to be a factor that influences the way students engage in argumentative discourse and reasoning (e.g., Noroozi, 2016). The interrelationships between engagement and epistemic beliefs could be further tested by considering contextual factors such as students' capabilities or teachers' instructional styles.

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以虛擬實境技術發展情境遊戲重現地方文化導學教材—以國小教育為例

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【摘要】隨著元宇宙空間的進步發展，虛實結合教育打破了既有的空間與時間限制，進而讓知識學習方式變得更深更廣。本研究旨在利用「虛擬實境」結合「情境遊戲」作為教材導學系統輔助國小生，探討國小生於課前實作進行自主學習，對學習過程與興趣是否具顯著差異影響。研究目標針對國小五至六年級學生，在課堂前實施導學教材使用，讓學生進行自主學習，並於課堂中提供隨堂測試了解學生學習進度。本組將使用 Unity 作為設計媒介，融入地方文化背景，以情境遊戲重現教學指標，打造適用教學上的 VR 遊戲導學教材，期望能輔助學生透過此設計奠定跨領域能力與提高學習態度。

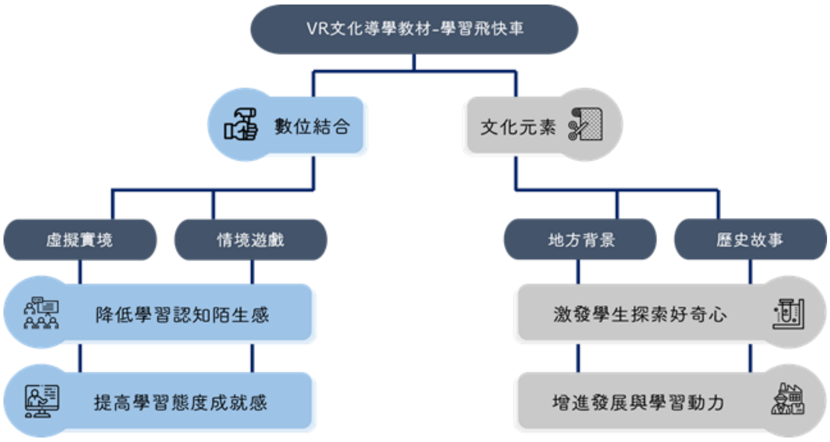
【關鍵詞】虛擬實境；地方文化；自主學習；情境遊戲；導學教育

1. 前言

近年教育發展以將學生培養為自主學習之終身學習者為導向，因應行動通訊技術的發展，虛擬實境成為了擁有更高的傳輸效率可成為輔助學習工具。在學習過程中，教材的易用性為其一重要的元素，因此本研究嘗試開發虛擬實境文化體驗教材，並實地讓國小學童透過虛擬實境頭盔操作文化教材，探討其教材易用性及使用者滿意度。現今經過科技浪潮許多在地文化逐漸面臨被遺忘的問題，如：旗山糖廠的旗尾線，因隨著農產品不再仰賴鐵路運輸及產業逐漸沒落等因素，便於 1982 年遭到拆除；而於課堂上，學生可以發表自己對於消失旗尾線的想像，卻無法更深入表達出具象性的認知，由此可知，學生們對於曾經的歷史是好奇且充滿想像的，但大部分只能透過影像或書籍去了解，無法有實際體驗的機會，進而對於學習目標也較陌生。因此本研究欲探討是否能藉由虛擬實境與情境遊戲來作為輔助教材，讓學生能自主導學，降低認知的陌生與提升虛擬實境在教學層面的易用效果，以此來影響學生學習態度。

2.文獻探討

心態是潛藏心內用來幫助我們採取行動，行動影響成敗，所以心態決定了一個人的成就。史丹佛大學教授 Carol Dweck 就將心態劃分為「成長心態」與「固定心態」，並且他發現當學校課程越來越艱深時，持固定心態的學生，會過得特別困難，並且成績表現會突然下降，因為情況是不可以改變的，所以特別容易感到挫敗，充滿壓力，甚至會放棄，這種情況在小學過渡到中學，與及中學過渡到大學時特別明顯。所以當孩子接觸與生活周遭有關的事物時，能夠提高其專注度以及興趣，並透過實踐學習的方式更能夠讓孩子在之後仍舊持續關心並自主學習(2021，蔡秀妤、顏珮如)，而製作文化課程相關教材，將主題選擇息息相關的文化去進行製作,加以 VR 投入教學更能夠提升學生學生身歷其境的感受,並提高學生情感的緊密性,而在提升土地情感的同時也能夠提升學生的主動性（2019，黃詩旻），讓學生在課程結束後也會主動去了解對於自己成長的故鄉、當地的文化以及相關的知識，以此來增加成長心向。



圖一 本研究設計目標動機

因此 VR 的誕生，將傳統的平面內容化成實體，不再是老師單方面的傳遞知識，而是讓學生實際接觸加深印象和激發興趣，透過實際操作有效協助學生提升自主學習成效與文化認同感(葉承峰、楊晰勛，2021）。以技術的角度來說，虛擬實境共具有三項特徵，即「沉浸、互動、構想」，並強調人在虛擬系統裡的主導作用(程正孚，2017)。虛擬實境在教育上應用的優勢，是讓過去僅能使用黑板和口頭的傳統式教學，到現今能使用一體機頭盔的數位式學習，廣泛以虛擬實境將傳統的平面內容化成實體環境，透過讓學生實際操作親臨感受的方式，去加深加廣了解所學，以利學生能在過程中激發積極學習態度，除此之外也能讓學生藉由成就感與沉浸感去加深學習印象。

3.研究設計與說明

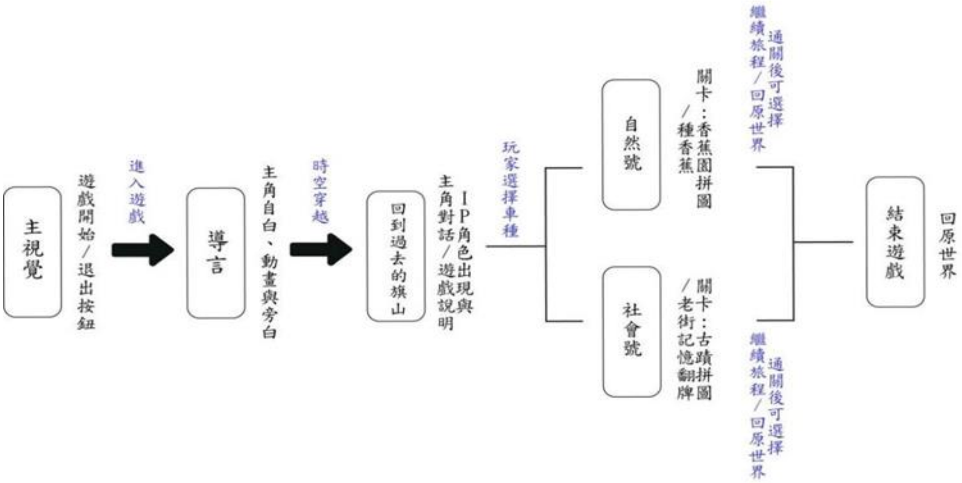
3.1 研究重點與設計方向

本研究之目的可分為：（一）**認識地方文化背景與重要意義**（二）**提升虛擬實境結合教學應用發展**（三）**輔助教材與自主導學之成效探討**，預計使用虛擬實境結合情境遊戲，提升學生的學習動機並具有積極態度令學生在課堂中的表現可進一步成長，使其獲得成就感來提高自主學習的意願，也可令教師在教學過程中更快速的進行並獲得更好的成效。

圖二 本研究設計重點方向

3.2 學習飛快車

本研究以歷史文化作為設計主軸，利用車站、老街等大地理設定位置，並加入動態火車與代表性元件，進行一連串情境故事的遊戲玩法，讓國小生能在遊玩期間，透過虛擬實境體會當代歷史景物，且能在學習過程後藉由內部關卡測試所學進度，來了解自身在於整體導學裡，是否有達到預期成效。此外，為激發國小生的學習動力與態度，更納入車票獎勵機制及適合學童觀看的動畫風格，讓學生能夠以簡易的畫風容易去操作整體教材，也能從中去獲取相對應的滿意度及成就感。



圖三 本研究設計基本架構

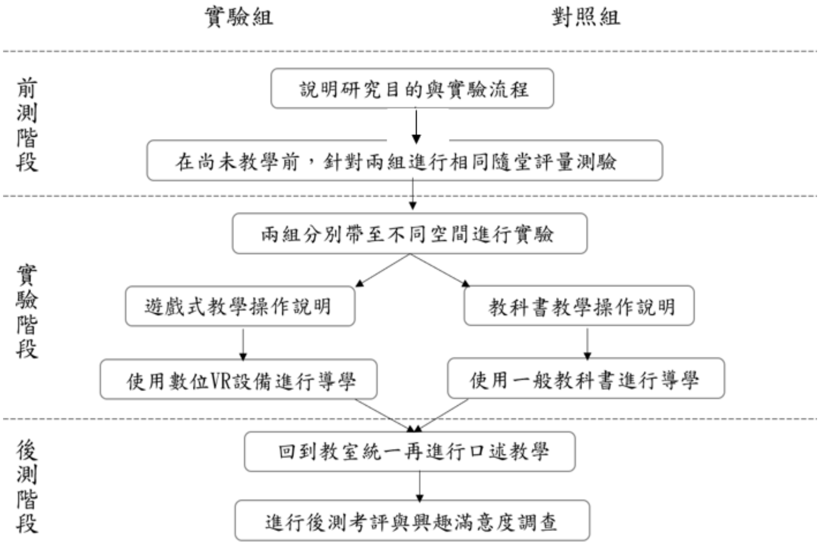
表一 本研究設計項目程序

主視覺開場設計	文化場景建置模擬圖	遊戲引擎製作流程	遊戲教材使用畫面
			

4.研究方法及步驟

4.1 實施目標與範圍

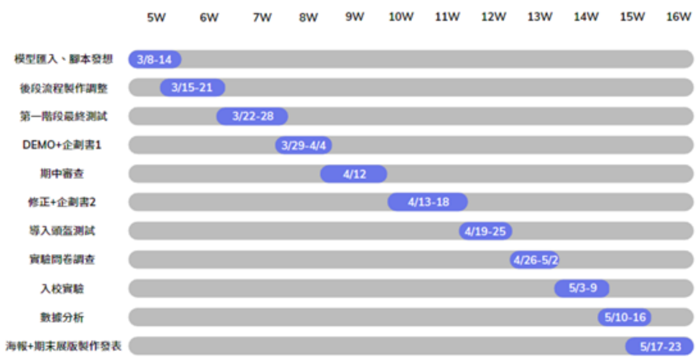
本研究調查與實施目標定以高雄市某國民小學學生為例，欲以問卷考評調查前後測作為本研究成效考據，透過將目標對象隨機分派至「教材導學實驗組」與「傳統教學對照組」。



圖六　本研究設計實驗方法與流程

4.2 研究方法與流程

本研究採用實地訪談法、問卷調查法及取樣實驗法三大階段，探討國小生在有無使用教材導學之過程與趣態度上是否有顯著差異影響。本研究之後續實驗方法利用實驗組與對照組基本分類方式進行研究活動，在正式實驗前會事先對兩組實驗對象進行前測隨堂考評，再進入導學環節，待導學結束後，會讓兩組學生同步進行傳統口述教學，來觀察學生預習效果為何，最後再進行後測考評了解學生總體學習態度效果是否有達到預期展望，此外更會對學生實施滿意度與易用度測量來判讀本研究之目標成功率。



圖七　本研究設計時程甘特圖

由於本設計主要會使用 Meta Quest2 VR 頭盔作為載體，因此在實驗中本團隊會攜帶四部該頭盔前往，並將實驗對象採四人一組的模式分組，方便與本團隊人員進行一對一使用教學，並預計總體實驗時間包含問卷測試會分為 30 分鐘的教材學習時間、15 分鐘的教學測試時間，總加為每一輪一堂課(45 分鐘)時程，且會進行五輪活動，故整場實驗共計約四個小時。

5. 預期結果與未來展望

本研究期望能**擴展虛擬實境在當今領域的作用**，並改變校園傳統教育方式，嘗試創新學習在技術媒合下碰出新的火花，搭配情境遊戲及文化背景減少學生對於學習背景的陌生感。

圖八 本研究設計結論展望

研究後續最快將於今年五月份洽談入校實驗，並透過以下自編問卷：QUIS 問卷(滿意度量表)、SUS 問卷（系統易用性量表）兩項來進行此教材是否有實際輔助到對小學教師於教學時的實際效果，以及學生對於此教材系統易用性、學習成果與內容滿意度的研究成果。

表二 本研究設計自編問卷

QUIS 使用者互動滿意度量表					
1.操作畫面的使用感受	非常糟糕	糟糕	普通	良好	非常良好
2.操作畫面的互動引導	非常乏味	乏味	普通	有趣	非常有趣
3.螢幕上資訊呈現位置	非常困惑	困惑	普通	清楚	非常清楚
4.學習過程獲得成就感	非常不符合	不符合	普通	符合	非常符合
5.學習過程有沉浸感受	非常困難	困難	普通	容易	非常容易
SUS 系統易用性量表					
1.我認為這個原型介面可以幫助我順利完成操作	非常不同意	不同意	沒意見	同意	非常同意
2.我認為這個操作畫面的設計讓人感覺很舒服清晰	非常不同意	不同意	沒意見	同意	非常同意
3.我認為大多數人可以很快學會如何操作這個作品	非常不同意	不同意	沒意見	同意	非常同意
4.我有信心在作品介面上能使用正確的方式操作	非常不同意	不同意	沒意見	同意	非常同意
5.我非常樂意繼續使用這個方式的教材介面	非常不同意	不同意	沒意見	同意	非常同意

在兩項問卷中，QUIS 問卷(滿意度量表)設計欲了解操作畫面對學生的使用感受和互動引導心得、螢幕資訊呈現是否能過傳達正確內容、學習過程是否對學生有達到成就感和沉浸感等為主要思考；SUS 問卷（系統易用性量表）則進一步探討學生在整體使用下的清晰度、掌握姓、意願度等面向，從以上這些觀點讓本研究能有更明確的精進方向。

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Taking the Virtual Reality Technology Development Context Game to Reproduce Local Cultural Guidance Textbooks — Take Elementary Education as an Example

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Abstract: *With the progress of the metaverse, the combination of virtual and real education breaks the existing space and time limit, and then makes the knowledge learning method deeper and wider. This study aims to use the "virtual reality" to combine the "situation game" as a teaching material guide system to assist elementary students to explore independent learning before the class of elementary school students to study, and has a significant difference in the learning process and interest. The study goals are based on grades 5 to six of students in elementary school, and the use of guidance textbooks in front of the classroom can be used to allow students to learn independently, and provide them with the study progress of students in the classroom. This group uses Unity as a design medium, incorporates the local cultural background, reproduces teaching indicators with context games, and creates a suitable teaching Textbook for teaching. It is hoped that students can help students lay off cross -domain capabilities and improve their learning attitudes through this design.*

Keywords: virtual reality, local cultural, independent learning, situational games, guided education

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元宇宙在教育评价中的应用现状社会网络分析

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【摘要】 元宇宙是当下研究热门之一，作为多项智能技术的整合体，能够提供沉浸的交互多感官体验，该虚拟与现实相互交融的空间能够推动教育各个环节的创新发展，能够一定程度解决不同环节的尚存问题，但目前对教育元宇宙特别是元宇宙在教育评价中的应用的研究尚浅，亟需推进丰富的理论与实践研究。本文对元宇宙及与教育评价融合做出简介，并基于社会网络分析方法借助 SATI 和 UCENET 软件对元宇宙在教育评价中的应用现状进行分析，简要回顾已有相关研究，旨在对其未来发展提供启示。

【关键词】 元宇宙；虚拟现实；教育评价；智能技术

1.简介

元宇宙一词最早出现于 1992 年美国小说家尼尔•斯蒂芬森的科幻小说《雪崩》中，小说中的人类能够通过设备，自由的进入 3D 虚拟现实世界。发展到今日，元宇宙是以人工智能、大数据、虚拟现实、增强现实、全息投影、物联网等多种智能技术与传感器为核心基础，虚拟世界与现实世界相互融合渗透的共享空间，是一种基于数字孪生的现实世界镜像，能够应用在社交活动、教育、医疗等生产实践的多个领域，使用者能够通过创建数字身份，参与到元宇宙空间中，并产生交互式、沉浸式体验。(Dwivedi et al., 2022; Zhang et al., 2022d)

"元宇宙+教育"是一种融合创新的新型体验式教育形态，能够多维度创新教育资源、工具、环境等教育领域关键要素，能够全方位创新教学活动、评价、管理等教学关键环节。在元宇宙空间中，传统"面对面"教学、在线教学、沉浸式教学三者将紧密结合起来，有机地连接学习时空、学习者、教育活动，形成教育智能新生态。学习者能够依托穿戴设备、传感器及增强现实、虚拟现实等技术，沉浸在没有时空限制的教学环境中，基于现实物理空间与虚拟空间的联通实现教学场景的创新。元宇宙空间能够打破多重教育壁垒，实现多元教学资源的连接互通，使得学习者能够更加平等的、便捷的接触链接到空间中的所有资源，并与之产生更深入的交流互动，直接进行体验式、游戏化、个性化学习，促使更好的习得、构建知识概念。(Dwivedi et al., 2022; Zhang et al., 2022d; Chen, 2022; Kye et al., 2021; Zheng et al., 2022)

"元宇宙+教育评价"是对教学关键环节的创新再造。相较于传统教育评价，在元宇宙空间中，能够基于大数据、学习分析、情感识别等技术，依托智能设备与传感器，采集学习者全方位海量数据，并及时进行精准化分析判断，对教育过程做出更加全面的形成性评价，能够更加专注于学习者的成长历程，注重学习者综合素养的提升，打破传统教育以分数为主的桎梏，营造智能时代以学习者能力发展为中心的教育形态。(Zhang et al., 2022d; Chen, 2022; Kye et al., 2021; Q. Zhang et al., 2018b; Tang & Hai, 2021d)

2.研究设计

2.1. 数据来源

为探究元宇宙在教育评价领域应用的研究现状，本研究以 web of science 为检索数据库检索相关文献，并且为保证研究的科学性和权威性，将检索数据库限定与于 web of science 核心数据库（Web of Science Core Collection）。首先以”Metaverse” plus “educational assessment or educational evaluation”为检索式进行文献检索，得到相关文献共计 3 篇，由于文献基数较少，如果进行量化分析可能无法得到科学的结论，因此决定扩大主题词的范围，将“educational assessment or educational evaluation”改为“education”，通过元宇宙在教育领域的应用窥探其在教育评价领域发挥的作用。再次以检索式”Metaverse” plus “education”在此进行检索，得到文献 99 篇，两次检索累计得到文献 102 篇。

2.2. 研究工具

本研究主要以文献题录信息统计分析工具（Statistical Analysis Toolkit for Informetics, SATI)和社会网络分析工具（University of Californiaat Irvine Network，UCINET）作为数据分析工具。SATI 是中国应用较为广泛的文献题录信息统计分析可视化软件，它支持从知网（CNKI）、万方（WANFANG）、维普（VIP）、CSSCI （中国社会科学引文索引）、Web of Science 等文献数据库导出 EndNote、NoteExpress、Txt、XML 等格式的题录数据，提供文献去重和字段合并等数据预处理操作，可实现对作者、机构、关键词、主题词、文献来源、年份等的频次和频率的基础统计，能够进行共现分析和聚类分析，并将统计分析结果可视化。UCINET 是一款社会网络分析工具，它能够分析处理 1-网络和 2-网络，并对网络进行假设检验，还能够理由软件内部集成的 NetDraw 实现可视化分析。

2.3. 研究步骤

首先，将在 Web of Science 中获取的 102 篇文献以“Plain text file”的格式导出数据，并压缩成 zip 格式。其次，将压缩包上传至 SATI，选择文献去重、词干提取、默认停用词、应用分词和智能清洗，手动设置需要合并的关键词和停用词，将高频字段显示个数以及矩阵大小设置为 50，进行题录信息统计分析，并导出关键词和作者频次表、频次矩阵以及二值矩阵。其次，将从 SATI 中导出的矩阵导入 UCINET 进行关键词共现分析以及作者合著网络分析。

3. 结果与分析

3.1. 高频关键词分析

一般来说，关键词是一篇文章表达主题的集中体现，能够体现出研究的方向和要点，在某研究领域中出现频次越高的关键词，越能够代表该领域的研究热点（许双月，2022）。因此本研究通过统计关键词频次，探究元宇宙在教育领域的应用热点问题。在对高频关键词进行分析之前，先研究该领域关键词频次的时间演变历程（图 1）。从图中可以看出，该领域关键词自 2010 年开始出现，2021 年之后开始迅速增加，尤其是元宇宙这一关键词的变化尤为明显，受时代发展以及技术的限制，有关元宇宙的研究近几年才受到学界的广泛关注，正处于起步阶段，在未来还需要更多的时间对其进行广泛而深刻的探索。

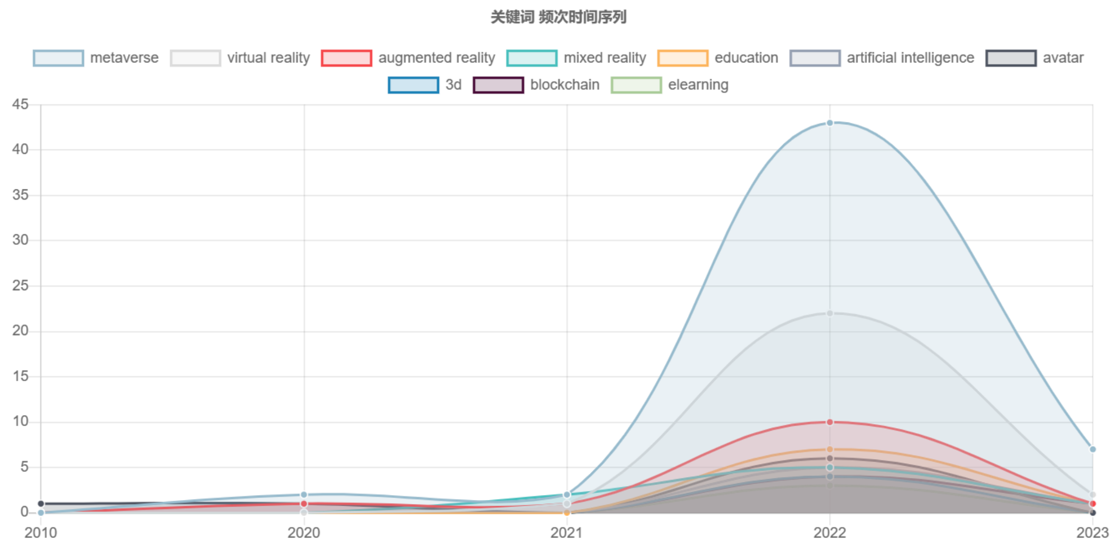

图 1 关键词词频时间序列

进行高频关键词分析首先要计算出高频关键词的阈值。根据普赖斯公式($M=0.749\times\sqrt{N_{max}}$)计算高频关键词阈值 M（虞秋雨和徐跃权，2020）,Nmax 指的是关键词频次的最大值，最高频次为 65，得到与 M 为 6，因此关键词频次大于等于 6 的为高频关键词，共计 8 个（如表 1）。从表中可以看出元宇宙、虚拟现实、增强现实、混合现实以及教育这几个关键词频次排名靠前，说明多数学者的研究中都涉及与这几个关键词相关的内容，是该领域的研究热点。其中虚拟现实、增强现实、混合现实是实现元宇宙应用于教育领域的关键技术，使得元宇宙呈现在日常生活中成为可能。

表 1 高频关键词词频

No.	keyword	frequency	No.	keyword	frequency
1	metaverse	65	5	education	10
2	virtual reality	33	6	artificial intelligence	8
3	augmented reality	15	7	avatar	8
4	mixed reality	11	8	3d	6

3.2. 关键词共现分析

关键词共现指两个关键词形成的词汇对在在同一篇文献中同时出现，则表明两个关键词之间具有一定的共性（钟伟金和李佳，2008），根据词汇对共同出现的情况分析整个文献集代表的研究领域中各主题之间的关系。关键词对共同出现的频次越多，表明这两个词代表的主题的内在联系越密切。通过关键词贡献网络分析可以归纳出学科的研究热点。利用 UCINET 对关键词共现矩阵进行分析得到关键词共现图谱（图 2），再对二值矩阵进行分析计算得到关键词共现网络的密度为 0.1698，数值较低，说明关键词之间的联系的紧密程度较差。图中节点代表关键词，关键词频次越高节点越大，关键词之间的联系表示其共现关系，连线越粗关系越紧密。从图中可以看出，元宇宙位于整个网络的中间位置，它与虚拟现实、增强现实、混合现实、教育以及人工智能等关键词之间的连线较粗，说明学者会将元宇宙与以上关键词放在一起进行研究。为实现元宇宙有效应用于教育领域，使教育发生根本性变革，离不开虚拟现实、增强现实、混合现实等技术的研发与创新。目前对于元宇宙在教育领域中的应用扔处于初步发展阶段，主要应留在理论层面的研究，例如 Zhang 等人(Zhang et al., 2022)对教育

中的元宇宙的定义、框架、功能、潜在应用、挑战和未来研究课题的探讨，而在实践层面探索较少。并且从已有文献中发现，学者对元宇宙在教育评价中的应用研究相对较少，尚未形成较为成熟的模式，这是我们以后需要重点关注的方向。

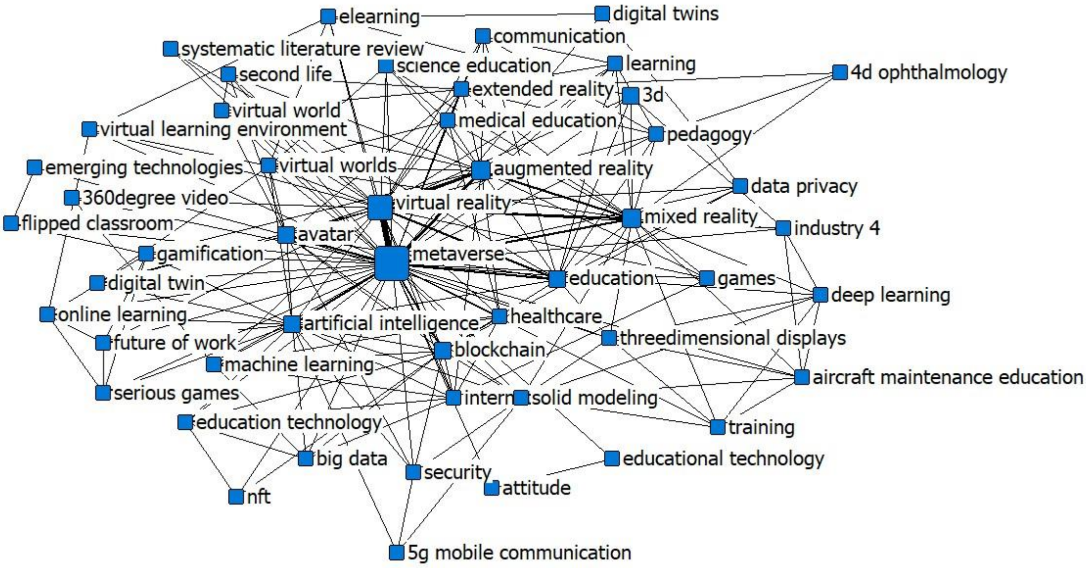

图 2 关键词共现图谱

3.3. 作者合著网络分析

本研究进行合著网络分析时主要分析发文量排名前 50 的作者。将从 SATI 中倒出的作者发文频次共现矩阵导入 UCINET 生成可编辑的.##h 文件，并用 NetDraw 绘制作者合著网络图（图 3）。图中正方形节点代表作者，节点大小表示发文量，节点越大该作者发表文献数量越多，节点间的连线表示作者之间具有合著关系，连线越粗关系越密切。在 NetDraw 进行 K-cores 分析，分析后得到的分组以节点颜色作为区分，其中形成网络的节点中，灰色节点数量最多，说明这些作者在元开展宇宙在教育中的应用的研究中合著规模大，其团队具有较大的影响力，其中红色节点都为孤立节点，与其他作者之间没有合著关系。该网络的读经计算为 0.0376，说明网络的连通性不好，在该领域的研究中虽然已经形成了多个小团体，但是还没有大规模的合作。

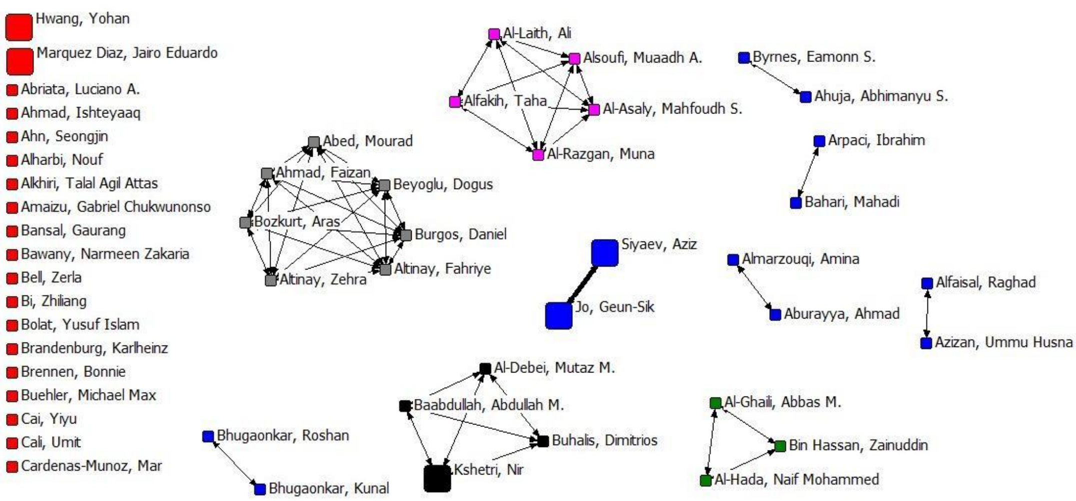

图 3 作者合著网络图

4.总结与展望

元宇宙的发展是对多项智能技术的整合发展，继续深入研究能够促进教育领域的智能化发展。首先，对于教育元宇宙空间的基础研究程度不够深入，须进一步推动，并开展相关的基础设施的建设以及技术设备的普及，保障后续研究的持续推进；其次，对于元宇宙与教育评价环节结合的理论与实践研究不足，须开展并总结更多实践经验，促进理论与实践的结合，丰富两者融合创新的典型案例，为教育元宇宙的深入发展注入动力；最后，元宇宙应用于教育评价时，将会采集学习者的海量数据，其中数据隐私与安全须重点关注，以防数据泄露造成不正当使用，导致严重数字安全后果。当前教育领域与元宇宙的结合尚浅，在教育评价环节更甚，既要发挥元宇宙的优势进行广泛实践，促进教育的发展，也要提防元宇宙存在的可能隐患。

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A Social Network Analysis of Current State of Applying Metaverse in Educational Evaluation

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Abstract: *Metaverse is one of the current research hotspots. As an integration of multiple intelligent technologies, it can provide immersive interactive multi-sensory experience. Metaverse, with blended virtual and real reality, can promote the innovation and development of various aspects of education and can solve the emerging problems of different aspects to a certain extent. However, the current research on the educational metaverse, especially the application of the metaverse in educational evaluation, is still shallow, and it is urgent to promote rich theoretical and practical research. This paper makes an introduction to the metaverse and its integration with educational evaluation, and analyzes the application status of the metaverse in educational evaluation based on the social network analysis method with the help of SATI and UCENET software, briefly reviews the existing related researches with the aim of providing insights for its future development.*

Keywords: metaverse, virtual reality, educational evaluation, intelligent technology

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A Framework for Student Engagement Level Prediction: A User Perspective

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Abstract: *Most engagement prediction models focus on maximising prediction accuracy in a classification framework or minimising mean square error in a regression framework. However, the goal of an engagement prediction model from a user perspective is to be able to detect disengagement. In this work, we present a regression framework that* encompasses *the approach and evaluation metrics suitable for detecting disengagement. The disengagement level threshold and confidence level threshold are introduced to allow flexibility in the use of the tool. Moreover, the SMOGN oversampling strategy and an undersampling strategy housed in an ensemble are proposed to tackle the imbalance data distribution typically found in engagement detection. They are evaluated on the DAiSEE dataset for benchmarking.*

Keywords: engagement detection, imbalanced regression, oversampling, undersampling

1. Introduction

The COVID-19 pandemic has allowed many to experience the use of technologies for meeting virtually (Venton & Pompano, 2021) (Mukhtar, Javed, Arooj, & Sethi, 2020). However, one of the shortcomings of these virtual meetings are lower engagement levels (Venton & Pompano, 2021). This is particularly salient in virtual learning environments where teachers often feedback that the inability to know if students are engaged in their virtual classrooms unlike in physical classrooms. Hence, the possibility of an engagement level detection tool for teachers is being explored.

Various works (Nezami, et al., 2019) (Abedi & Khan, 2021) (Liao, Liang, & Pan, 2021) (Kaur, Mustafa, Mehta, & Dhall, 2018) (Gupta, Jaiswal, Adhikari, & Balasubramanian, 2016) (Dhall, Sharma, Goecke, & Gedeon, 2020) (Altuwairqi, Jarraya, Allinjawi, & Hammami, 2021) (Whitehill, Serpell, Lin, Foster, & Movellan, 2014) (D'Mello, Dieterle, & Duckworth, 2017) have explored different engagement detection problem setup and methods. Due to nature of data which captures faces of participants, the student engagement datasets are typically kept private and not shared publicly. Out of the many student engagement datasets, two datasets, namely Dataset for Affective States in E-Environments (DAiSEE) (Gupta, Jaiswal, Adhikari, & Balasubramanian, 2016) and Engagement prediction in the Wild (EW) of Emotion Recognition in the Wild (EmotiW) challenge in 2020 (Dhall, Sharma, Goecke, & Gedeon, 2020) are more widely used as these datasets are available upon request. The DAiSEE dataset is annotated by 10 untrained crowdsourcers for every 10 seconds clip while the EmotiW dataset is annotated by 5 experts for every 5 minutes clip. They are both annotated into 4 groups - for DAiSEE dataset, (1) very low, (2) low, (3) high and (4) very high engagement levels; for EmotiW dataset, (0) completely disengaged, (1) barely engaged, (2) engaged, (3) highly engaged. Both datasets have imbalanced distribution with the lack of disengaged samples.

These datasets have been set up as both classification (Abedi & Khan, 2021) (Liao, Liang, & Pan, 2021) and regression (Wu, Yang, Wang, & Hattori, 2020) (Liao, Liang, & Pan, 2021) problems in literature. However, setting up as a regression problem could be more suitable. The closer relationship between (1) very low and (2) low compared to (1) very low and (4) very high engagement can be reflected in the model. Further, the use of a regression model can allow the user to select an engagement level threshold for disengagement, which could differ for different activities.

The main purpose of this engagement tool is to help educators or students themselves detect disengagement. However, due to the imbalanced distribution and sparsity of data, it is difficult to build a model that can accurately predict disengagement, as seen in (Abedi & Khan, 2021) where balancing strategies are required to predict very low / low engagement samples in a classification framework. In this paper, we propose a framework that can help to identify low engagement and provide the user about its confidence level on the prediction in a regression framework. More specifically, we present new metrics that would be useful to the end user and benchmark various strategies to improve performance on imbalanced datasets.

2. Proposed Methodology

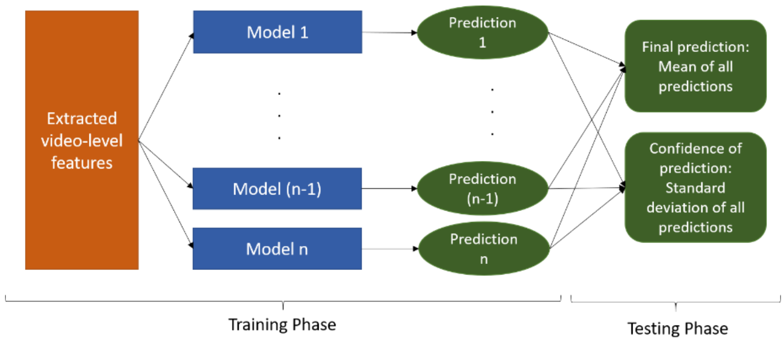

Figure 1. Proposed framework for student engagement level prediction.

The proposed framework for student engagement level prediction is illustrated in Figure 1. From a user perspective, two key factors when using an engagement detection tool are (1) to be able to adjust the disengagement threshold and (2) to know how confident the model is of the prediction made. We refer to this as the flexibility of the engagement detection tool. With a regression model, the value of (1) can be adjusted accordingly with levels of engagement varying from 0 to 1, from disengaged to highly engaged. A lower threshold can be fixed to reduce false positive alerts on disengagement while a higher threshold can be used to filter out more instances of disengagement for retrospective analysis.

First, video-level features would be extracted from the video frames in the dataset (Section 2.1). With the extracted features, multiple models would be built and trained to make multiple predictions. Thereafter, the mean of all the predictions would be calculated as the final prediction and the standard deviation of the predictions would be used as an indicator for the level of confidence for the prediction. The use of a confidence metric helps to address (2), more details are given in Section 2.2. Two varying strategies to manage the imbalance distribution and evaluation metrics would be discussed in Section 2.3 and 2.4 respectively.

2.1. Video-level features

The video-level feature vector is adopted from (Abedi & Khan, 2021), made up of affect and behavioural features. The affect features include the mean and standard deviation of valence and arousal from the consecutive frames using pre-trained Emonet (Abdul-Mageed & Ungar, 2017) on AffectNet (Mollahosseini, Hasani, & Mahoor, 2019), which is one of the largest datasets for facial expressions in the wild. The behavioural features showing the eye and head movement in the video are obtained from OpenFace (Baltrusaitis, Zadeh, Lim, & Morency, 2018), a publicly available toolkit for facial behaviour analysis. The features extracted from OpenFace are the coordinates of gaze position, head position, roll, pitch and yaw for head rotation. With the extracted raw features, we calculated the velocity and acceleration to better represent the gaze and head movement. The trend of gaze and head movement is captured by the mean and standard deviations of velocity and acceleration. We further extended the feature vectors by 5 dimensions using different thresholds on AU45_r (a feature from OpenFace) to determine the number of blinks per frame (Ranti, Jones, Klin, & Shultz, 2020). Following the method described, we constructed the feature vectors for DAiSEE dataset. The overall structure of the 42-element feature vector can be shown in Table 1.

Table 1. Feature Vector Structure.

Feature type	Feature description	Dim	Toolkit
Affect	valence mean	1	Emonet
	valence stdv	1	
	arousal mean	1	
	arousal stdv	1	
Behavioural	gaze velocity mean (x,y)	2	OpenFace
	gaze velocity stdv (x,y)	2	
	gaze acceleration mean (x,y)	2	
	gaze acceleration stdv (x,y)	2	
	head translational velocity mean (x,y,z)	3	
	head translational velocity stdv (x,y,z)	3	
	head translational acceleration mean (x,y,z)	3	
	head translational acceleration stdv (x,y,z)	3	
	head rotational velocity stdv (x,y,z)	3	
	head rotational acceleration mean (x,y,z)	3	
	head rotational acceleration stdv (x,y,z)	3	
	blink rate (AU45_c)	1	
Extended behavioural	AU45_r	5	OpenFace

2.2. Ensemble methods for confidence

The final prediction of the approach is calculated as:

$$\hat{y}_{mean} = \frac{\sum \hat{y}_i}{n} \qquad i = 1, \ldots, n$$

where $\hat{y}_{mean}$ is the final prediction, $\hat{y}_i$ is the prediction of model i and n is the total number of models. By setting a disengagement threshold θ_{thres}, where $\hat{y}_{mean} \leq \theta_{thres}$, one would be able to identify disengaged samples.

The confidence (standard deviation) of the model prediction is calculated as:

$$\hat{y}_{SD} = -\sqrt{\frac{\sum(\hat{y}_i - \hat{y}_{mean})^2}{n}}$$

where $\hat{y}_{SD}$ is the confidence of the model prediction. The higher the value, the more confident is the model. By using $\hat{y}_{SD}$, samples that have diverse predictions from different models (lower confidence levels) can be identified and dropped using a standard deviation threshold, σ_{thres}.

2.3. Strategies for Imbalanced Dataset

In engagement detection, we hope to capture instances where students have low engagement, to either bring students back to attention or to perform a retrospective analysis for understanding. Therefore, the important ranges are towards the lower range of the engagement level scale, and these are poorly represented in the typical engagement detection datasets. To tackle this, two different strategies are proposed.

2.3.1. Data-based strategy - SMOGN: Synthetic Minority Over-Sampling Technique for Regression with Gaussian Noise

SMOGN is a popular strategy for tackling imbalanced regression problems (Branco, Torgo, & Ribeiro, 2017). It combines random under-sampling strategy with two over-sampling strategies: SMOTER (Torgo, Ribeiro, Pfahringer, & Branco, 2013) and the introduction of Gaussian Noise. This combination allows the generation of synthetic examples by reducing the risks faced by SMOTER and at the same time greater diversification. This helps reduces the imbalance between the classes and sample each class equitably. More details can be found in (Branco, Torgo, & Ribeiro, 2017).

2.3.2. Model-based strategy - Undersampling for each model in ensemble

In this strategy, each model in an ensemble would be built and trained using only a subset of the whole dataset (undersampling). The number of samples in each class can be decided by the user to allow for a more balanced dataset. Each model would be trained using a different subset, randomly selected from the whole dataset. This would vary the predictions in the various models. Hence, if the different models have similar predictions, the final prediction $\hat{y}_{mean}$ would be considered to have higher confidence.

2.4. Evaluation Metrics

In most regression works, the metric used for evaluation is the Mean Square Error (MSE). While MSE is useful for comparing models against one another, it does not provide insights that the user could relate. We propose a few other metrics to help us further evaluate the model's effectiveness on engagement detection. We separate the MSE into MSE for low engagement samples and high engagement samples, namely Low Engagement Mean Square Error (LE_MSE) and High Engagement Mean Square Error (HE_MSE) respectively. This helps us to evaluate the model's effectiveness in high and low engagement samples and is particularly useful in a very imbalanced dataset. Moreover, we introduce the calculation of true positive (TP), false positive (FP) count and F1 score when given a certain θ_{thres}.

3. Experimental Study

In our experiments, we demonstrated the data-based strategy of SMOGN and the model-based strategy of undersampling on the DAiSEE (Gupta, Jaiswal, Adhikari, & Balasubramanian, 2016) datasets.

For the SMOGN strategy, Random Forest (RF) regressor, Gradient Boosting Regressor (GBR), support vector regression (SVR) and multi-layer perceptron (MLP) models were used. For RF and GBR, the total number of estimators is 100. For SVR, the epsilon value is set at 0.01. For MLP, we train and test on a 3 layered MLP model having 64 hidden neurons and $\tanh$ activation function in each layer. This is followed by a final sigmoid layer to calculate the regression scores. We use the Adam optimizer with MAE loss with batch size 32 for 200 epochs to train the model. The setting for the SMOGN is to over-sample the samples with lower distribution. In DAiSEE, we oversampled (1) very low and (2) low samples.

For the undersampling ensemble approach, a hundred decision trees with varying number of samples per class were tested - three settings were used: (1) balanced number of samples per class, (2) 6 times more samples selected in non-minority classes and (3) distribution similar to original distribution of data. θ_{thres} is set to 0.5 in our experiments.

3.1. Datasets

The original DAiSEE dataset that was downloaded is split into 3 phases, containing 5482 clips from 33 users for training, 1720 clips from 38 users for validation, and 1866 clips from 32 users for testing. The training and validation sets were combined for training in our experiments. A total of 143 clips that were without labels were removed from the test set. Table 2 provides the distribution of samples across the train and test sets in the DAiSEE dataset.

Table 2. DAiSEE Data Distribution.

Phase	0	1	2	3	Total
Train	57	374	3561	3210	7202
Test	4	81	861	777	1723
Total	61	455	4422	3987	8925

3.2. Experimental Results

Table 3. DAiSEE dataset results.

Approach	No.of models	MSE	LE_MSE	HE_MSE	TP (count)	FP (count)	F1 score
RF	1(100)	0.0224	0.1016	0.0183	0	1	0
GBR	1(100)	0.022	0.1078	0.0175	2	2	0.045
SVR	1	0.0271	0.1039	0.0231	3	9	0.062
MLP	1	0.0336	0.1072	0.0297	0	0	0
Data-based strategy: SMOGN							
RF(SMOGN)	1(100)	0.0258	0.0849	0.0228	4	8	0.082
GBR(SMOGN)	1(100)	0.0373	0.0583	0.0362	21	119	0.187
SVR(SMOGN)	1	0.04	0.0793	0.0379	13	142	0.108
MLP(SMOGN)	1	0.052	0.0605	0.0516	33	350	0.141
Model-based strategy: Undersampling each model in ensemble							
Decision Trees (50, 50, 50, 50)	100	0.0594	0.0258	0.0611	55	463	0.182
Decision Trees (50, 300, 300, 300)	100	0.0366	0.0446	0.0362	27	136	0.218
Decision Trees (50, 100, 300, 300)	100	0.0288	0.0615	0.0271	21	70	0.239

The results for the DAiSEE dataset are presented in Table 3. Without any strategies, RF and GBR have achieved better MSE than SVR and MLP. However, when looking at the TP and FP counts, GBR would be a more suitable model as it can detect 2 instances of student being disengaged compared to 0 in RF. When the imbalance data strategies are employed, there is a trade-off of HE_MSE for a lower LE_MSE. This in turn allowed more TP counts as LE samples are more accurate, as well as higher FP counts when HE samples are less accurate. In the model-based strategy, the MSE is lowest when the ratio is the samples is similar to the current distribution of data among classes.

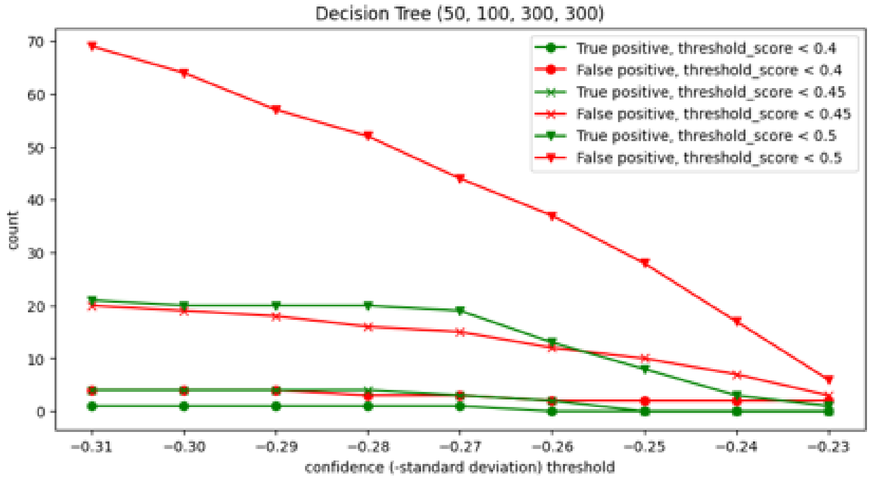

Figure 2. Variation of θ_{thres} and σ_{thres} in ensemble approach.

Figure 2 presents the changes in TP and FP, when θ_{thres} and σ_{thres} are varied in Decision Trees (50, 100, 300, 300) approach. Given $\theta_{thres} = 0.5$, the TP and FP can be reduced to 20 and 52 respectively when the $\sigma_{thres} = -0.28$.

4. Conclusion and Future Directions

This work presents a framework that focuses on building and evaluating an engagement detection tool that can detect disengagement. The framework allows flexibility with the introduction of the disengagement level threshold θ_{thres} and confidence level threshold σ_{thres}. Furthermore, the work evaluated the SMOGN oversampling strategy and an undersampling strategy housed in an ensemble on the DAiSEE dataset. The results reflected the challenges of the engagement detection problem - specifically in identifying disengagement. Our future work would explore effective approaches on the collection and annotation of data for the engagement detection problem to allow us to build a useful engagement detection tool for educators.

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Development of an Avatar Expression Remix System to Identify Avatars' Facial Expressions for Authentic Social Interactions in the Metaverse

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Abstract: *This study aims to understand how the metaverse has been used in educational settings from 2013 to 2022. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was adopted. A total of 22 refereed journal articles were selected. Metaverse applications in education were classified and challenges were explored. First, two categories of the applications of the metaverse were classified: metaverse as a target for development and standalone virtual worlds in which various educational activities can be conducted; and metaverse as a tool for solving problems and performing educational tasks that are difficult to solve in real life settings. Second, challenges in terms of these two categories were discussed. Regarding applications of the metaverse as a target, (a) few platforms have enabled the users to act as avatars that mirror their own behaviours; (b) rare custom tools have been developed to meet the instructional design needs; (c) most platforms have required VR headsets, increasing the threshold for participation; and (d) privacy and ethical issues remain. Regarding applications of the metaverse as a tool, (a) scant studies have examined how social interactions and collaboration occur; (b) few platforms have provided a truly immersive learning environment in which the avatars can mirror real users' behaviours and interact with other avatars and virtual objects; (c) few studies have presented the instructional design; and (d) most of the studies are small-scale pilot studies. The implications of metaverse in education were discussed.*

Keywords: metaverse, avatar expression animation remix, avatar facial expression, social interaction, Learningverse

1. Introduction

In the post-pandemic, blended learning supported by online learning platforms will become a new normal in higher education. To increase social interactions in online learning, digital worlds such as Gather.Town (Latulipe & Jaeger, 2022), VRChat (Cahyadi et al., 2022), and VirBELA (Mora-Beltrán et al., 2020) are becoming increasingly popular in education to enhance students' learning engagement and performance. These platforms are also termed the metaverse - a network of digital worlds with a focus on social connections where people act as avatars to interact and collaborate with each other in real time supported by various technologies (Xu et al., 2022). However, few metaverse platforms allow users to act as avatars that mirror their own behaviours, including facial expressions. Understanding avatars' facial expressions in the metaverse is important for authentic social interactions and effective collaboration (Park et al., 2021), which in turn, can inform pedagogical decision-making and refinement (Emerson et al., 2020).

Although many studies have been conducted to track avatar facial expressions, the majority of them have only focused on eye- and mouth-tracking in video-based online teaching (e.g., Jun, 2021; Tang et al., 2021) or collaboration in virtual environments (Wu et al., 2021). In addition, studies on tracking avatar's facial expressions in the metaverse could hardly be found. Studies on recognition of avatars' facial expressions that directly mirror real users' expressions in the metaverse are rarer in the current literature. In the light of it, this study aims to develop an avatar expression remix system in the metaverse platform – 'Learningverse' developed by the first author's research team to understand avatars' facial expressions. Next section introduces the 'Learningverse' platform and challenges of avatar facial expression recognition, followed by the design of the avatar expression remix system. Finally, conclusions are drawn, and future work is explored.

2. Avatar expressions in the metaverse – 'Learningverse'

2.1. 'Learningverse': A metaverse ready for learning

'Learningverse' is an innovative metaverse platform for educational purposes (see Figure 1). This platform includes three core elements of a metaverse, which are (1) avatar, (2) virtual space and (3) network. Various solutions are embedded in four system layers – interface, environment, interaction, and security and privacy (Park & Kim, 2022), to functionalise the three core elements in 'Learningverse'. Additionally, the platform offers a low-threshold solution for users to participate in the metaverse, requiring only an ordinary computer with a common webcam to mirror the real user in detail, including facial expressions, body posture, and gestures.

Figure 1. System framework of 'Learningverse'.

2.2. Challenges of avatar facial expression recognition in the metaverse

The utilisation of avatars in the metaverse for the expression of emotions is a topic of significant interest, as it offers a means for users to convey their feelings to other avatars. Generally, the expression of the avatar mirrors a real user from the webcam video source (Grewe et al., 2022). However, mirroring the expressions of real users directly onto avatars in the metaverse presents several challenges. This approach is dependent on the user's facial expressions captured by a webcam, but even slight changes in the user's expression can result in minor modifications to the avatar, which is difficult to be detected by other avatars. The stylisation of the avatar into a cartoon character (e.g., Latulipe & Jaeger, 2022; Mora-Beltrán et al., 2020) can further exacerbate the issue by introducing interpretation biases and leading to misunderstandings of the original emotions being conveyed. The uncanny valley phenomenon, which refers to the negative emotional response of a viewer to an animated character that becomes too human-like in appearance and motion (de Borst & de Gelder, 2015; Grewe et al., 2022; Kätsyri et al., 2015), also adds to the challenges in effectively expressing emotions through avatars in the metaverse. Given these challenges and potential limitations, the research team designed an avatar expression remix system that takes into account the needs for effective communication and social interaction in the metaverse.

3. Design of the avatar expression remix system

The design of the avatar expression remix system is a crucial step towards improving the expression transmission in the metaverse. Its aim is to ensure the accuracy and clarity of the conveyed emotions, ultimately leading to more effective communication and social interaction among participants. The system incorporates four main steps: Step 1 - user expression recognition, Step 2 – emotion analysis, Step 3 – avatar expression animation remix, and Step 4 - avatar expression rendering. The recognition of the user's expression in Step 1, and the analysis of their emotions in Step 2 serve as the foundation for remixing avatar expression animation in Step 3, allowing for a more precise and comprehensible expression on the avatar. Step 4 brings the avatar to life and allows for an effective transmission of emotions in the metaverse - Learningverse. Through its design, the avatar expression remix system addresses the challenges inherent in directly mirroring expressions on avatars and provides a means for promoting a more engaging and meaningful experience for all users in the metaverse. The framework of the avatar expression remix system is presented in Figure 2.

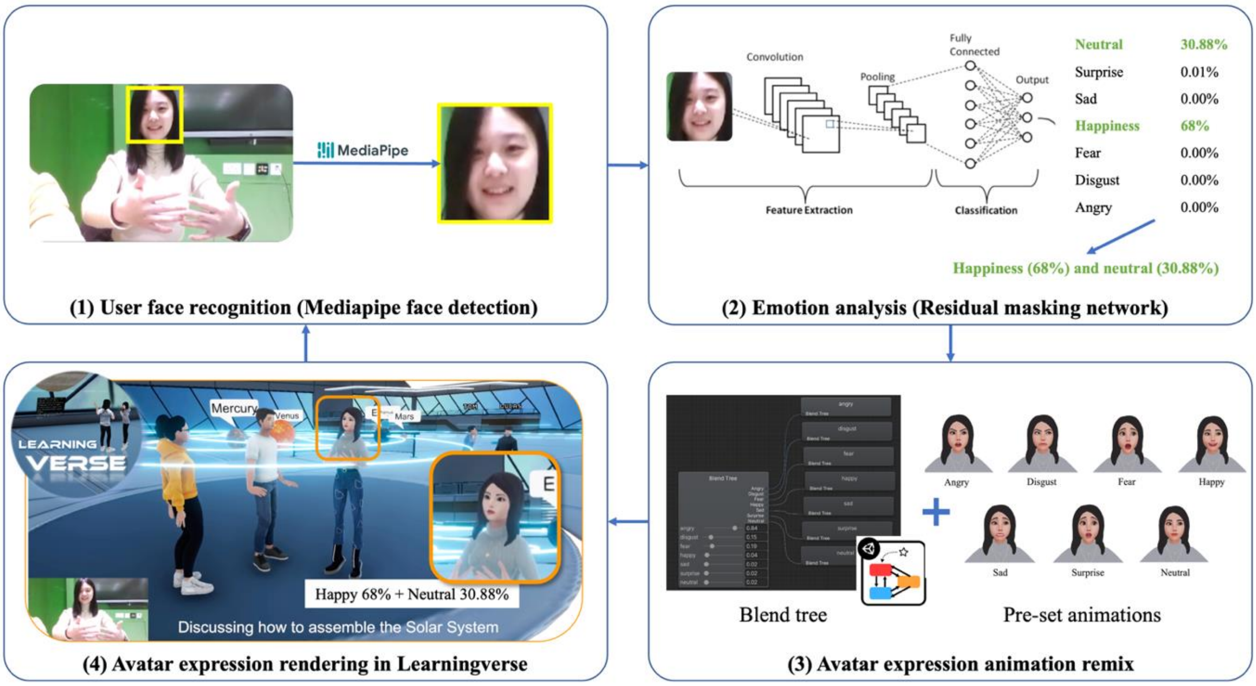

Figure 2. The framework of the avatar expression remix system.

3.1. Step 1 - User expression recognition

The user expression recognition step of the avatar expression remix system utilizes Mediapipe face detection technology. This technology is specifically designed to capture and recognize facial features and expressions (Farkhod et al., 2022; Rane et al., 2023), making it an essential component of the recognition step in the avatar expression remix system. By using Mediapipe face detection, the system is able to accurately identify and track user expressions, providing the necessary input for the subsequent steps of the process. The use of Mediapipe face detection ensures that the recognition of user expressions is handled with precision and efficiency, providing the foundation for the effective communication and social interaction in the metaverse – ‘Learningverse’.

3.2. Step 2 - Emotion analysis

In the emotion analysis step of the avatar expression remix system, the residual masking network is employed to accurately recognize and categorize seven common emotional states expressed by users: neutral, anger, sadness, fear, disgust, happiness, and surprise. The residual masking network is a deep learning algorithm that has been trained on a large dataset of facial expressions and emotions (Pham et al., 2021), and is capable of assigning specific parameters to each of the seven emotions it identifies. The output of this step is then utilized to drive the remixing of the avatar expression animation, ensuring that the final avatar expression accurately reflects the user’s intended emotional state in a robust and reliable manner.

3.3. Step 3 - Avatar expression animation remix

In the avatar expression animation step, the research team first creates pre-set animation clips for each of the seven recognized emotions, with a parameter value of 100%. To further ensure the robustness and reliability of the final animation, the team employs a series of filtering techniques to eliminate false triggers. These includes the exclusion of values in the output of the previous step with a parameter of less than 20% and the elimination of extreme data over 0.5-second intervals by using low-pass filter (Guyader et al., 2017).

3.4. Step 4 - Avatar expression rendering in ‘Learningverse’

In the Avatar expression rendering in ‘Learningverse’ step, the animation clip blend tree constructed in Unity effectively blends the animation clips together. The results of the filtering process from the prior avatar emotion animation remix step are utilized as the weights for the animations in the blend tree, resulting in a smooth and expressive representation of the avatar that accurately conveys the user’s intended emotional state. This representation of the avatar is achieved through the careful integration of advanced deep learning techniques and state-of-the-art animation technology, delivering a seamless and sophisticated user experience.

4. Discussion

The avatar expression remix system developed in this study is an innovative technical solution in that it can make avatars’ expressions become more evident; hence avatars can be more expressive during the social interactions and communication (Wu et al., 2022). The remix system can help address the challenges of difficulties of reflecting users’ facial expressions accurately onto avatar’s facial expressions, impossibilities of recognising cartoon characters’ facial expressions (e.g., Mora-Beltrán et al., 2020), and the uncanny valley effect (de Borst & de Gelder, 2015; Grewe et al., 2022; Kätsyri et al., 2015) in the course of pursing human-like appearance.

5. Conclusion and Future work

This study reports on the development of an avatar expression remix system which comprises four steps of user expression recognition, emotion analysis, avatar expression animation remix, and avatar expression rendering in the metaverse platform - 'Learningverse'. The study contributes to the literature regarding the development of the avatar expression remix system for avatars' seven facial expression recognition in the metaverse.

Future work will focus on evaluation of the avatar expression remix system and refinement of the avatar expression remix system. Logging functions will be developed to record student expression data in real time, combined with log data from other sources of collaborative learning activities (e.g., conversation, interaction, movement data) for multimodal learning analysis in the metaverse.

This study has its limitation. It adopts residual masking network with seven generic emotions for avatar expression remix. However, in the educational context, some other emotions, such as curiosity, wonder, and engagement (Osika et al., 2022) are more informative for teaching and learning. Future work can focus on improving the remix system by including these emotions to make avatars' expressions more relevant to educational needs.

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Tapping into Informal Learning Spaces using Metaverse and Seamless Collaborative Gamified Learning

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Abstract: *Metaverse is becoming increasingly popular in different types of everyday activities. It is most commonly pictured as a digital world in which people reside and gain knowledge using avatars while interacting with each other and various computer-generated graphics. Seamless learning describes the usage of mobile technologies to make learning a continuous process not limited by certain space or time frames, which gives the metaverse an opportunity to be a go-to technology for students when changing their learning environments. In this paper, we explore the use of metaverse to bridge the gap between informal and (non-)formal working environments. Four different scenarios were described, each of which gives insight into the uses of metaverse-based seamless learning, emphasizing the change in learning spaces and their corresponding advantages. This could allow students to effortlessly switch between formal and informal learning spaces without any limitations.*

Keywords: metaverse, education, seamless learning, gamification, collaboration

1. Introduction

The term metaverse was first described as a parallel virtual world constructed using computer technology that people all over the world could access using goggles and headphones (Mystakidis, 2022). About 30 years later, that concept has become fully achievable which resulted in virtual worlds experiencing significant development and attracting a plethora of interested parties. The metaverse, as a virtual world, provides a potential new environment for seamless learning. Seamless learning implies that a student can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using a personal device as a mediator (Chan et al., 2006). A seamless learning environment bridges private and public learning spaces where learning happens through different efforts and across different contexts (Seel, 2011).

2. Related Work

Mystakidis (2022) defines metaverse as “a post-reality universe, a perpetual and persistent multiuser environment merging physical reality with digital virtuality”. Most researchers refer to the metaverse as a digital world that allows people to reside in and acquire knowledge through the use of avatars, visualizing objects and information from the real world, and communicating, collaborating, and co-creating knowledge within (Ng, 2022). Moreover, exploration and investigation in seamless learning spaces provide a potential to extend formal learning, usually limited to the classroom, into informal learning, embracing the opportunities for out-of-school learning driven by the personal interests of students (Chan et al., 2006). With mobile technologies at hand, learning is not limited to certain spaces or time frames but takes place continuously and in different locations, students can learn seamlessly – both in the classroom and out of the classroom, both during school time and after school time (Seel, 2011). Since computers are tools that provide more efficient and effective engagement in group work processes (Dlab et al., 2020), collaborative learning (CL) is another important process defined as "an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product" (Laal & Laal, 2012). Collaborative learning drives students to greater achievement and higher productivity while giving them much-needed psychological health and self-esteem (Laal & Ghodsi, 2012). Another valuable aspect to consider is the gamification of learning experiences. Gamification has been embraced in recent years since using gameplay elements like points, badges, leaderboards, etc. can enhance the learning process (Saleem et al., 2022; Zainuddin et al., 2020). Jagušt et al. (2018) showed that using gamification could help students sustain and enhance their own performance levels, especially when using adaptive gamified conditions when challenged at a suitable level.

3. Bridging the learning spaces through Metaverse

Metaverse enables students to learn wherever they are by switching between the real world and the virtual world quickly, easily, remotely, and seamlessly using a computer or mobile phone as an intermediary, which is congruent with the premise of seamless learning (Zhang et al., 2022; Chan et al., 2006). Students' learning takes part in a three-dimensional space, a blend of formal, non-formal, and informal learning spaces. Although students spend more time in informal environments than in formal environments (Looi et al., 2010), technology has the potential to be a mediator between formal and informal learning, creating a continuous learning experience and encouraging students to learn anytime and anywhere (Chan et al., 2006), while metaverse extends this and allows students to gather and work together in virtual worlds potentially leading to improvement in communication and collaboration (Mystakidis, 2022). Although metaverse's key role is emphasized in the informal learning space dimension where it integrates into learners' tacit learning experiences, it is no doubt bound to all three previously mentioned dimensions. In general, students engage in seamless technology-supported learning in non-formal and formal learning spaces, which happens as part of the curricular topics. Students work as a team in formal and non-formal learning environments. Their work is then preserved and transferred into the metaverse environment, so they can continue engaging in this experience via virtual reality. Informal spaces contribute to enhancing and strengthening these learning experiences, which is then reflected in the non-formal and formal learning spaces.

To further elaborate on the educational potential of the metaverse across different spaces, we have created three scenarios. In the first scenario, students engage in hands-on robotics activities in-school and assemble robots individually or in small groups. These robots are then reflected as virtual gadgets in the metaverse, and students can engage with them at their own pace, coding different functions and testing the programs in virtual environment simulators. Once out of the metaverse, students' work is immediately reflected in the non-formal and formal learning spaces, facilitating the educational dynamics and ensuring seamless boundary transitions. The students then test their code in a physical world, thereby materializing the virtual designs and verifying the written programs. In the second scenario, students start their collaborative art projects as homework in a virtual environment. They create parts of the puzzle image using simple drawing tools in their metaverse classroom and try to virtually connect them into one single joint image. The homework is complete when all the students in a group agree on the final composition. In the classroom, the teacher prints out individual drawings, and students color them using watercolors and this time create a joint physical image. Finally, specific to this scenario, the teacher takes a photo of the image and puts it on the wall of the virtual classroom in the class metaverse. The third usage scenario starts as an educational board game that students play in their afterschool time. By answering the questions on the cards, students collect points, which are, as the game evolves, saved into a mobile app connected with the class metaverse data. After school, students continue playing the game in the virtual environment, but now their avatars can gain an advantage by exchanging points won in the real-world game for the virtual goods like in-game items. Again, the students solve educational problems, so they will learn or repeat the curricular topics while playing the game. The next day, the game continues in the classroom or after-class, with updated points and experience the players collected in the virtual environment the evening before.

4. Conclusions

Due to the popularity of metaverse and the importance of seamless learning in today's education, the option of connecting these two concepts in a scenario that partly takes place in the physical world (formal and non-formal) and partly in the metaverse (part of the informal world) was explored in this paper. Seamless learning is challenging for students since they are in motion between the different forms of space and time, but technology allows them to transition seamlessly between different worlds, continuing their learning experiences. The goal of this study was to explore the ways in which students transfer their real-world group work or projects to the virtual world and vice versa while maintaining the state, information, and collaborative elements. This also taps into the potential of informal learning spaces, where students already spend a significant amount of time and where their learning motivation is high. This way, learning is not limited to the school, and students are able to learn continuously, expanding the knowledge acquired at school and enriching their learning with meaningful connections with their informal learning experiences.

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Empathic Smart Learning Agent

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Abstract: *Understanding of the emotions and education stage of the learners are critical to improving the quality of both teacher-led learning as well as artificial learning companions. While the use of computer vision for emotion recognition has been studied in various applications, representations of emotional states are limited to angry, disgust, fear, happy, neural, sad and surprised. Mental states in learning including stress, focus and competent mastery have not been studied in an integrated framework. To estimate the emotion and mental state of learning, a hybrid computer vision and physiological approach is proposed. Furthermore, a machine learning framework for classifying the four stages of learning is introduced. Analysis on how a robust emotion understanding can help gauge learning progress, learning difficulties and learning well-being will be presented. Special focuses will also be given to measuring concentration in learning activities as well as measuring emotion response in learning difficult concepts. Comparisons are also conducted between electrocardiogram devices and optical wearable devices for obtaining the heart-rate-variability.*

Keywords: computer vision, heart rate variability, empathic learning, physiological monitoring, four stages of learning

1. Introduction

Emotion is an important component that influences attention, learning, and problem solving (Tyng, el al., 2017). While computer vision has been reported with some success in measuring emotion in learning (Yang, el al., 2018) and (Lasri, el al., 2019), representations of emotional states are limited to angry, disgust, fear, happy, neural, sad and surprised. Mental states models that incorporate different stages in learning such as stress, focus and competent mastery have not been studied. Heart Rate Variability (HRV) is an important physiological measure that reflects the imbalances of our autonomic nerve system (Ernst, G. 2017). The measurement of HRV is also found to correlate well stress levels in children (Michels, el al., 2013) and University students (Hjortskov, el al., 2004). Electrocardiogram-based emotion recognition is also a possible system for measuring mental states in various applications (Hasnul 2021). To resolve emotion and mental state learning issues, a hybrid computer vision and heart rate variability approach is proposed. The empathic learning agent can be applied towards assisting lead education, e-learning and other learning activities. Various machine learning models can be applied in this framework, including reinforcement learning (Akalin, el al., 2021).

In order to expand and improve on the understanding of the learning process beyond emotion, the machine learning of the four stages of learning is introduced in this work. The four stages of learning based on competence are:

1. Unconscious incompetence

   The learner does not understand or know how to do something and is not aware of the deficit.

2. Conscious incompetence

   The learner does not understand or know how to do something and is aware of the deficit.

3. Conscious competence

The learner understands or knows how to do something. However, heavy concentrations, conscious involvements and repeated practice are often required in this stage.

4. Unconscious competence

   The learner has competent mastery of the knowledge or skill and the skill can be performed while executing another task.

The stages of learning are also assessed by short questions from the teacher or from multiple questions in the case of e-learning. Videos of the emotion expression of the learner and the physiological measurement such as heart rate are recorded as additional parameters in updating the probability of the learning stages. Analysis on how a robust emotion understanding can help gauge learning progress, learning difficulties and learning well-being will be presented. Special focuses will also be given to measuring concentration in learning activities as well as measuring emotion response in learning difficult concepts. Comparisons are also conducted between electrocardiogram devices and optical wearable devices for obtaining the heart-rate-variability.

2. Computer Vision and Physiological Measurement for Learning Companion

Emotion recognition models are often trained with annotated pictures and videos of everyday life without any special focus on the education mental state. Adaptations and modifications are necessary to reflect the more subtle emotion expressed in different learning stages and activities. Furthermore, the determination of gaze is also found to be very helpful in estimating the four learning stages. variations in learners' personalities and their normative facial expressions are needed. Mental load and mental stress can be determined by physiological response. Skin impedance response has been demonstrated to be effective in measuring mental stress. However, the use of skin impedance devices on fingers and wrists often hinder various learning activities involving the hands. In this work, we evaluated the use of wearable heart rate monitors for measuring heart rate and heart rate variability. Recently, the evidence supporting the use of HRV in measuring mental state and activities are rapidly expanding. In machine learning of learning stages, the ground truth of the learning stages have to be provided by human observers. In our experiment, investigators have communicated on the definitions of the four learning stages and the teachers and parents who are familiar with the learner's progress in the subject matter provide the label of the learning stages. The confidence of the observer for fine tuning the performance of the machine learning algorithm. In the case that the truth labels for the learning stages are unavailable to the learning algorithm, the following additional knowledge and measurements are introduced and estimated using the Bayesian statistics inference framework. First prior knowledge of the expected learning competence of the learner is modeled as of probability. The initial estimate of the probability is based on average competence or peers and/or the prior competence of similar learning tasks, or provided by the teacher or parent who is familiar with the learning progress of the student.

3. Preliminary Results in Hybrid Emotion Learning

Experiment is carried out to measure the feasibility of hybrid emotion learning using HRV and computer vision. Emotion capturing experiment is conducted on a YouTube viewing session with a free choice of video selected by the subject. Video is recorded at 1280x720 resolutions and heart beat intervals and HRVs are provided by a chest-taped electrocardiogram device. The YouTube video selected by the subject is video recordings related to the Super Mario games. The subject is then asked to do regular e-learning exercises in mathematics and languages. Figure 1 shows the emotion detected in the experiment. The pink line indicates the data from part of the e-learning sessions and the blue lines are the data from the YouTube viewing session. The dominant emotion is neutral which is typically observed in most sedentary activities of young learners. Although the video is chosen by the subject from videos related to a famous computer game, the emotion of happiness is rarely detected and the emotion of fear is quite abundant. Table I shows the percentage of emotions of interest observed during these two sessions.

Table 1. Emotions of interest percentage for YouTube viewing and e-learning activities.

Emotions	Happy	Fear	Sad
YouTube viewing	4%	16%	12%
e-learning	32%	7%	14%

Figure 1. Top computer vision emotion detection result e-learning (pink line), YouTube viewing (blue line), middle: rr intervals, bottom: HRVs.

From the HRV data of Figure 1, we can see that the HRV's in the e-learning session are much larger than the YouTube viewing session. The likely reasons are firstly, fear suppresses HRV and secondly, YouTube viewing is a passive activity compared to that of e-learning exercises. While the computer vision emotion results provides useful insights into the learning state, the majority state of neutral is difficult to gauge or assess. The HRV provides useful insights in those cases where emotions results are not representative of the mental state of the learner.

4. Conclusions

Preliminary results have shown the potential of inferring emotions and learning stages from a combined framework of computer vision, physiological measurement system providing HRV. Several machine learning methods are being currently studied to improve on accuracy of the inferences of the differences in different learning stages. While the external determination of the four stages of learning by visual observations only may not be achievable for all learning scenarios, more experiments and analysis could reveal what learning levels and subjects are most appropriate for this joint estimation of competence, emotion and state of learning.

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Hong Kong: The Education University of Hong Kong.

A General Machine Learning-Based Framework for Predicting Students' Performance Given in Multi-Class Label

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Abstract: *This paper presents a general framework for predicting student performance in educational settings using machine learning techniques. The framework consists of three sequential modules: data pre-processing, feature engineering, and modeling. The framework can handle the general classification problems across different domains and contexts. We demonstrate the performance of the framework on a student performance dataset (649 students) from the UCI machine learning repository, achieving 73.8% accuracy in five-class prediction.*

Keywords: machine learning, student performance prediction, classification, educational data mining

1. Introduction

Predicting student performance is a crucial task in educational data mining, as it aims to identify students at risk of failing or dropping out, provide personalized feedback and intervention, and enhance teaching and learning outcomes. However, predicting student performance is far from trivial, as it encompasses various factors influencing students' academic achievement, such as personal characteristics, family background, school environment, and learning behavior. Furthermore, student performance data often exhibit complex structures and distributions, such as high dimensionality, multicollinearity, missing values, and outliers, creating challenges for data analysis and modeling (Yağcı, 2022). Numerous existing methods for predicting student performance depend on domain-specific knowledge and assumptions, limiting their applicability and generalizability across different educational settings and contexts. For instance, some methods employ predefined features or rules that may not adequately capture the diversity and complexity of student performance data (Baia et al., 2021). Other methods utilize simple or linear models that may not account for the nonlinear relationships and interactions among the features and the target variable (Alsammak et al., 2022). Additionally, some methods focus on binary prediction (pass/fail), neglecting finer-grained levels of student performance.

In this paper, we introduce a general machine learning-based framework for predicting student performance, capable of handling classification problems across various domains and contexts, as depicted in *Figure 1* below. The framework comprises three sequential modules: data preprocessing, feature engineering, and modeling. The data preprocessing module aims to clean and explore raw data, identifying potential issues or patterns. The feature engineering module strives to select or create the most relevant and informative features from the original data using diverse techniques. The modeling module endeavors to build and evaluate different machine learning models using tree-based methods.

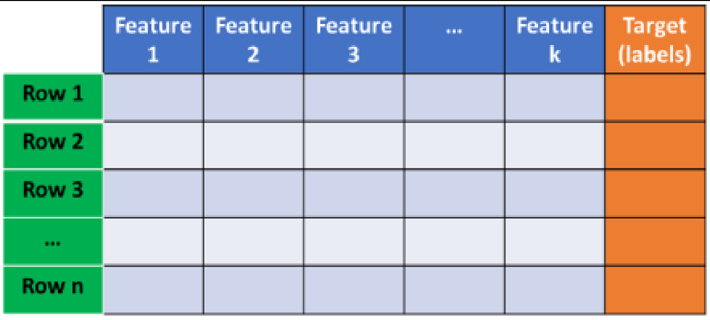

Figure 1. The General Classification Task in Tabular Form.

The remainder of this paper is organized as follows: Section 2 describes the general classification task data format that our framework can accommodate and presents the details of each module in our framework, explaining their rationale and implementation. Section 3 showcases the performance of our framework on a student performance dataset from the UCI machine learning repository (https://archive.ics.uci.edu/ml/datasets/student+performance) as a case study. Section 4 discusses the strengths and limitations of our framework and offers directions for future work. Section 5 concludes this research.

2. Methods - The General Framework for Classification Task

Our framework comprises three main sequential modules as shown in *Figure 2*, starting with the pre-processing data module, then the feature engineering module, and ending with modelling module. For simplicity, we use M1, M2, and M3 as the abbreviation for Module 1, Module 2, and Module 3).

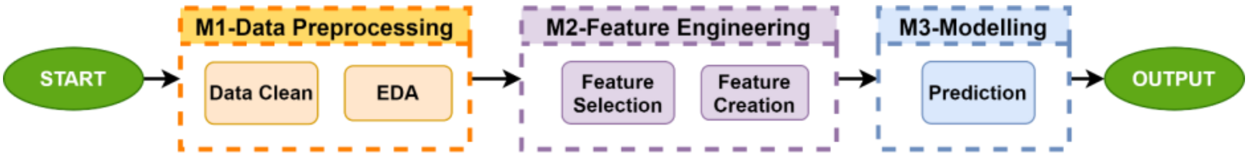

Figure 2. The Three Sequential Modules in our Framework (M1, M2, and M3).

2.1. M1-Data Pre-processing

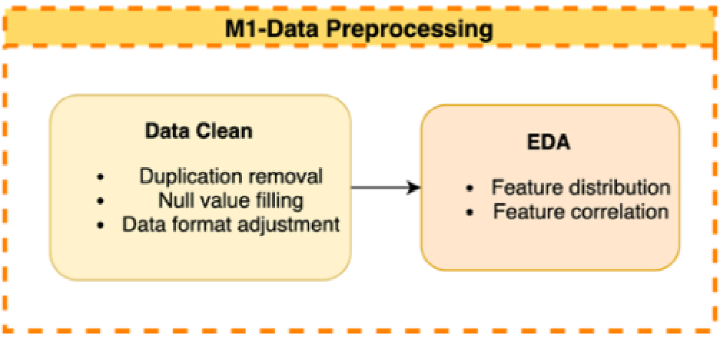

Figure 3. The M1-Data Pre-processing.

M1-Data Pre-processing is composed of two sequential sub-modules: Data Cleaning and Exploratory Data Analysis (EDA). The Data Cleaning sub-module removes duplicated data points, detects null or missing values, and adjusts data formats. Some educational data contains missing values, two primary options are removal or imputation, and the choice depends on the specific situation. For tasks with few null values, removal may be appropriate; however, for problems requiring a sufficient amount of data, imputation could be used. By default, our framework fills null values using the mean, but it also provides the option to use k-Nearest Neighbors (kNN) imputation when data exhibits local patterns or when missing values are not missing completely at random.

The EDA sub-module serves to investigate feature and target label distributions and analyze relationships between features (correlation). This is achieved through a combination of data visualization and statistical approaches. Features can be categorized as numerical or categorical based on data types. For continuous variables, Kernel Density Estimation (KDE) plots are employed, while count plots are utilized for categorical variables. Visualization techniques offer a comprehensive overview of the dataset, revealing the most common value ranges for numerical features and the most dominant classes for categorical data, thus providing insights into the data's characteristics.

2.2. M2-Feature Engineering

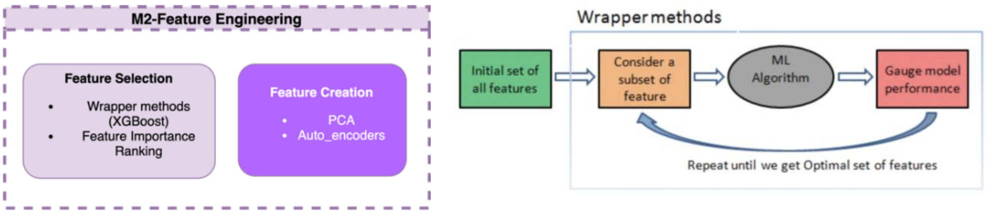

Figure 4. The M2-Feature Engineering (Left: Module Content; Right: Feature Selection Mechanism).

The feature engineering module aims to select or create the most relevant and informative features from the original data using various techniques. The module consists of two sub-modules: feature selection and feature creation (optional).

The feature selection sub-module uses a wrapper method to select a subset of features that maximizes the performance of a specific machine learning algorithm. The redundant features would be the bottleneck for most classification algorithms and significantly reduce the explainability model itself. We use XGBoost as the standard algorithm because of its good performance and high tolerance of data quality. Besides we also print out the feature importance based on our selected subset of features. This could help us understand the predictor's degree of impact on the target, which contributes to the model result explanations.

For optional feature creation, two methods are provided: Principal Component Analysis (PCA) and Auto-Encoders. PCA is a traditional method that transforms the features into orthogonal components that explain the most variance (Heaton, 2016). PCA works well for datasets with many features and a clear linear structure. Auto-Encoders are neural network models that learn to encode and decode the data into a lower-dimensional representation (Zhang et al., 2017). Auto-Encoders can outperform PCA for large and non-linear datasets. We use the Silhouette Coefficient to evaluate Auto-Encoders, which measures how well each data point belongs to its cluster. It ranges from -1 to 1, with higher values indicating better clustering.

2.3. M3-Modelling

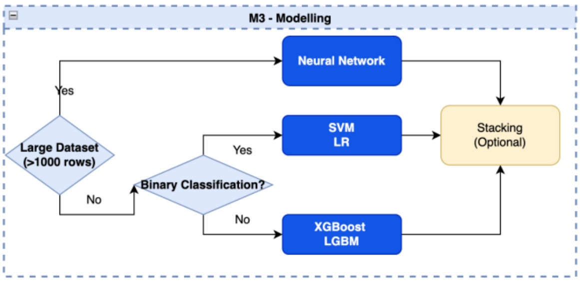

Figure 5. The M3-Modelling Composition.

The modeling module aims to build and evaluate different machine learning models using suitable algorithms for the data size and the target type. The module has three branches: large dataset, normal size dataset binary classification, and normal size dataset multi-class classification. For large datasets (>1000 data points), we use neural networks to leverage their high capacity and flexibility. For normal size datasets with binary targets (pass/fail), we use SVM and logistic regression, which are classic and robust methods for binary classification (Zhang et al., 2017). For normal size datasets with multi-class targets (e.g. A/B/C/D/F)), we choose XGBoost and LGBM due to their ability to handle imbalanced datasets and produce highly accurate results with relatively low computational cost (Ke et al., 2017). These algorithms have also demonstrated strong performance across various domains, making them highly versatile for multi-class classification tasks. We use random search cross validation to optimize the parameters for each model and compare their accuracy and speed. We also provide the option for model ensemble techniques to combine multiple models and improve the robustness and performance of the prediction.

3. The Case Study: Student's Performance Prediction using UCI Open-Sourced Dataset

We applied our framework to the student performance dataset (student-por.csv) from the UCI machine learning repository (https://archive.ics.uci.edu/ml/datasets/student+performance). The dataset consists of 649 records of students' personal, family, and academic information, as well as their final grades in five classes (A/B/C/D/F). We used 90% data (584 students) for training and 10% for testing (65 students).

3.1. M1 Output: Pre-Processing and EDA

-Pre-Processing: Our framework first checks the raw data and finds no missing or duplication occurred. Therefore, no clean operation is required.

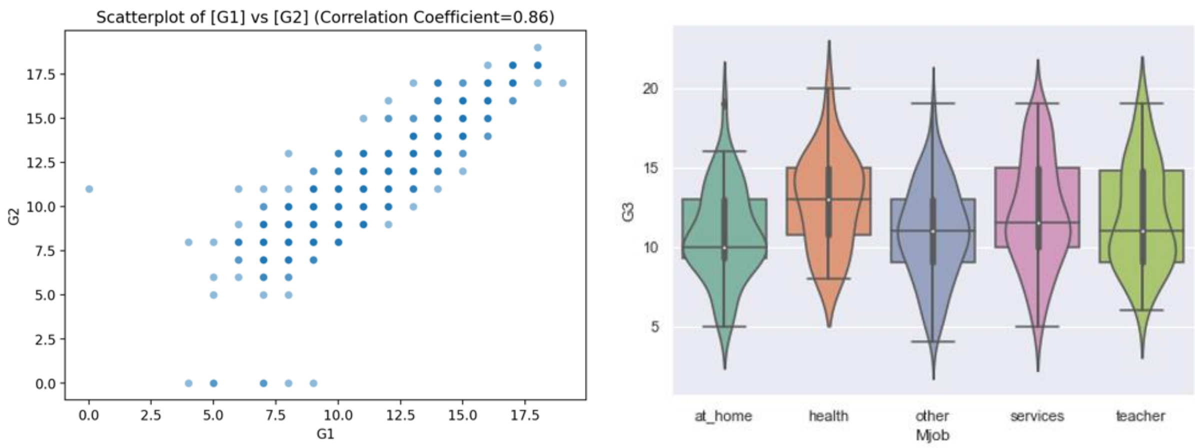

Figure 6. EDA Partial Result (Left：Bivariate Scatter Plot; Right:Categorical Feature Distribution).

-EDA: From the above Figure, we can find that:

- Left: Student's 1st and 2nd period Grade (G1 and G2) is highly correlated (Pearson Correlation Coefficient 0.86).
- Right: categorical feature student's Mother's job (Mjob) in teaching, health, and services have higher grades.

3.2. M2 Output: Feature Engineering (Feature selection + Feature importance ranking)

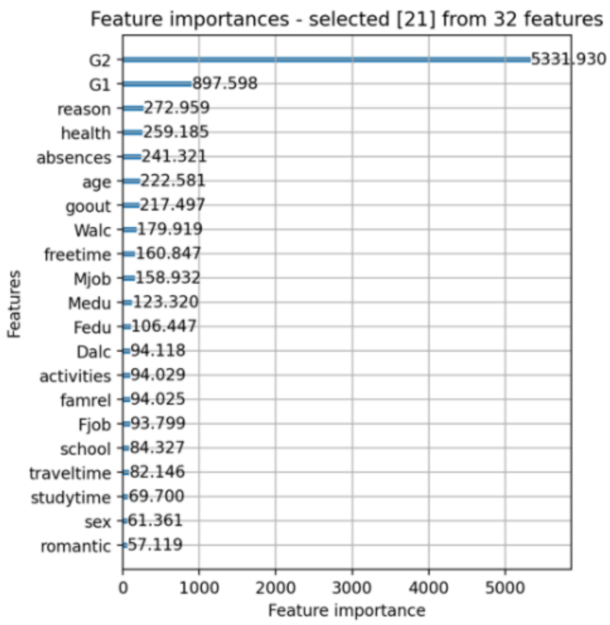

Figure 7. Feature Importance Ranking after wrappers method.

Here we use 5-fold cross-validation to find that five features are the optimal choice for our models (initially, we have 32 features). The feature importance is shown in *Figure 12* from the most influential factor (G2) to the least one (romantic). Therefore, we select those 21 features as the input predictors.

3.3. M3 Output: Modelling Result

Figure 8. Multiple Class Classification Model Comparison.

Given the limited size of our dataset (649 data points), we opted not to use a neural network for classification. Furthermore, stacking was not implemented as it was deemed unnecessary due to the absence of a neural network and the similarity between the chosen algorithms, XGBoost and LightGBM (LGBM), both of which effectively prevent overfitting. Figure 8 below illustrates the test set model performance using data from 65 students.

The decision to select XGBoost and LightGBM as the default algorithms for the educational data classification task was influenced by their superior performance over the baseline model, which utilized a decision tree with an accuracy of only 60%. In predicting the ABCDF class, XGBoost achieved an accuracy of 64.6%, while LightGBM demonstrated an even better accuracy of 73.8%.

4. Discussion

In this paper, we proposed a general machine learning-based framework for predicting students' performance in educational settings. The framework consists of three sequential modules: data preprocessing, feature engineering, and modeling. We applied the framework to the UCI student performance dataset and obtained promising results.

In the discussion section of our research paper, we highlight the suitability of boosted tree models for educational datasets, which frequently exhibit characteristics such as small sample sizes and limited class or program sizes. The boosted tree models' algorithmic mechanisms, including XGBoost and LightGBM, offer several advantages that make them an ideal choice for this context. Firstly, these models are robust to overfitting, as they employ a combination of weak learners (shallow decision trees) to create an ensemble model (Almasri et al., 2019). This approach allows them to learn complex patterns in the data while minimizing the risk of overfitting, which is crucial when working with small datasets (Zhang et al., 2017). Secondly, boosted tree models can efficiently handle imbalanced class distributions, often present in educational datasets, by adjusting sample weights to enable more accurate predictions and better performance (Cortez & Silva, 2008). Furthermore, interpretability is essential in the educational context, as it helps to understand which features contribute most significantly to student performance. Boosted tree models provide feature importance measures, making it easier to identify and interpret the relationships between input variables and the target outcome. Lastly, these algorithms are highly flexible and scalable. They can efficiently handle both continuous and categorical variables, as well as missing data, making them well-suited for educational datasets containing diverse and incomplete information (Zheng & Casari, 2018). Additionally, they can effectively handle larger datasets as more data becomes available.

5. Conclusion

In conclusion, our framework was able to extract relevant features and their interactions from the original data using a wrapper method. We selected 21 predictors out of 33 attributes that had the highest importance for the classification task. These predictors reflect both the academic and personal factors that influence students' performance. Using these predictors, our framework achieved an accuracy of 73.8% in predicting students' grades in five classes (A, B, C, D, F). This LGBT accuracy is higher than some previous studies proposed algorithm such as random forest used by Cortez & Silva in 2008. Our framework also provided insights into the relationships between the predictors and the grades, as well as the distribution and characteristics of the data in EDA section.

However, our framework also had some limitations that need to be addressed in future work. One limitation was the small size of the dataset (649 records), which prevented us from using more techniques such as neural networks or stacking models that require larger datasets to produce reliable results. Another limitation was the lack of external validation or generalization of our framework to other datasets or domains.

Therefore, we suggest some recommendations for future research based on our framework. One recommendation is to develop an easy-to-use web application that can allow non-engineer users to apply our framework to their own datasets and obtain predictions and insights. This would increase the accessibility and usability of our framework for educators and researchers who want to use machine learning methods for student performance prediction. Another recommendation is to explore other classification algorithms or methods that may further improve the efficiency and accuracy of our framework.

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Design and Develop a Learning Environment with Dynamic Scaffoldings for Primary Students' Mathematical Problem Solving

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Abstract: *The research aimed to comprehensively analyze the notion of dynamic technology-supported scaffoldings which has great potential for relieving learners' cognitive burden and mathematics learning difficulties (MLD) in addressing the problem-solving process when integrated with appropriate pedagogical design. By adopting the structural ScaffoldiaMyMaths system data and proposed experiments, we hope to investigate the impact of learning environment-enabled dynamic scaffoldings and provide sufficient technical support for instructors and students in promoting primary learning and mathematics education.*

Keywords: dynamic technology-supported scaffoldings, learning difficulties, mathematics education, primary schools

1. Introduction

As a key subject in Hong Kong curricula, mathematics education always attracts attention. In the current situation, students with mathematics learning difficulties, who have persistent low mathematics performance without a disability diagnosis, need more care and facilitations whether in or out of the complete e-learning environment (Swanson, Lussier & Orosco, 2013). In such situations, a more interactive and tailor-made mathematics learning environment named *ScaffoldiaMyMaths* is developed to accommodate diverse students and meet students' different needs, particularly those with learning difficulties.

2. Methodology

2.1. Design Principles of ScaffoldiaMyMaths

Scaffoldings have great potential for relieving learners' cognitive burden and difficulties in addressing the problem-solving process when integrated with appropriate pedagogical design. This is particularly true of dynamic technology-supported scaffoldings (Quintana, et al., 2004). On the basis of the aforementioned, it appears worthwhile to examine the effect of dynamic technology-supported scaffoldings in maths problem solving among Hong Kong primary school students with MLD in the research. In terms of scaffolding change, there is consensus among researchers that scaffolding can be customized with different patterns of fading, adding, fading/adding, or none on the basis of performance, self-selection, a fixed schedule, or none (Pea, 2004) but no study has examined the effect of fading scaffolding, especially by comparing the effect of fading and both adding and fading, among students with LD.

The principles of context-specific scaffolding together with dynamic scaffoldings have been employed in the system。 In *ScaffoldiaMyMaths*, the instructional lessons will be composed of five sets of problems in Fractions: where each set consists of 10 tasks with the same underlying structure (i.e., solution rationale) but different surface characteristics (i.e., cover stories and values). For each task, we design the scaffoldings accordingly. Explanation prompts in the form of workout examples and problems (EP) will be designed as the key representative scaffoldings (Atkinson & Renkl, 2003). The scaffolding is designed to be run under these four different conditions: 1) fixed fading scaffolding; 2) fixed adding and fading scaffolding; 3) performance-based fading scaffolding; and 4) performance-based adding and fading scaffolding.

2.2. Research Methodology

The study has a 6-8 month cluster randomized, experimental-control intervention trial involving a screening phase, a pre-and post-test assessment phase (standardized tests for fractions word problems, Mathematics self-concept and motivation tests), and an intervention phase via *ScaffoldiaMyMaths*. The sample size of the proposed study is estimated using a power analysis. With a power of 95% and an alpha level of 0.05, a sample size of around 520 primary students is needed to detect a difference between the combinations of the intervention with an effect size of 0.6 based on a recent study (ter Vrugte et al., 2017). We assume that the dropout rate over the study is 10% and the clustering effect is 0.01. After taking these two factors into consideration, an initial sample size of 572 is required. Students with MLD will be recruited and identified by the following criteria: 1) they are enrolled in Primary School Grades 4, 5, and 6; 2) items from KeyMath-3 Diagnostic Assessment (KeyMath-3 DA) will be validated and used for comparatively accurate selection of students with MLD (Connolly, 2007). This assessment was developed for students aged 4 years 6 months to 21 years 11 months. The test measures three general mathematics content areas: basic concepts, operations, and applications; the cut-off score is 35% (Murphy, et al., 2007); 3) demonstrate a deficit in the target skill by earning a cut score at or below 30% accuracy on a researcher-developed screening test on fraction word problems (Shin and Bryant, 2017); and 4) normal or above-normal intelligence with referencing their IQ scores if applicable (Jitendra, et al., 2002); On the other hand, students who are typical achievers will be identified by their school teachers based on their semester exam scores in Mathematics. We will randomly select 40 primary schools through internal (i.e., the personal relationship of team members, recommendations from colleagues) and external recruitments (i.e., on-campus posters, emails, phone calls and social media). The participants under each condition need to go through the Fractions problem-solving test, Mathematics self-concept and motivation test with identical pre and post-tests. As mentioned above, 520 students will be randomly assigned in approximately equal proportions to the cells of a 2 x 2 x 4 between-subjects factorial design. Thus, 260 students will be assigned into experimental groups with 130 MLD students (32-33 students will be assigned to four scaffoldings conditions with 10-11 students from each grade).

3. Anticipated Results and Discussion

To consider the hierarchical data structure (different primary schools and different districts), the data will be analysed using multilevel structural equation modelling (ML-SEM) (Lüdtke et al., 2008) with the MPLUS software (Muthén & Muthén, 2007) to identify the intervention effect while considering the clustering effect of the data. To obtain further information, 2 (students with MLD versus typical achievers) x 2 (fading scaffolding versus fading and adding scaffolding) x 2 (fixed scaffolding versus performance-based scaffolding) three-way MANCOVA will be conducted on dependent variables including the conception of fraction, mathematics self-concept and motivation using the pre-test scores as the covariate. So that to discuss that are the impacts of *ScaffoldiaMyMaths* supported learning in terms of four scaffoldings on students' performance and the interaction effect of the scaffolding changes and the scaffolding logic on students' maths problem-solving. As well as what are the changes in self-concept and motivation between students with MLD and typical students impacted by *ScaffoldiaMyMaths* supported learning. Hedge's g will be employed to represent the intervention effect size by CMA3.0. Additionally, we will utilise an "intention-to-treat" analysis to assess differences in outcome that incorporate those participants not completing the study.

4. Future Plan

Moreover, much research has emphasized that students' voices are important on this issue. Therefore, future research should investigate students' opinions regarding online learning to examine the challenges faced by students, and more care should be paid to underprivileged and lower-ability children (Keefe, 2020). Thus, the current situation triggers us to accelerate technological development and pay more attention to preparing teachers and students to adapt optimally to the uncertainty of the post-pandemic arena.

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Chatbot and Bridge of Multiplayer Educational Game World and Summary Generation Service

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***Abstract**: This work-in-progress paper presents the development of chatbot as an add-on to an existing multiplayer educational game world (MEGA World) and the chatbot bridge that accesses the existing summary generation service (Ask4Summary). The chatbot in the game world acts as an interface between the student and the course content. With the existing research's supports – as long as teachers can create virtual worlds in MEGA World to grant their students game-based learning and assessment opportunities and experiences and they can feed course relevant teaching and learning materials (in different text formats such as Microsoft Word docx file, Microsoft PowerPoint file, pdf file, or webpage in HTML format) into Ask4Summary – this on-going project can then provide students assistance in learning, to provide summaries for the questions according to the course materials, and to improve student's game-based learning experience and performance at the same time. In the end of this paper, the evaluation plan is also explained.*

Keywords: chatbot, natural language processing, educational game, human-computer interaction, online learning.

1. Introduction

Nowadays online learning is gaining popularity for reasons of the availability of high-speed internet and subject-specific e-contents. Online learning system: (i) is a learner-centric environment, (ii) enables learners to learn at their own pace and time at any location, (iii) offers optimized utilization of resources, and (iv) provides quality learning opportunities. Online learning can be broadly classified into two main modes: asynchronous and synchronous. Asynchronous learning is self-paced and involves studying learning materials independently. This mode may also include interaction with a tutor or instructor through discussion forums, emails or messaging. Synchronous learning, on the other hand, is tutor-led and takes place in real-time through pre-scheduled online classes using platforms such as Microsoft Teams, Google Meet, or Webex (Nagarajan & Wiselin, 2010).

The popularity of computer games, coupled with their engaging and immersive nature, has inspired academics to develop game-based online learning modules (Tobias & Fletcher, 2007). Game-based learning utilizes a similar concept by creating an engaging and enjoyable learning experience, allowing learners to acquire knowledge with greater ease and gradually increasing the difficulty level. Educational games are interacting, have motivational qualities, enhance the cognitive process, and have a gradual increase in difficulty level, hence, resulting in improved learning performance and understanding of the subject (Tobias, S. et al., 2011).

In educational games non-player controlled characters (i.e., NPCs) play an important role by providing necessary guidance, navigation, and even answers to the queries of the learners (Virvou & Katsionis, 2008; Yin, et al., 2021). These NPCs are mostly animated characters resembling humans or cartoon characters (Dehn & van Mulken, 2000). Chatbots –

can act like NPCs – are mainly conversational agents that are designed for Human-Computer Interaction (HCI) and provide a conversation platform much similar to human natural language conversation (Winkler & Söllner, 2018). Human-Computer Interaction (HCI) focuses on the design, evaluation, and implementation of interactive computing systems for human use. It involves the study of how people interact with technology and how technology can be designed to better support human needs and tasks (Rogers, Y. et al., 2011). Chatbots are using algorithms to process natural language and work mainly on a rule-based algorithm or artificial intelligence-machine learning (AIML). As an example, Chatbot A.L.I.C.E. is following the rule-based NLP algorithm (Wallace, 2009) and Charlie Chatbot is developed by Mikic et al. (2009) based on AIML to provide interactions with learners on an online learning platform.

Chatbots play important role in the education field, provide a desired interface between learner and learning setup, examples include the English learning chatbot BookBuddy (Ruan, et al., 2019), the intelligent course tutor chatbot Sammy (Gupta & Jagannath, 2019), and the MOOC collaborative chatbot colMOOC (Tegos, et al., 2019). The educational chatbots have a wider role and may have one or more of the following objectives: (i) to support and monitor learning objectives and progress, (ii) to respond learner questions, (iii) to get learners motivated, and (iv) to help human teachers/tutors understanding learner academic performance.

2. Existing Research – MEGA World and Ask4Summary

The proposed chatbot and its bridge has been considered, analyzed, and implemented on existing educational game world research, MEGA World (https://megaworld.game-server.ca/), and summary generation service, Ask4Summary (https://ask4summary.vipresearch.ca/). Both existing research are open access without fee so the outcome of this proposed research can also be accessible by everyone. MEGA World is a multiplayer game in which the learners (as players) can interact with non-player characters (NPCs), items, and other learners/players. MEGA World as an educational game platform was proposed and developed by Chang and Kinshuk (2010). In MEGA World, teachers can design as many learning activities with multiple learning objectives as they want and their students can explore the chessboard-like game world (see Figure 1) to complete the learning activities (Kuo, et al. 2010). In this game, players (i.e., learners) are offered a variety of different quests that are designed and can be used to measure their proficiency in school subject matters.

MEGA World supports any language and is capable of accessing any existing external resources (e.g., multimedia, materials, online meetings, etc.) (Chang & Kinshuk, 2010). Teachers can create their virtual worlds as well as create learning and assessment activities (i.e., quests in the game) for students. Students can learn specific knowledge and reach the learning goal by taking and solving those quests while playing (Kuo, et al., 2010). MEGA World currently has eight quest types include speaking (Chang, et al., 2019), greeting, item collection and delivery, sorting, treasure hunting and digging, calculation, fill-in-the-blank, and short answer quest type. Teachers are also provided editors like map and quest editors so they can freely expand their game worlds and design quests in different levels for different subjects/topics according to their own teaching plan.

Figure 1. MEGA World.

Ask4Summary (Pal, Chang, & Iriarte, 2021) has a system periodically running backend services to process text-based content (e.g., a course's learning materials). When Ask4Summary processes these text-based content, it uses Natural Language Processing (NLP) techniques that include tokenization, n-grams extraction, and part-of-speech (PoS) tagging. Ask4Summary allows teachers to upload their teaching and learning materials for the machine to read and digest a couple of days before the semester. After Ask4Summary has processed text-based materials (in different file formats like PDF, DOCX, PPTX, and webpages in HTML), it can start serve learners by generating summaries for their course relevant questions. It identifies the keywords from a user’s question and uses cosine similarity to summarize the associated content and present to the user. Ask4Summary can serve learners via web system and Moodle plugin (Saleh, Chang, & Iriarte, 2022).

3. Chatbot and Its Bridge

The proposed research includes the development of the user interface in MEGA World (i.e., the Guardian in the game world), the bridge (i.e., the Bridge) between the user interface and Ask4Summary (referring the published algorithm and the source code of Ask4Summary Moodle plugin). The proposed components use multiple programming languages as well as frameworks, including Python for running backend services, PHP for server-side scripting, AJAX and JSON for communication endpoints and data package, MariaDB for database, and HTML, CSS, and JavaScript for the website development.

The chatbot (i.e., the Guardian) is added to the bottom of the game panel (see Figure 2). The Guardian panel has the option for learners (i.e., players) to edit/recreate their own Guardian avatar. By clicking on the Guardian avatar a window opens where the players can have a conversation with their Guardian.

Figure 2. Guardian Panel in MEGA World.

When a player signs into MEGA World for the first time, a Guardian is automatically created and linked with the player. In case the player isn’t satisfied with the outlook of his or her Guardian, he or she can change its outlook or even create a new one. No matter what outlook the generated Guardians have, they have no difference at this moment in terms of responding to players’ questions. In the future, however, the research considers making different Guardians to have different characteristics, personality, response styles, and perhaps emotions. Therefore, currently the research can have clear idea about what kind of outlook Guardians might need to have to make players satisfied; but in the future, the research can investigate what characteristics, personality, or response styles a chatbot should have so it can help learners more efficiently.

When a player asks his/her Guardian a question, the question is first stored in the database at the Guardian side (e.g., keep it in the Guardian mind) and then sent via AJAX to the Guardian Bridge (e.g., a librarian) to find the summary for the question. The Bridge returns a confirmation token which is later used by the Guardian for checking the job status. Upon getting the summary from the Bridge, the Guardian will talk back to the player. Figure 3 shows the workflow and the architecture of the Guardian and the bridge.

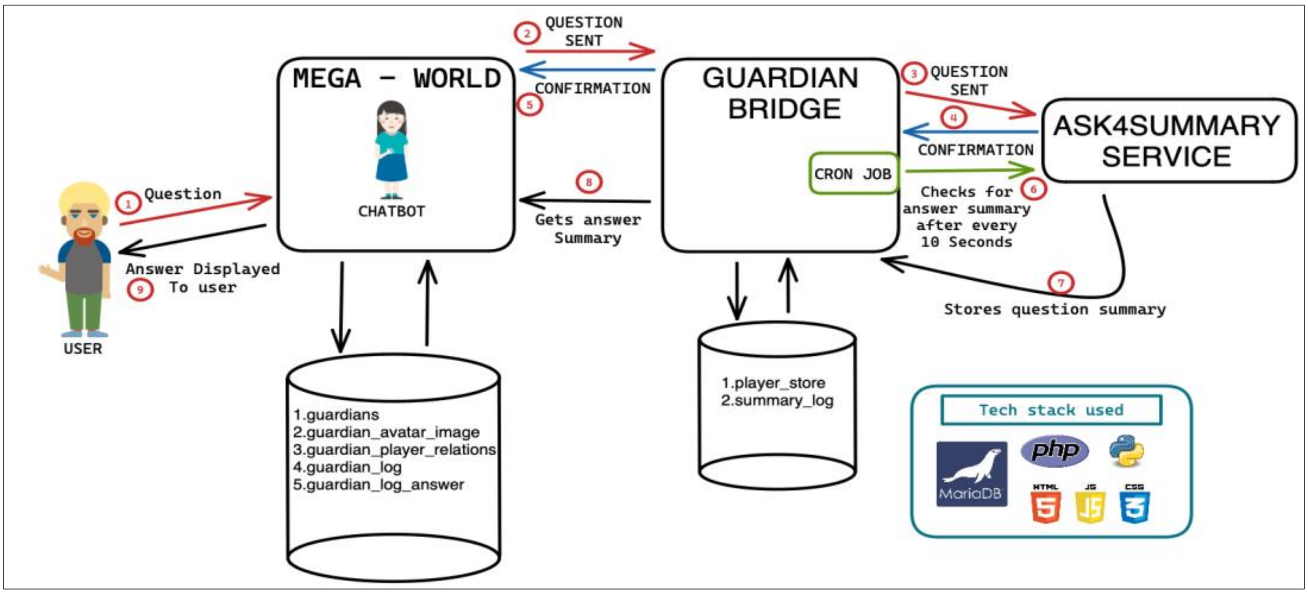

Figure 3. Chatbot Architecture

4. The Use Case

To use the Guardian players need to create an account and at least one avatar in MEGA World, will create an entry in Guardian_player_relations table which is responsible for linking the player to Guardian. Each avatar created by the players has its own Guardian. The conversations between an avatar and a Guardian are also remembered by individual Guardian.

As Figure 2 shows, the way for the players to interact with their Guardian is on the bottom game panel. The players can click the Guardian panel and change how their Guardian avatar looks the same way they can change their player avatar. When the players click their Guardian, a chat window for them to talk to the Guardian opens up. The chat window contains all the previous chat messages between the particular avatar – remember, a player can have more than one avatar and each avatar will have its own Guardian; the chat window will only show the historical records between specific avatar and its Guardian even when two avatars choose the same Guardian. Within this window, the players can send messages to their avatar's Guardian.

To ask a question the players can enter the question and either hit the Enter key on the keyboard or click the Send button on the screen. When the question is received by the Guardian, it will be stored in the "Guardian_log" table along with the "player_id" and "direction" (i.e., either coming from the players or the Guardian). After that, the Guardian sends the question to the "Guardian Bridge" which is further forwarded the question to Ask4Summary service. The Ask4Summary generates the summary related to the question and based on the course materials by finding the best matches with cosine similarity method. Figure 4 shows that the Guardian responds to the players for their questions with the generated summaries received from Ask4Summary.

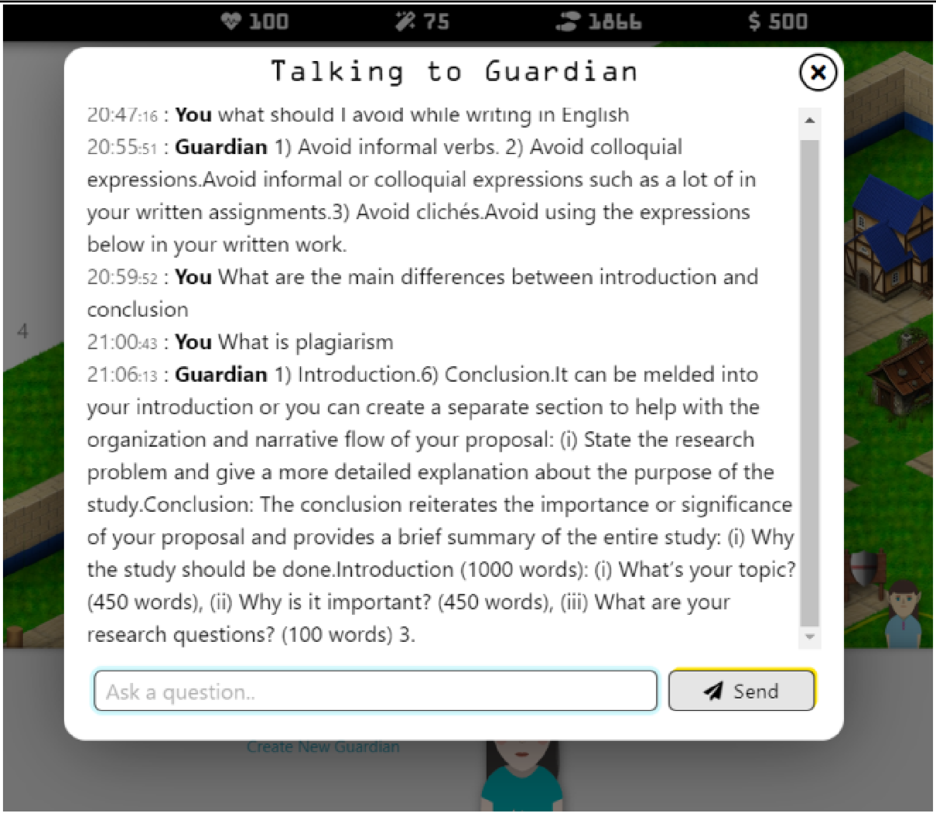

Figure 4. Guardian provides the generated summaries for players' questions.

The chatbot can assist students in completing in-game quests created by instructors. For instance, an English learning quest created by an instructor may require the student to write a sentence in English. Using the chatbot, a student can ask a question such as, "what should I avoid while writing in English?" The generated summary can then guide the student in formulating an answer and help them avoid errors that might occur when writing in English.

5. Evaluation Plan

The proposed research considers doing an evaluation with control and experiment group to assess the effectiveness of the Guardian feature in the educational game and the usability of the Guardian. Students in both groups will use MEGA World as a supplemental educational resource for a course. Students will be asked to fill out pre-survey questionnaires (include computer game attitude scale and learning motivation toward the course) anonymously – the evaluation will have no restriction on the player account and avatar creation; therefore, there is no way for the teacher or the research team to identify a student from his or her player account and avatar. Students in the control group will be provided the link to access Ask4Summary's web system by the Guardian, while the students in the experiment group will be able to ask their questions directly via the Guardian. At the end of the course, students will be asked to fill out post-survey questionnaires (include learning motivation toward the course and system usability scale toward the Guardian feature. With the collected data, the research team could have better idea on (i) whether the Guardian feature in the educational game is appreciated? (ii) would the usability of Ask4Summary-enabled Guardians be rated better? and, (iii) would the access of the game and/or the Guardian have impact on students' learning motivation? The research team can further do collaboration research on (iv) the effectiveness and correctness of generated summaries and (v) the impact of the satisfaction degree of generated summaries – rated by the course teacher – on students' perceived usability toward the Guardian feature.

6. Conclusion

The implementation of the chatbot in MEGA world allows students to ask more questions as it appears as an avatar within the game environment. In contrast, other available chatbots like BARD-google or chatGPT require students to leave the online learning platform. In the future, the chatbot's functionality can be improved by (i) limiting the user from asking additional questions while the chatbot generates a summary for the last question, (ii) altering the chatbot's persona based on the player's interaction, and (iii) using a faster NLP algorithm to generate summaries more quickly. However, the current chatbot is constrained by several factors, including (i) the quality and relevance of the corpus provided by the instructor, which affects the correctness of generated summaries, and (ii) limited computational resources that slow down the summary generation process.

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