西南大學
SOUTHWEST UNIVERSITY

GCCCE2024

第28届
全球华人计算机教育应用大会

The 28th Global Chinese Conference on Computers in Education

中国 重庆 | 西南大学(北碚校区)

Chongqing,China
Southwest University(Beibei Campus)

2024年6月1日—6月5日

June 01, 2024 —June 05, 2024

大会论文集(英文论文)

Main Conference Proceedings(English Paper)

教育学部

Publisher: Global Chinese Conference on Computers in Education
Title: Conference Proceedings (English Paper) of the 28th Global Chinese Conference on Computers in Education (GCCCE 2024).
Editors: Hui-Chun Chu, Daner Sun, Yu Lu, Jerry Chih-Yuan Sun, Siu Cheung Kong, Geping Liu
Edition date: 2024.06
Edition: princeps
ISSN: 3005-3226

第 28 届全球华人计算机教育应用大会

The 28th Global Chinese Conference on Computers in Education

GCCCE 2024 大会论文集 (英文论文)

GCCCE 2024 Main Conference Proceedings (English Paper)

Editors

Hui-Chun Chu, Soochow University, Taiwan

Daner Sun, The Education University of Hong Kong, Hong Kong

Yu Lu, Beijing Normal University

Jerry Chih-Yuan Sun, Yang Ming Chiao Tung University, Taiwan

Siu Cheung Kong, The Education University of Hong Kong, Hong Kong

Geping Liu, Southwest University

Table of Contents

EPT 4

Poster Session A

Poster Session B

1. Message from the Organizer

The Global Chinese Conference on Computers in Education (GCCCE) is a bilingual (Chinese and English) international academic conference organized by the Global Chinese Society for Computers in Education (GCSCE). It has developed into an annual event for Chinese and non-Chinese scholars, educators, and policy makers around the world to share and exchange the latest research results in the field of computer education applications. The 28th Global Chinese Conference on Computers in Education (GCCCE 2024) was held from June 1 to June 5, 2024 at Southwest University. In response to the advent of the artificial intelligence era and its impact on digital learning environments, the theme of this year's conference is "Reshaping the Future Learning Spaces with Intelligent Learning Environments."

The GCCCE conference brings together education policy makers, scholars, educators, principals, and frontline teachers from around the world to exchange and share the latest research work and achievements in computerized education applications. The conference program includes keynote speeches, paper presentations, workshops, doctoral forums, K-12 teacher forums, and corporate exhibitions. Meanwhile, the EPT (English Paper Track) was established for the fifth time in this conference, and a total of 45 article submissions were received. This demonstrates the growing attention from non-Chinese researchers to the GCCCE Conference over the past five years, attracting numerous authors from English-speaking countries to participate and exchange ideas. Furthermore, this year's GCCCE will continue the tradition of the previous conference by arranging two English keynote speeches and inviting two top international scholars to deliver the talks.

Since the Covid-19 pandemic, this is the first time that the conference has canceled online participation and replaced it with physical interaction. It is hoped that after three to four years of the Covid-19 epidemic, this conference will restore the physical interaction between scholars and enhance the friendship among the global participants. The GCCCE 2024 conference includes ten conference themes:

C1: Learning Sciences & Computer-Supported Collaborative Learning

C2: Mobile, Ubiquitous & Contextual Learning

C3: Joyful Learning, Educational Games & Digital Toys

C4: Technology in Higher Education & Adult Learning, and Teachers’ Professional Development

C5: Technology-Enhanced Language and Humanities Learning

C6: Artificial Intelligence in Education & Smart Learning Environments

C7: Learning Analytics & Assessments

C8: STEM & Maker Education

C9: Educational Technology: Innovations, Policies & Practice

EPT: English Paper Track

Within EPT and each sub-conference, an Executive Chair, Co-Chairs, and Program Committee (PC) Members were appointed to manage the review and programming processes. Some sub-conferences also have review committee members and advisors. GCCCE 2024 invites Chinese paper submissions from Chinese scholars worldwide and English paper submissions globally. This conference has received a total of 375 submissions from 692 authors. These paper submissions come from nine countries and regions, including China, Taiwan, Hong Kong, Singapore, and Macau. The statistical data of the regions of the submitting authors are shown in Table 1.

Table 1. Statistics of the regions of authors submitting to the nine sub-conferences and EPT of GCCCE 2024

Region	CN	TW	HK	SG	MO	KZ	KR	AU	CL
No. of author	631	116	22	20	11	4	2	1	1
No. of papers	310	47	10	11	7	0.4	1	1	1
No. of Accepted papers	228	46	7	7	6	0.4	1	1	1

Note: CN – China, TW – Taiwan, HK – Hong Kong, SG – Singapore, MO – Macau, KZ – Kazakhstan, KR - South Korea, AU – Australia, CL – Chile

Each submission was assigned to at least three PC members for the first round of review. The results were then meta-reviewed by the chair and co-chairs of the corresponding sub-conference or EPT before a final decision was made. Through this rigorous review process, 253 papers were accepted (see Table 2), with an acceptance rate of 67.4%. Among them, 6 papers were nominated for the Best Chinese Research Paper Award (limited to long papers accepted by the sub-conferences), 4 were nominated for the Best English Research Paper Award (limited to long papers accepted by the EPT), 5 were nominated for the Best Student Paper Award (limited to long papers accepted by the sub-conferences and the EPT), 5 were nominated for the Best Technical Design Paper Award (limited to long or short papers accepted by the sub-conferences and the EPT), and 4 were nominated for the Best K-12 Teachers' Paper Award (limited to long or short papers accepted by the K-12 Teachers' Forum).

Table 2. GCCCE 2024 The status of submissions and acceptance for each sub-session

Sub-conference	Submission	Accept	Full paper	Short paper	Poster	Elimination	Acceptance Rate
C1 Learning Sciences & Computer-Supported Collaborative Learning	46	33	17	14	2	9	72%
C2 Mobile, Ubiquitous & Contextual Learning	20	13	5	5	3	7	65%
C3 Joyful Learning, Educational Games & Digital Toys	31	22	14	8	0	9	71%
C4 Technology in Higher Education & Adult Learning, and Teachers' Professional Development	37	28	16	6	6	9	76%
C5 Technology-Enhanced Language and Humanities Learning	22	17	11	5	1	5	77%
C6 Artificial Intelligence in Education & Smart Learning Environments	75	43	23	15	5	32	57%
C7 Learning Analytics & Assessments	35	23	11	9	3	12	66%
C8 STEM & Maker Education	36	26	12	8	6	10	72%
C9 Educational Technology: Innovations, Policies & Practice	28	21	7	9	5	7	75%
EPT	45	26	12	10	4	19	58%
Total	**375**	**252**	**128**	**89**	**35**	**123**	**67%**

This conference has invited four academic experts to deliver keynote speeches. They are Dean Luo Shengquan from the Faculty of Education at Southwest University, Prof. Jim Slotta from the University of Toronto, Prof. Chen Wenli from Nanyang Technological University in Singapore, and Chair Prof. Gwo-Jen Hwang from National Taichung University of Education in Taiwan. The keynote speeches are as follows:

Keynote 1: Instructional Big Data Applications and Instructional Transformation

Speaker: Luo Shengquan, Professor and Dean of the Faculty of Education at Southwest University

Keynote 2: The role of emerging technologies in 21st century education: Supporting multidisciplinary inquiry communities

Speaker: Jim Slotta, University of Toronto

Keynote 3: Multi-Modal Learning Analytics for Collaborative Learning Design: Promise and Challenges

Speaker: Chen Wenli, Associate Professor of Nanyang Technological University

Keynote 4: Research topics and designs of artificial intelligence in education

Speaker: Gwo-Jen Hwang, Chair Professor and Vice President of National Taichung University of Education in Taiwan

These four keynote speeches, nine sub-conferences, EPT, one topical discussion panel form the main conference, and two multi-person symposium-style Subforums make up the main conference. The main conference invited a topical discussion panel theme, "Artificial Intelligence Enabling Educational Innovation (人工智能赋能教育创新)." Subforum 1 is titled "Research and Practice of Educational Big Models - Innovative Application of Generative Artificial Intelligence (教育大模型的研究与实践-生成式人工智能的创新应用) ," and Subforum 2 is titled " AI-driven innovation in educational research: ideas inspiration and methods exploration." Both subforums address significant topics in the era of artificial intelligence.

Like previous conferences, this year's event also features three pre-conference events: the K-12 Teachers' Forum, the Workshops, and the Doctoral Students' Forum. This year's K-12 Forum includes a total of 39 papers from mainland China, Hong Kong, and Taiwan, and has recommended 4 outstanding papers for the Best K-12 Teachers' Paper Award (limited to long or short papers accepted by the K-12 Teachers' Forum).

The workshops were also well attended. 9 workshops on various research topics were set up, and 124 papers were included in this year's conference. The topics of these nine workshops are described as follows.

Workshop 1: Facing Metaverse on Applying New Technologies in Education

Workshop 2: Large Language Models in Education

Workshop 3: Learning Engagement and Learning Behavior Modeling

Workshop 4: Digital Game-based Learning and Gamification Teaching Strategies in Key Competencies Education

Workshop 5: Computer-Supported Personalized and Collaborative Learning

Workshop 6: Innovative Technologies for Enhancing Interactions and Learning Motivation

Workshop 7: Design, Analysis, and Evaluation of Collaborative Learning in the Human-Computer Coordinated Perspective

Workshop 8: Next-Generation AI Education for K-12: Cultivating Future Innovators

Workshop 9: Artificial Intelligence-Enabled Innovation in Knowledge Building Research and Practice

In addition, the Doctoral Student Forum of this conference featured contributions from 10 doctoral candidates. A total of 6 experts and scholars will be invited to make comments and review. The forum was divided into three parts: a short lecture, presentations and discussions, and one-on-one private mentoring sessions.

The conference would like to thank all those who collaborated to make this session possible. We express our sincere gratitude to the Executive Chairs, Co-chairs, committee members, and volunteers of the nine sub-conferences, the EPT, the workshops, the K-12 Teachers' Forum, and the Doctoral Student Forum, and the Local Organizing Committee members for their help during the preparation of the conference. We would like to extend a special thank you to the conference chair for his guidance and support in the conference coordination.

We sincerely hope that you will enjoy the various conference activities of GCCCE 2024 and gain rich inspiration and wonderful experiences from them. Let us work together to build a more resilient and internationalized GCCCE academic community and pass on the spirit of GCCCE.

Siu Cheung Kong, The Education University of Hong Kong, Hong Kong
Conference Chair

Hui-Chun Chu, Soochow University, Taiwan
International Programme Coordination Chair

Daner Sun, The Education University of Hong Kong, Hong Kong
International Programme Coordination Co-Chair

Yu Lu, Beijing Normal University, Mainland China
International Programme Coordination Co-Chair

Jerry Chih-Yuan Sun, Yang Ming Chiao Tung University, Taiwan
International Programme Coordination Co-Chair

2. Conference Organization

Organizer:

Global Chinese Society for Computers in Education (GCSCE)

Host:

Southwest University

The Faculty of Education, Southwest University

Conference Chair:

Siu Cheung Kong, The Education University of Hong Kong

Consultants:

Tak-Wai Chan, National Central University, Taiwan

Ju-Ling Shih, National Central University, Taiwan

International Program Coordination Chair:

Hui-Chun Chu, Soochow University, Taiwan

International Program Coordination Co-Chairs:

Daner Sun, The Education University of Hong Kong

Yu Lu, Beijing Normal University

Jerry Chih-Yuan Sun, National Yang Ming Chiao Tung University, Taiwan

Local Organizing Chair:

Geping Liu, Southwest University

Members of the Organizational Committee:

Tao Xie, Southwest University

Jining Han, Southwest University

Ying Liang, Southwest University

English Paper Track Program Committee

Executive Chair

Owen H.T. Lu, National Chengchi University, Taiwan

Co-Chairs

Brendan John Flanagan, Kyoto University, Japan

Yi-Hung Liao, National Pingtung University, Taiwan

Kai-Yu Tang, National Chung Hsing Universiry, Taiwan

Programme Committee Members

Cathy S. Lin, National University of Kaohsuang, Taiwan

Hsiao-Ting Tseng, National Central University, Taiwan

Chien-Wei Tseng, National Taichung University of Science and Technology, Taiwan

Chi-Sheng Huang, National Taichung University of Science and Technology, Taiwan

Sui-Kong Cheung, The Education University of Hong Kong

Chester S.J. Huang, National Kaohsiung University of Science and Technology, Taiwan

Albert C.M. Yang, National Chung Hsing University, Taiwan

Chien-Chun Wang, National Quemoy University, Taiwan

3. Keynotes

Keynote speech 1

- Monday, June 3, 2024, 09:40 AM - 10:40 AM
- Venue: concert hall (音樂廳)

Speech title：Instructional Big Data Applications and Instructional Transformation

Luo Shengquan,
Professor, Doctoral Supervisor. Dean,
Faculty of Education and Teachers, Southwest University

Speech Abstract:

With the continuous development of technology, the field of education is also gradually integrating big data technology. The application of pedagogical big data plays a crucial role in the transformation of education. Prof Luo Shengquan will discuss the application of pedagogical big data in the field of education and elaborate on its positive impact on pedagogical change.

Speaker Bio:

Luo Shengquan, Professor, Doctoral Supervisor. Dean, Faculty of Education and Teachers, Southwest University. He is the recipient of national talent title, deputy secretary-general of the National Curriculum Academic Committee, executive director of the Comprehensive Practice Branch of Primary and Secondary Schools of the China Education Society, member of the Special Committee on Comprehensive Practice Guidance of the Basic Education Teaching Guidance Committee of the Ministry of Education, chairman of the Wisdom Teaching Committee of the Chongqing Municipal Education Society, and the editor-in-chief of the Future in Educational Research international journal. Finalist of "Most Influential Young Scholars". He is a finalist of "The Most Influential Young Scholar" in China. He is also a special professor of "Bayu Scholars" in Chongqing. Leading Talents in Philosophy and Social Science of Chongqing Municipality. Leading Academic and Technical Personnel of Chongqing Municipality. Leading expert of Chongqing Young Experts Workshop. Visiting scholar at Michigan State University and University College London. She mainly researches on the principles of education, teacher education and curriculum and pedagogy. He has published more than 200 academic papers in Guangming Daily, Educational Research and other newspapers and journals, 9 papers in Educational Research, and 4 long articles reprinted in Xinhua Digest; he has presided over 3 projects of the National Social Science Foundation (including 1 key project), 1 international cooperation project, and more than 20 provincial and ministerial projects; he has published and compiled academic papers such as "Transformation of Teaching Methods under the New Curriculum", "Outline of Academic Burden", "Academic Burden Problem Solving: Models He has published and compiled more than ten academic works, such as "Transformation of Teaching Mode under the New Curriculum", "Outline of Academic Burden", "Solution of Academic Burden Problem: Model and Governance Mechanism", etc. He has won more than ten awards, such as the First Prize of Ministry of Education's Award for Outstanding Achievements in Higher Educational Schools' Scientific Research (Humanities and Social Sciences), the National Teaching Achievement Award, the Mingyuan Education Award, the Nomination of QIAN Xuesen's Gold Medal of Urbanism (Education), the Outstanding Achievements in Social Sciences Award of Chongqing, and the First and More than 10 awards. He mainly researches on the basic theory of education, curriculum reform of basic education, teaching materials construction, and teachers' professional development.

Keynote speech 2

- Monday, June 3, 2024, 2:00 PM - 3:00 PM
- Venue: Tian Jiabing Building (田家炳), Room 802

Speech Title: The role of emerging technologies in 21st century education: Supporting multidisciplinary inquiry communities

Jim Slotta, Professor
University of Toronto

Speech Abstract:

This talk will explore recent trends in technology, media, and information, including a discussion of advances in artificial intelligence, physical computing, and classroom portal technologies. I will discuss the importance of fostering 21st-century competencies, and the need for education to prepare students as citizens, critical thinkers, problem, solver, and communicators. I will present recent advances in my own research of the Critical Action Learning Exchange (CALE), including a review of recent collaborations with teachers in South China. I will also discuss the importance of developing inquiry-oriented learning environments, including an important role for the physical and social classroom environments. I will argue that 21st century technologies are best suited for new forms of 21st century learning, and that we have new opportunities to care for all students, as they form identities as learners and future citizens.

Speaker Bio:

Jim Slotta is Professor and President's Chair in Knowledge Technologies and Education at the Ontario Institute for Studies in Education, University of Toronto. Since 2005, Dr. Slotta has led a team of students, designers and developers to investigate new models of collaborative and collective inquiry. These studies have advanced a pedagogical model known as Knowledge Community and Inquiry (KCI), in which students and teachers collaborate as a learning community to engage in STEM inquiry projects. Slotta currently directs the ENCORE lab (http://encorelab.org) in which KCI curriculum and technology environments are developed and researched. From 2006 - 2011, Slotta served as Canada Research Chair in Education and Technology, serving as PI or co-I on more than 30 funded projects and supervising 20 doctoral and post-doctoral researchers. In 2019, Slotta launched the Critical Action Learning Exchange

(CALE), where teachers develop, exchange and discuss competency-centered curriculum that empowers students as learners, providing meaning and purpose to their schooling experience and scaffolding their formation of learner and career identity.

Keynote speech 3

- Tuesday, June 4, 2024, 08:30 AM - 09:10 AM
- Venue: Tian Jiabing Building (田家炳), Room 802

Speech Title: Multi-Modal Learning Analytics for Collaborative Learning Design: Promise and Challenges

Chen Wenli
Associate Professor,
Head, Learning Sciences & Assessment
Nanyang Technological University

Speech Abstract:

The Multi-Modal Learning Analytics (MMLA) aims comprehensively understand and optimise learning and the environments in which learning by measuring, collecting, analysing and reporting of various modalities of data about learners and their contexts. Drawing on the learning sciences and cognitive neuroscience theories and methods, Dr Chen Wenli's research team has conducted studies that involve collecting and analysing diverse modalities of data in collaborative learning contexts with the aim to understand and optimize the collaborative learning design. The multi-modal data include cognitive (brain activity captured by fNIRS), visual attention (eye movement tracked by eye tracker), and behavioural (verbal, textual, gesture etc) data when learners are engaged in various collaborative learning activities (e.g., with or without individual preparation, with or without group awareness). Both inter-brain synchrony and joint attention between collaborators are examined to inform the level of synergy among the learners in collaborative learning. By analysing multi-modal data in temporal manner, they can provide insights in both collaborative learning outcome and process. This fine-grained analysis offers valuable information on the collaborative learning trajectory of different groups participating in various collaborative learning design. The MMLA and temporal analysis approaches provide promising results in advancing our understanding and support of computer-supported collaborative learning design. In addition, the methodological, practical; and ethical challenges associated with MMLA are discussed.

Speaker Bio:

Dr Chen Wenli is an Associate Professor and Head of the Learning Sciences and Assessment Academic Group at the National Institute of Education, Nanyang Technological University (NTU) Singapore. She is a specialized in Computer-Supported Collaborative Learning (CSCL) and learning analytics. Dr Chen's school-based research projects address the challenges of transforming and enhancing teaching and learning and applying her research outcomes to impact school practices. Dr Chen has been invited to deliver keynote speeches at numerous international conferences and has received several Best Paper Awards. She was honoured with the “Distinguished Researcher Award” by the Asia-Pacific Society for Computers in Education and the "Nanyang Education Award" from NTU.

Currently, Dr Chen serves as the Editor-in-Chief for the Journal of Computers in Education, and Learning: Research and Practice, and as the Associate Editor for Instructional Science, Asia Pacific Journal of Education, and Research and Practice in Technology Enhanced Learning. Additionally, she is an editorial board member for the International Journal of Computer-Supported Collaborative Learning.

Dr Chen is currently the executive committee member for the Asia Pacific Society of Computers in Education and the Global Chinese Society of Computers in Education. She was the co-chair of the CSCL community committee of the International Society of the Learning Sciences (ISLS) (2016-2021). She was the Program Committee Chair or Co-chair for the International Conference of CSCL in 2022, International Conference on Computers in Education 2017, Global Chinese Conference on Computers in Education 2014, and the Organizing Committee Chair for International Conference of the Learning Sciences 2016, and International Conference on Computers in Education 2012.

Keynote speech 4

- Wednesday, June 5, 2024 11:00-12:00 AM
- Venue: Tian Jiabing Building (田家炳), Room 802

Speech Title: Research topics and designs of artificial intelligence in education

Gwo-Jen Hwang
Chair Professor and Vice President,
National Taichung University of Education

Speech Abstract:

The rapid development of artificial intelligence (AI) in recent years has attracted widespread attention; issues related to the application of AI in education have been hotly debated by scholars. However, how to apply AI in educational settings and analyze the advantages it brings is still a challenging issue. Scholars with technical backgrounds may encounter difficulties in experimental design and data analysis; on the other hand, scholars with educational backgrounds may feel the technical challenges.

This talk will focus on the application of artificial intelligence and data analytics in education, as well as research issues and development directions. Prof. Hwang will illustrate how academics from different backgrounds can enter the research on the application of artificial intelligence in education through practical examples of using AI in educational settings. In addition to illustrating the benefits of AI and data analytics for learners, teachers, and educational decision makers, Prof. Hwang will also provide specific explanations of possible research designs and evaluation methods. This presentation will be of great value to researchers who are interested in conducting AI in education studies.

Speaker Bio:

Prof. Gwo-Jen Hwang is a Chair Professor and Vice President of Taichung National University of Education. Professor Hwang's academic specialties include action and ubiquitous learning, game-based learning, flipped learning, and artificial intelligence applications in education. He has led more than 150 projects and received numerous research awards, including the "Annual Most Outstanding Researcher Award " from the Ministry of Science and Technology (MOST) in 2007, 2010, and 2013, the " Outstanding ICT Elite Award" in 2015, and the "Ministry of Education's Excellent Teacher Award" in 2019. In 2022, he was honored as a Distinguished Guest Researcher by the National Science and Technology Council, Taiwan.

Prof. Hwang has published more than 800 papers, including more than 400 in SSCI journals. He has served as a reviewer/editor/guest editor/editor-in-chief for more than 50 SSCI/SCI academic journals. He currently serves as a reviewer/editor/guest editor/editor-in-chief of Computers & Education: Artificial Intelligence (Scopus, Q1; EI), International Journal of Mobile Learning and Organisation (Scopus, Q1; ESCI), and Journal of Computers in Education (ESCI). International Journal of Mobile Learning and Organisation (Scopus, Q1; ESCI) and Journal of Computers in Education (ESCI, Scopus Q1); and also serves as Associate Editor of IEEE Transactions on Education (SCI).

A Review of Artificial Intelligence in STEM Education from 2016 to 2023

Junhua, Xian [1], Junjie, Gavin, Wu[1*], Danyang, Zhang[2], Shujing, Jiang[1]
[1] Faculty of Applied Sciences, Macao Polytechnic University, 999078, Macao SAR, China
[2] College of International Studies, Shenzhen University, 518000, Shenzhen, Guangdong, China
[*] gavinjunjiewu@gmail.com

Abstract: *STEM education is often intertwined with technology. The recent emergence of artificial intelligence (AI) has sparked increased interest in STEM education, leading to more reports highlighting the diverse applications of AI tools in enhancing student learning. This paper aims to investigate the trends and directions of AI in STEM education by analyzing 1,826 English publications from 2016 to 2023 based on the Web of Science Core Collection. CiteSpace was adopted to visualize the trends, authorship, and keywords in previous literature. Findings from the review cast light on the current progression and provide significant implications for future research of AI in STEM education.*

Keywords: Artificial intelligences, STEM education, CiteSpace, Keyword co-occurrences

1. Introduction

STEM education is known as a transdisciplinary approach to promoting learners' development of critical thinking and problem-solving skills by integrating science, technology, engineering, and math curriculum frameworks (Ortiz-Revilla et al., 2020; Falloon et al., 2020; Takeuchi et al., 2020). STEM education assists students in increasing interest in learning through guided learning (Johnson et al., 2020). In addition, the implementation of STEM education has been shown to help increase students' willingness to participate in discussions of current policy issues and develop the skills necessary to make informed decisions in daily life (Kayan-Fadlelmula et al., 2022). STEM education also fosters positive attitudes, increases student engagement and interest, and provides opportunities and context for the practical application of scientific concepts (McComas & Burgin, 2020).

STEM education is quite often intertwined with technology. For example, Chacko et al. (2015) leveraged touchscreen technology to blend hands-on experiments with traditional instructions, allowing students to participate in biology and science classes through electronic tablets and smartphones. This approach facilitated a high level of concentration among students in the classroom. Furthermore, Zhuang et al. (2018) developed an app utilizing games to assess students' academic performance and improve learners' skills and interest in engineering studies. In addition, Ellis et al. (2020) emphasized that students learn to use computer technology as supporting tools effectively improving their ability to apply their STEM knowledge and skills into practice. However, advances in technology continue to transform student learning both within and beyond the traditional classroom setting (Miller & Wu, 2021). The recent emergence of artificial intelligence (AI) has sparked increased interest in STEM education, leading to more reports highlighting the diverse applications of AI tools in enhancing student learning. Consequently, the aim of this paper is to investigate the trends and directions of AI in STEM education with the assistance of the CiteSpace software.

2. Previous Reviews

Recent reviews have emphasized the growing significance of AI in education, particularly in STEM education. Zawacki-Richter et al. (2019), for example, reviewed the integration of AI in higher education studies from 2007 to 2018. They concluded that the advent of AI technology into the educational environment is gradually realizing the goal of technology-enhanced learning as it advances and becomes more widespread, and the phenomenon is especially evident in STEM educational programs. Other review studies also confirmed the increasing integration of AI in STEM education, such as Chen et al. (2022 a) and Humble and Mozelius (2022).

Specific to the implementation of AI in STEM education, two recent review papers offer useful insights. Feng et al. (2021), by focusing on the use of intelligent tutoring systems, analyzed 22 publications across four databases. Their review suggested the effectiveness of such systems in enhancing conceptual learning, problem-solving, and model building. Similarly, Xu and Ouyang (2022) examined 63 research studies within this field of research from 2011 to 2021, synthesizing six categories of AI applications and discussing their effects on STEM education.

Though prior review studies have provided valuable insights into the use of AI in STEM education, most of the relevant studies involved a small number of publications, pointing to the issue of generalizability. As such, this study uses bibliometrics to visualize and analyze AI in STEM education, including the statistics of article publication volume in previous years, cooperation between authors, and the most frequently used keywords. More specifically, the study answers the following research questions:

RQ 1: What are the developmental trends of and the major publication venues for AI studies in STEM education?

RQ 2: Who are the most prolific authors of AI studies in STEM education?

RQ 3: What are the high-frequency keywords associated with AI studies in STEM education?

3. Methods

3.1. Data Collection

CiteSpace, a Java-related visual literature analysis software, was utilized to investigate the focal points of selected articles and demonstrate the trends and directions of using AI in STEM education (Chen et al., 2022 b). Additionally, CiteSpace is multifaceted, temporal, and dynamic, allowing the scientific knowledge atlas to present the structure, regularity, and distribution of AI in STEM education through visualization (Chen et al., 2022 b).

In an effort to provide a comprehensive, systematic, and scientific review of the extensive literature on AI in STEM education, this study used data obtained through an advanced search of the Web of Science Core Collection (WOSCC). The retrieval strategy employed the following keywords: TS (topic search) = ((“STEM education” OR “Science” OR “Technology” OR “Engineering” OR “Mathematics”) AND (“Education”) AND (“Artificial Intelligence” AND “AIED”)). The language setting was “English”, and the document type was specified as “Article”.

3.2. Data Analysis

A total of 1,826 articles were identified through the aforementioned data collection methods, and their characteristics were compared and analyzed using CiteSpace (Figure 1). First, the authors' partnerships were analyzed. Secondly, we are analyzing keyword co-occurrences in this research field, followed by the analysis of major clusters of literature co-citations. Thirdly, emerging trends were identified through sudden citations in the literature. It is worth mentioning that the parameter settings of this study were selected papers published during 2016-2023 and parameterized using 1-year time slices, with a selection criterion of N = 50.

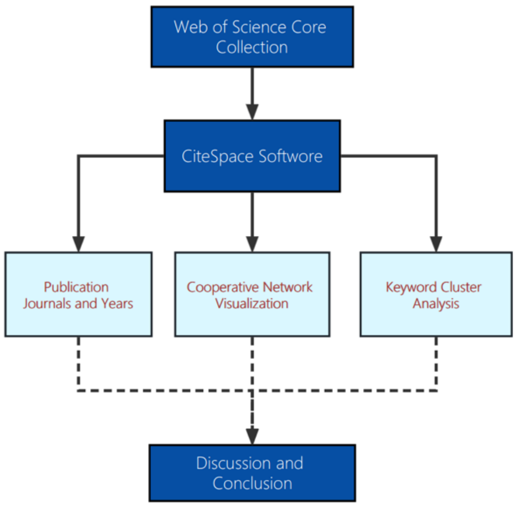


Figure 1. Flow diagram of the studies in visualization and analysis.

4. Results

4.1. Publications Journals and Years

Figure 2 illustrates the overall developmental speed of AI research in STEM education. The cumulative number of publications refers to the parameters on the left (orange bar chart), and the number of publications per year refers to the parameters on the right (blue line graph). Based on the analysis, this graph can be broadly categorized into two segments: the initial stage from 2016 to 2019, characterized by a low volume of AI articles in STEM education. The subsequent phase, spanning from 2019 to 2023, demonstrated a rapid development, closely related to the momentum of the development of AI technology.

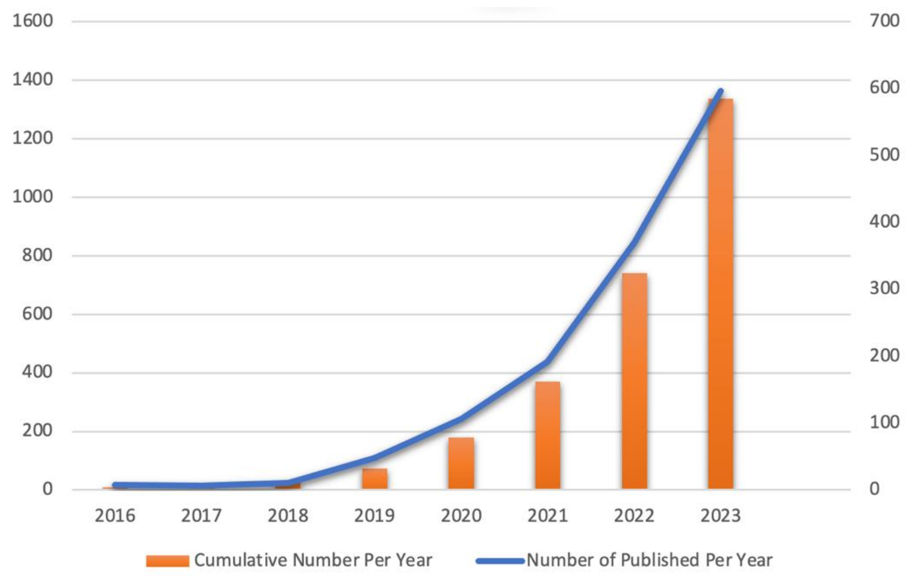


Figure 2. Graph of papers published (2016-2023).

The journals featuring more than 100 published papers about AI in STEM education studies are detailed in Figure 3. Notably, Computers & Education, arXiv, Computers in Human Behavior, and Nature were the most popular publication venues of AI for STEM education, followed by other educational technology, medical, and psychological journals.

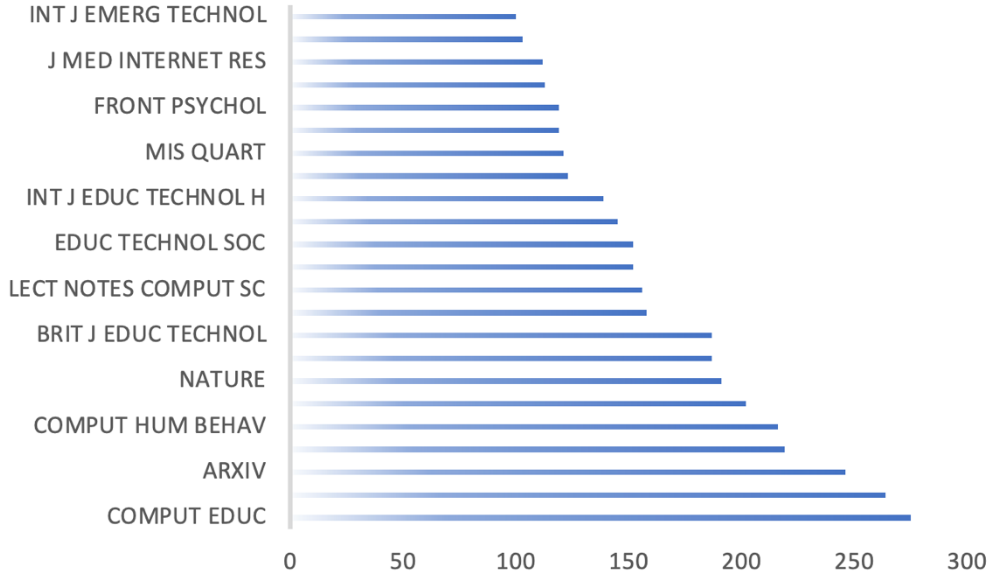


Figure 3. Journals with more than 100publications.

4.2. Cooperative Network Visualization

A visual representation of collaborative author relationships is shown in the following Figure 4. The size of the red circles represents the number of papers authored by each scholar. The different color nodes indicate the time of publication, and the distance between the two nodes reflects the strength of the collaborative connection (Wu et al., 2022). For example, Thomas K. F. Chiu has established himself as one of the most prolific authors with the most articles (N = 13) and the latest work on AI in STEM education. Hwang Gwo-Jen (N = 6) and Chai Ching Sing (N = 5) came in second and third place respectively. The distribution of proximity between them also revealed that the frequency of collaboration between them was very close.

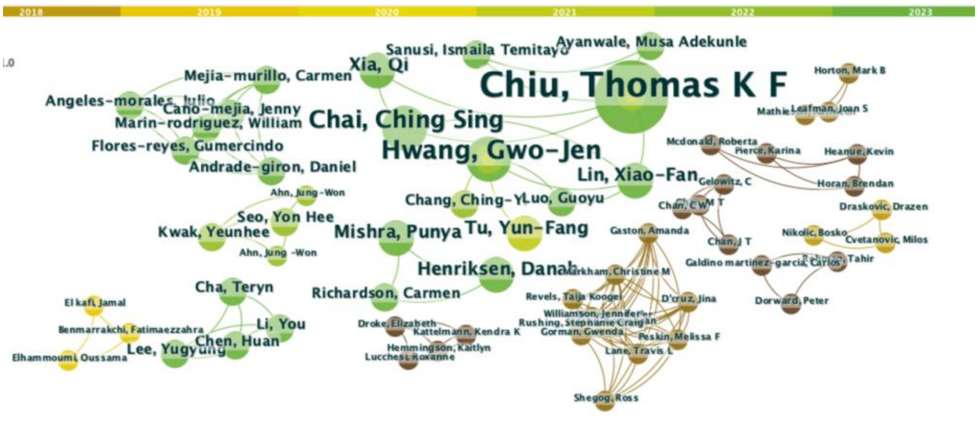


Figure 4. Co-authorship.

Furthermore, the well-connected clusters represent a research community with the same research topic (Wu et al., 2022). Then analyzing the clustering of green nodes in detail can find the most popular research keywords in 2023 (Figure 4). For instance, the team of Thomas K. F. Chiu's research context mainly focuses on K-12 education with various research topics ranging from learner-centered (e.g., student interactions) to teacher-centered (e.g., teacher education) issues, and they preferred the self-determination theory as the framework to support the statement (Table 1).

Table 1. Collaboration analysis of the representative author

Clusters	Representative Author	Collaboration History (Citing Article)	Collaboration History (Research Keywords)

1	Chiu, Thomas K F	Chai CS, 2021, EDUC TECHNOL SOC, V24, P89	artificial intelligence; self-efficacy; readiness; social good; literacy; behavioral intention
		Xia Q, 2022, COMPUT EDUC, V189, P, DOI 10.1016/j.compedu.2022.104582	ai education; k-12 education; inclusion; diversity; self-determination theory; motivation
		Chiu TKF, 2021, TECHTRENDS, V65, P796, DOI 10.1007/s11528-021-00637-1	artificial intelligence (ai) education; curriculum design; k-12 schools; holistic approach
		Chiu TKF, 2022, IEEE T EDUC, V65, P30, DOI 10.1109/TE.2021.3085878	co-creation process; curriculum design; pre tertiary education; teacher education
		Chiu TKF, 2023, INTERACT LEARN ENVIR, V0, P, DOI 10.1080/10494820.2023.2172044	motivation; self-determination theory; teacher support; student expertise; chatbots
		Xia Q, 2023, BRIT J EDUC TECHNOL, V54, P967, DOI 10.1111/bjet.13305	prior knowledge; self-determination theory; self-regulated learning
		Yau KW, 2023, EDUC INF TECHNOL, V28, P1041, DOI 10.1007/s10639-022-11161-x	teacher conceptions; phenomenography; teacher professional development
		Chai CS, 2023, SUSTAINABILITY-BASEL, V15, P, DOI 10.3390/su15010605	behavioral intention; competence; autonomy; social good
		Sing CC, 2022, ETR&D-EDUC TECH RES, V70, P765, DOI 10.1007/s11423-022-10111-1	theory of planned behavior; secondary education; moderation effects
		Xia Q, 2023, EDUC INF TECHNOL, V28, P8691, DOI 10.1007/s10639-022-11547-x	self-regulated learning; self-determination theory
		Chiu TKF, 2023, INTERACT LEARN ENVIR, V0, P, DOI 10.1080/10494820.2023.2253861	generative ai in education; teacher education; learning; teaching; assessment; administration
		Hu X, 2023, EDUC INF TECHNOL, V28, P8789, DOI 10.1007/s10639-022-11556-w	student-student interaction; group interaction patterns; educational dialogue; t-seda
		Sanusi IT, 2023, EDUC INF TECHNOL, V0, P, DOI 10.1007/s10639-023-12250-1	secondary school; behavioral intention; teachers; nigeria
2	Henriksen, Danah	Woo LJ, 2023, TECHTRENDS, V67, P767, DOI 10.1007/s11528-023-00888-0	creativity; writing; technology; learning; education; instruction; artificial intelligence; chatgpt
		Mishra P, 2023, TECHTRENDS, V67, P207, DOI 10.1007/s11528-023-00839-9	creativity; technology; education; research; future; learning
		Richardson C, 2023, TECHTRENDS, V0, P, DOI 10.1007/s11528-023-00921-2	chatgpt; generative ai; responsible innovation; futures thinking; future
3	Cha, Teryn	Chen H, 2023, EDUC INF TECHNOL, V28, P4093, DOI 10.1007/s10639-022-11326-8	experiential learning platform; ai; data science; qualitative research
		Li Y, 2023, THINK SKILLS CREAT, V48, P, DOI 10.1016/j.tsc.2023.101311	data science applications in education; improving classroom teaching; interdisciplinary projects
4	Andrade-giron, Daniel	Villarreal-Torres H, 2023, EAI ENDORSED TRANS S, V10, P, DOI 10.4108/eetsis.3489	automated machine learning; higher education; data mining; delinquency
		Villarreal-Torres H, 2023, EAI ENDORSED TRANS S, V10, P, DOI 10.4108/eetsis.vi.3455	autom; machine learning; student dropout; higher education; h2o.ai; data mining ID persistence

4.3. Keyword Cluster Analysis

The keywords in the selected papers, as a concise representation of the theme and content of academic papers, are relevant to reflect the current research trends within the field of study (Chung et al., 2014; Chen et al., 2020). Thus, the present study also conducted an analysis of keywords used by the reviewed papers. Illustrated in Figure 5 is a comprehensive display of the distribution of keywords in using AI within STEM from 2016 to 2023. The font size of the keywords corresponds to the frequency and the centrality of intermediaries (Uskov et al., 2019; Yang et al., 2021). The purple outer circle of the nodes in the figure represents the mediated centrality of the nodes (Uskov et al., 2019). Specifically, artificial intelligence had the highest centrality (0.18), which lies between Cluster Machine Learning (0.1) and Cluster Deep Learning (0.09). This means that getting well known about artificial intelligence is key to understanding both clusters (Chen et al., 2020). Figure 5 highlighted that AI in STEM education has been mainly researched based on keywords such as Deep Learning, Machine Learning, Big Data, Higher Education, Technology Acceptance Model, Science, Medical Education, Information Technology, and Virtual Reality, which indicate the researcher that the research hotspots of AI in STEM education focus on these areas. Familiarizing with the concepts and application scenarios of these related terms as a basis for further research (Sun et al., 2023).

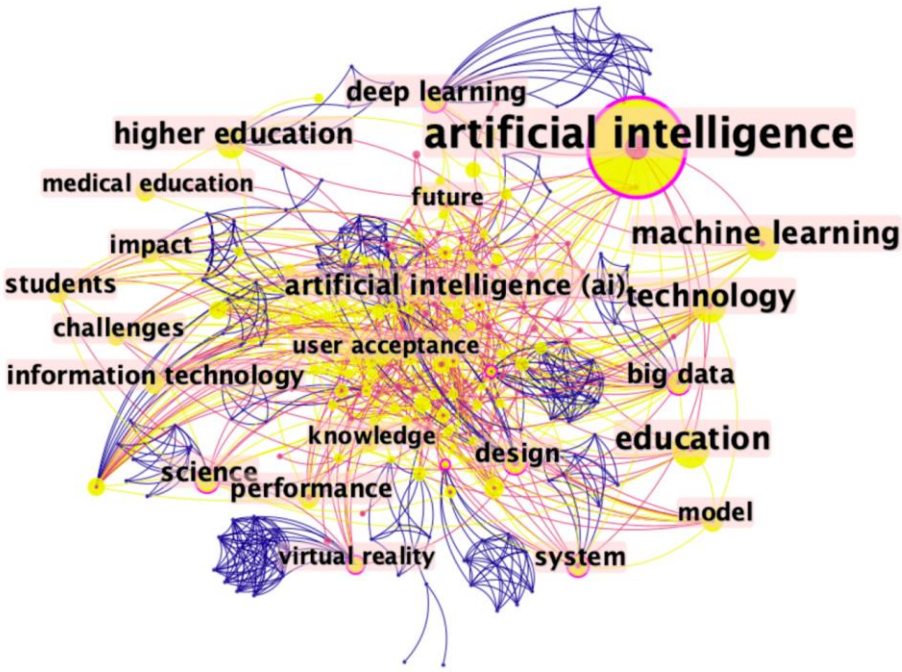


Figure 5. Keywords of AI in STEM education.

Furthermore, the high-frequency keywords table (Table 2) delineated the research focal points and emerging trends in the field of AI in STEM education. The centrality reflects the magnitude of the keyword's pivotal role in achieving different links due to its mediating properties, while a centrality greater than 0.1 indicates that the keyword has an important academic role (Chen et al., 2022 a). Examining the period from 2016 to 2023, the top 10 keywords with reference to the centrality of the mediator were artificial intelligence (0.18), education (0.11), technology (0.11), machine learning (0.1), higher education (0.1), big data (0.1), deep learning (0.09), performance (0.09), systems (0.08), and science (0.07), with the top six keywords exhibiting a centrality greater than 0.1.

Table 2. High-frequency keywords

Keywords	Count	Centrality	Year

Artificial Intelligence	600	0.18	2017
Education	122	0.11	2016
Technology	105	0.11	2019
Machine Learning	97	0.1	2019
Higher Education	75	0.1	2016
Big Data	61	0.1	2017
Deep Learning	52	0.09	2016
Performance	50	0.09	2018
System	46	0.08	2020
Science	46	0.07	2018
Design	46	0.06	2017
Students	43	0.05	2018
Information Technology	43	0.05	2019
Challenge	40	0.05	2020
Model	38	0.04	2019
Impact	36	0.04	2019
Virtual Reality	36	0.04	2016
Medical Education	32	0.04	2017
Knowledge	32	0.04	2021
Future	31	0.04	2017

5. Discussion and Conclusion

The present review study attempted to offer valuable insights into the current progression of AI in STEM education. We used a bibliometric approach to visualizing the current state of research on AI in STEM through the analysis of 1,826 publications using keywords and literature in the field. The results of the study will help researchers to identify research trends about AI in STEM education.

Regarding RQ 1, the integration of AI in STEM education has undergone notable changes in three distinct stages: a period of slow development (2016-2018), followed by rapid advancement (2019-2021), and then a period of steady rise (2022-2023). This can be attributed to the swift development of artificial intelligence, which provides boundless resources and potential for educational technology adoption and attracts more researchers to pay attention to this field (Xu & Ouyang, 2022). Given the continuous development and progress in AI technology, it is anticipated that the volume of AI papers in STEM education will continue to grow substantially (Chen et al., 2020).

Based on the findings, AI studies in STEM education have been extensively documented in a wide range of journals spanning multiple disciplines, including educational technology (e.g., Computers & Education, Computers in Human Behavior), computer science (e.g., arXiv), psychology (e.g., Frontiers in Psychology), and medical research (e.g., Journal of Medical Internet Research). Chen et al. (2022 b) have argued for the "AIED's close relationship with computer science and software engineering" (p. 28). The current findings not only supported their assertion, but also illustrated the transdisciplinary nature of AI studies in STEM education, drawing research attention from diverse disciplinary perspectives.

RQ 2 explored the representative scholars and their scholarly collaborations within the academic community. Our analysis suggested that quite a many established researchers in the field of using AI in STEM education came from developed countries or regions, such as Hong Kong SAR, Taiwan, the US, and the UK. On the contrary, little has been reported from developing or under-developed contexts (e.g., Africa, ASEAN). This finding could be closely linked to the availability of educational resources and the policies set forth by local governments.

For RQ 3, Figures 5 and Table 2 shed light on the keywords and research frontiers associated with AI in STEM education. It was not uncommon to discover that AI has been closely linked to keywords such as deep learning, machine learning, big data, and information technology, since these technologies were foundational to the development of AI technology. Additionally, since educators are in the initial stages of applying AI in STEM education, the topics of user acceptance and the technology acceptance model were important topics for exploration (e.g., Al Darayseh, 2023). Interestingly, the analysis indicated the essential role of virtual reality, suggesting the potential parallel development of these two new technologies in the near future (Wu et al., 2024).

The findings have significant implications for future research in this domain. First, based on the analysis, most active researchers and institutions are from developed regions or countries. As such, there is a need for broader representation from less developed regions and countries. This diversity is crucial for promoting educational equity globally. Second, in addition to the exploring user acceptance of AI in STEM education, it is vital to explore sophisticated designs and implementations for the systematic integration of AI in STEM education (Chen et al., 2020, 2022 a). Attention to pedagogical and theoretical underpinnings is valuable during the educational process and more scholarly discussions about the effective use of AI in STEM education should be encouraged. Third, given the transdisciplinary nature of AI, there is also a need for further exploration of pedagogical practices across different subjects. However, the analysis suggested that AI has been more widely explored in medical education. Apparently, we need to expand scholarly efforts to other STEM disciplines so as to develop a more comprehensive understanding of the potential of AI in STEM education. Fourth, the instruction of STEM students in agentively selecting, ethically using, and critically assessing AI for STEM education is of great value. In addition, the digital divide strengthened by AI poses great challenges for STEM education, involving infrastructure, parental, teacher, learner attitudes, and pedagogical frameworks. Thus, the development of critical digital literacy becomes more increasingly crucial than ever in this context (Yang et al., 2024).

The study has certain shortcomings. Firstly, the choice of databases is relatively homogeneous, only Web of Science (Core Collection) was selected. In addition, only English literature was selected for this study, and the trend of research on AI in STEM in other languages is unclear. However, it is salient that the research and applications of AI in STEM are increasingly sparking interest among researchers across the disciplines. This study provides future researchers and educators insights into the research foci and development trends related to AI in STEM.

References

AI Darayseh, A. (2023). Acceptance of artificial intelligence in teaching science: Science teachers' perspective. *Computers and Education: Artificial Intelligence, 4*, 100132.

Chacko, P., Appelbaum, S., Kim, H., Zhao, J., & Montclare, J. K. (2015). Integrating technology in STEM education. *Journal of Technology and Science Education, 5*(1), 5-14.

Chen, B., Shin, S., Wu, M., & Liu, Z. (2022 a). Visualizing the knowledge domain in health education: a scientometric analysis based on CiteSpace. *International Journal of Environmental Research and Public Health, 19*(11), 6440.

Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during the rise of artificial intelligence in education. *Computers and Education: Artificial Intelligente, 1*, 100002.

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022 b). Two decades of artificial intelligence in education. *Educational Technology & Society, 25*(1), 28-47.

Chung, C. C., Cartwright, C., & Cole, M. (2014). Assessing the impact of an autonomous robotics competition for STEM education. *Journal of STEM Education: Innovations and Research, 15*(2).

Ellis, J., Wieselmann, J., Sivaraj, R., Roehrig, G., Dare, E., & Ring-Whalen, E. (2020). Toward a productive definition of technology in science and STEM education. *Contemporary Issues in Technology and Teacher Education 20*(3).

Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K-12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology, 29*, 369-385.

Feng, S., Magana, A. J., & Kao, D. (2021, October). A systematic review of literature on the effectiveness of intelligent tutoring systems in STEM. In 2021 IEEE Frontiers in Education Conference (FIE) (pp. 1–9). IEEE.

Humble, N., & Mozelius, P. (2022). The threat, hype, and promise of artificial intelligence in education. Discover Artificial Intelligence, 2(1), 22. https://doi.org/10.1007/s44163-022-00039-z

Johnson, C. C., Mohr-Schroeder, M. J., Moore, T. J., & English, L. D. (Eds.). (2020). Handbook of research on STEM education. Routledge.

Kayan-Fadlelmula, F., Sellami, A., Abdelkader, N., & Umer, S. (2022). A systematic review of STEM education research in the GCC countries: Trends, gaps and barriers. *International Journal of STEM Education, 9*(1), 1-24.

McComas, W. F., & Burgin, S. R. (2020). A critique of "STEM" education: Revolution-in-the-making, passing fad, or instructional imperative? *Science & Education, 29*(4), 805-829.

Miller, L., & Wu, J. G. (Eds.). (2021). Language learning with technology: *Perspectives from Asia*. Springer.

Ortiz-Revilla, J., Adúriz-Bravo, A., & Greca, I. M. (2020). A framework for epistemological discussion on integrated STEM education. *Science & Education, 29*(4), 857-880.

Sun, D., Zhan, Y., Wan, Z. H., Yang, Y., & Looi, C. K. (2023). Identifying the roles of technology: A systematic review of STEM education in primary and secondary schools from 2015 to 2023. *Research in Science & Technological Education*, 1-25.

Takeuchi, M. A., Sengupta, P., Shanahan, M. C., Adams, J. D., & Hachem, M. (2020). Transdisciplinarity in STEM education: A critical review. *Studies in Science Education, 56*(2), 213-253.

Uskov, V. L., Bakken, J. P., Byerly, A., & Shah, A. (2019). Machine learning-based predictive analytics of student academic performance in STEM education. *In 2019 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1370-1376). IEEE.

Wu, C. H., Liu, C. H., & Huang, Y. M. (2022). The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load. *International Journal of STEM Education, 9*(1), 1-22.

Wu. J. G., Zhang, D., & Lee. S. M. (2024). Into the brave new Metaverse: Envisaging future language teaching and learning. *IEEE Transactions on Learning Technologies*, *17*, 44-53.

Xu, W., & Ouyang, F. (2022). The application of AI technologies in STEM education: a systematic review from 2011 to 2021. International Journal of STEM Education, 9(1), 1-20.

Yang, S. J., Ogata, H., Matsui, T., & Chen, N. S. (2021). Human-centered artificial intelligence in education: Seeing the invisible through the visible. *Computers and Education: Artificial Intelligence, 2*, 100008.

Yang, Z., Wu, J. G., & Xie, H. (2024). Taming Frankenstein's monster: Ethical considerations relating to generative artificial intelligence in education. *Asia Pacific Journal of Education*, 1-14.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? International Journal of Educational Technology in Higher Education, 16(1), 1-27.

Zhuang, Y., Wang, L., & Chiang, F. K. (2018). The Design and Development of a Mobile Phone Application for STEM based on a Novel Engineering Approach. Int. J. *Adv. Corp. Learn., 11*(2), 16-20.

Modelling the Relationship among EFL Learners' L2 Grit, Engagement and Academic Achievement in Blended Learning

Bowen Jing[1], Huiqi Fan[1], [1]Lin Luan[1*]
[1] Beijing University of Posts and Telecommunications
[*] luanlin@bupt.edu.cn

Abstract: *The advent of the post-pandemic era has facilitated the reverse shuffle from online to blended learning, marking a"new normal" in language education. However, facing the abrupt paradigm shift, learners may exhibit poor engagement and undesirable achievement. Along with students' adversity in such blended learning settings, the role of personality traits, especially second language (L2) grit, in promoting language learning performance remains crucial yet under-explored. To address this issue, the current study aims to investigate the association among L2 grit, engagement and academic achievement in the blended learning context via structural equation modelling (SEM). 375 students from a Chinese university were enrolled in the study. They participated in a college English curriculum delivered through a blended learning approach with online learning activities on learning management systems (LMSs) integrated into face to face instruction. The results indicated that the two dimensions of L2 grit, consistency of interest (COI) and perseverance of effort (POE), indirectly predicted academic achievement with engagement as the partial mediator. These research findings suggest designing grit-building activities in blended learning to improve learners' English proficiency during post-COVID EFL education.*

Keywords: L2 grit, engagement, academic achievement, EFL learners, blended learning

1.Introduction

With the removal of physical restriction in the post-pandemic era, the transition from online to blended delivery mode has become a new normal in higher education. Blended learning is introduced as a harmonious combination of face-to-face instruction and online technology use in a synergistic manner (Dixon et al., 2021). However, such blended learning pattern has posed a great threat to students, giving rise to their loss of belonging, decreased engagement and undesirable academic performance (Banegas, 2023). Since grit has been proved to be an important personality strength that contributes to EFL learners' classroom involvement and academic success in challenging situations (Khajavy & Aghee, 2022), it is worthwhile to investigate how students' L2 grit impacts their engagement and academic achievement in a blended learning context so as to help learners readapting to the post-pandemic educational landscape.

2.Literature Review

2.1. L2 Grit

Grit is defined by Duckworth et al. (2007) as a non-cognitive personality trait that composes perseverance and passion for long-term goals. Since language learning is a lengthy process requiring sustained momentum (Solhi et al., 2023), the importance of grit has gained increasing attention of second language (L2) scholars and researchers. They propose the notion of L2 grit as a domain-specific construct in second language acquisition. According to Teimouri et al. (2022), L2 grit owns a two-fold structure with perseverance of effort (POE) and consistency of interest (COI). While POE refers to individuals' inclination to devote durable energy over a long period of time in L2 learning, COI is regarded as constancy of enthusiasm in realizing ultimate goal despite setbacks and obstacles in L2 learning.

2.2. Learning Engagement

Learning engagement refers to students' active investment of time and energy in learning process, which can be measured from behavioral, cognitive and emotional dimensions (Fredricks et al., 2004). It constitutes a crucial contributor of academic achievement in language learning (Sun et al., 2023). Despite Fredricks et al (2004)'s three-dimensional engagement framework, scholars (e.g. Luan et al., 2020) have developed a new four-component model of engagement, adding social engagement as a subtype. Considering that blended learning context encompasses social interaction with peers and instructors, this research employed the four-faceted conceptualization of engagement .

2.3. L2 grit, Learning Engagement and Academic Achievement

A myriad of previous studies have probed into the interplay of L2 grit, learning engagement and academic engagement in traditional classroom settings. For instance, Sun et al. (2023) have confirmed that gritty students exhibit more resilience and determination in language learning, which further motivates their engagement in class activities. Based on Khajavy & Aghee (2022)'s findings, L2 grit makes great contribution to EFL learners' language proficiency. In addition, the study conducted by Khajavy (2021) revealed that EFL learners' L2 grit indirectly predicted their performance in reading comprehension via the mediation process of engagement. Despite the existing literature, the association among L2 grit, engagement and academic achievement in a blended learning context remains under-explored. Compared to learning performance, engagement is proved to be a more proximal outcome of grit (Tang et al., 2019). Therefore, it is feasible to put forward the hypothesis that engagement mediates the link between L2 grit and academic achievement. This being the case, the current study aims to confirm the hypothesized association among the aforementioned three constructs via structural equation modelling (SEM) approach.

3. Method

3.1. Research Context and Participants

The present study was conducted in a 16-week compulsory English course at a comprehensive university in mainland China. A random sample of 375 non-English major undergraduates (70.7% males, 19-21 years old) were involved. The course was delivered in classroom setting via a blended approach, which means that the learning tasks released on learning management systems (e.g. Moodle) were integrated into teachers' face-to-face instruction.

3.2. Instruments

Revised from Teimouri et al. (2022) and Luan et al. (2023)'s well-established surveys, two questionnaires were developed in this study to gauge students' L2 grit and learning engagement (LE) in blended learning mode. A 5-point Likert scale ranging from 1 (Strongly Disagreed) to 5 (Strongly agreed) was used in both of the questionnaires. The L2 grit scale in the current study owns a non-hierarchical structure, comprising consistency of interest (COI) and perseverance of effort (POE) as two parallel dimensions, the LE survey is hierarchical with behavioral engagement (BE), cognitive engagement (CE), emotional engagement (EE) and social engagement (SE) as subscales. All of the 24 items (4 for POE, 4 for COI, 16 for learning engagement) were translated into Chinese, the native language of participants, for their better comprehension. In addition, participants' score (1-100) of final-term examination in the blended EFL curriculum served as the indicator of academic achievement. The examination was revised from College English Test Band 4 (CET4), a standardized English test whose validity in indicating college students' overall English competence has been widely confirmed in China (Li et al., 2022). The test was consisted of four sections, namely listening, translation, reading comprehension and writing.

3.3. Data Collection and Analysis

After removing the unqualified data, a total of 372 valid questionnaires were collected. The data analysis process involved three steps. First, we conducted a confirmatory factor analysis (CFA) to ensure the validity and reliability of both the questionnaires. Second, a structural equation model (SEM) was performed to confirm the hypothesized relationship among EFL learners' L2 grit (i.e. COI and POE), learning engagement and academic achievement. Third, the bootstrap procedure was operated. With the help of SPSS 26.0 and AMOS 24.0 software, we attempted to explore whether L2 grit positively predicted academic achievement with engagement playing a mediating role in a blended EFL learning context.

4. Results

4.1. CFA of the L2 Grit Questionnaire and Learning Engagement (LE) Questionnaire

Confirmatory factor analysis was operated to test the validity and reliability of the instruments. As for the L2 grit questionnaire, the CFA results showed that the factor loading of items ranged from 0.75 to 0.82, all surpassing the required minimum of 0.50. Average variance extracted (AVE) value of both POE and COI scales exceeded 0.59, reaching the minimum requirement of 0.50. The composite reliability (CR) values of POE and COI dimensions reached 0.85 and 0.86 respectively, greater than the threshold of 0.70. Moreover, the Cronbach's alpha of both dimensions (0.85 for POE, 0.86 for COI) in the L2 grit questionnaire met the critical value of 0.70. Therefore, the reliability of this questionnaire was confirmed. In addition, the fit indices of the survey were showed below: x^2/df =2.39, GFI = 0.97, IFI = 0.98, NFI = 0.97, RMSEA = 0.061. Based on the Chi-square criterion and the fitting statistics, the L2 grit questionnaire was proved to have good structural validity.

The learning engagement questionnaire was tested in a similar approach. According to the CFA results, the factor loading of all items (0.65-0.84) surpassed the baseline of 0.50. While average variance extracted (AVE) values of four sub-dimensions ranged from 0.59 to 0.66, the composite reliability (CR) values were in an interval from 0.85 to 0.89, all meeting the minimum standard. Besides, the Cronbach's alpha of all dimensions (0.83-0.89) surpassed the threshold of 0.70. Considering the structural fit of this survey, the relevant statistics were as follow: x^2/df =2.14, GFI = 0.93, IFI = 0.97, NFI = 0.94, RMSEA = 0.055. Therefore, this questionnaire is of good reliability and validity.

4.2. Path Analysis and the Mediating Effect

The hypothesized structural equation model was conducted in AMOS. This established model presented desirable structural fit with acceptable fitting statistics (x^2/df =1.99, IFI = 0.95, CFI = 0.95, NFI = 0.90, RMSEA = 0.052). Therefore, this model is eligible for the exploration of the complex relationship among L2 grit, learning engagement and academic achievement in blended learning context. The path analysis results are shown in Figure 1. Two components of L2 grit, POE and COI, positively predicted learning engagement (β=0.36, p<0.001; β=0.27, p<0.05), which in turn, promoted students' academic achievement (β=0.15, p<0.05). In addition, both COI and POE directly impacted academic achievement (β=0.17, p<0.05, β=0.19, p<0.05) in the blended learning mode.

Besides L2 grit's direct effect on academic achievement, POE and COI also functioned as the indirect antecedents of academic achievement with engagement as a partial mediator. According to Table 1, 95% confidence interval (CI) excluded zero, indicating that engagement mediated the link between L2 grit (POE, COI) and academic achievement The mediating effects were 21% and 19% respectively.

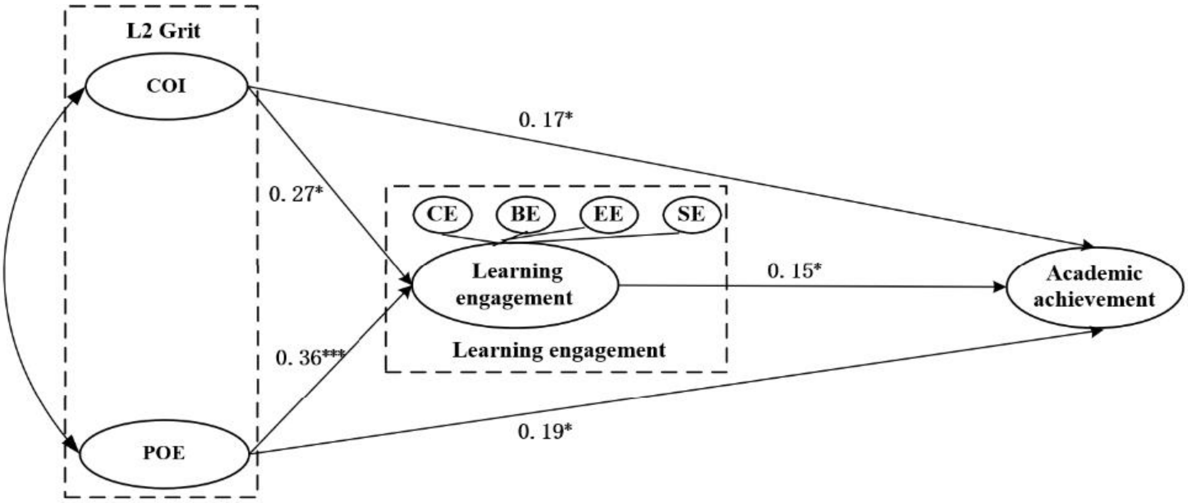


Figure 1. The hypothesized model of the relationship among grit, engagement and academic achievement

Table 1. Analyses of mediated effects through bootstrapping

	Academic achievement		
	β	95% CI	Mediating effect
POE	0.05	(0.02, 0.12)	21%
COI	0.04	(0.01, 0.10)	19%

5. Discussion and Conclusion

This study has explored the complex relationship among L2 grit, learning engagement and academic achievement in a blended learning mode via SEM approach. The results echo previous studies (e.g. Khajavy & Aghaee., 2022; Zhao et al., 2023), indicating that both POE and COI positively influence EFL learners' academic achievement with engagement serving as a partial mediator. According to Solhi et al (2023)'s findings, grittier students are self-regulated learners who are more proficient in deep learning and modifying cognitive strategies when encountering novel situations or meeting difficulties. To conquering obstacles, they devote considerable time, effort and passion engaging in the learning tasks and practicing their skills (Zhao et al., 2023). That might be a powerful explanation for grit's predicative role in engagement and academic achievement in the critical time of post COVID.

Pedagogical implications are also offered based on the research findings. Since L2 grit plays an important role in improving EFL learners' language development, instructors are encouraged to design grit-building activities in EFL classrooms (Ebadi et al., 2018). Specifically, to cultivate learners' persistence in language learning, college English teachers are recommended to set gritty figures as role models for students (Chen Hsieh & Lee, 2023). For instance, instructors can share with students the stories and videos of highly successful people, in which continuous effort makes a great contribution to their achievement. In addition, it is advisable for teachers to acknowledge and praise learners' effort in L2 learning assignment so as to inspire their long-term endeavor in the lengthy learning process (Yu & Ma, 2024). As shown in the research findings, COI parallels POE in enhancing EFL learners' engagement and achievement. This being the case, instructors are also required to create a positive classroom atmosphere in order to develop students' learning interest (Derakhshan & Fathi, 2023). According to Lee (2022), in today's digital era, wise integration of technology into classroom is conducive to enjoyable learning environment. To this end, EFL instructors are encouraged to incorporate AI tools, such as ChatGPT which is already proved as an effective affordance for interest stimulation, into future L2 learning (Ghafouri, 2024).

Despite contributions, limitations of this study should be identified. Firstly, the current research only enrolled students in a same university, which may constrain the generalizability of findings. The follow-up research will enlarge the sample size by recruiting more students of different educational and cultural backgrounds. Secondly, since the single-dimension construct is insufficient to represent the full potential of learners' engagement (Sun et al., 2023), the future study will shed a more nuanced light on the L2 grit's contribution to cognitive, behavioral, emotional and social engagement respectively.

Acknowledgements

This research was supported by the Teaching Reform Projects of Beijing University of Posts and Telecommunications (Grant number 2022Y013 and 2023ZD08).

References

Banegas, D. L. (2023). ″What if it's been space all this time?″: Understanding the spatiality of language teacher education. *System, 113*, 102978.

Chen Hsieh, J., & Lee, J. S. (2023). Digital storytelling outcomes, emotions, grit, and perceptions among EFL middle school learners: Robot-assisted versus PowerPoint-assisted presentations. *Computer Assisted Language Learning, 36*(5-6), 1088-1115.

Derakhshan, A., & Fathi, J. (2023). Grit and foreign language enjoyment as predictors of EFL learners′ online engagement: The mediating role of online learning self-efficacy. *The Asia-Pacific Education Researcher*, 1-11.

Dixon, T., Christison, M., Dixon, D. H., & Palmer, A. S. (2021). A meta‐analysis of hybrid language instruction and call for future research. *The Modern Language Journal, 105*(4), 792-809.

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: perseverance and passion for long-term goals. *Journal of personality and social psychology, 92*(6), 1087.

Ebadi, S., Weisi, H., & Khaksar, Z. (2018). Developing an Iranian ELT context-specific grit instrument. *Journal of psycholinguistic research*, 47, 975-997.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74(1), 59–109.

Ghafouri, M. (2024). ChatGPT: The catalyst for teacher-student rapport and grit development in L2 class. *System, 120*, 103209.

Khajavy, G. H. (2021). Modeling the relations between foreign language engagement, emotions, grit and reading achievement. In P. Hiver, A. H. Al-Hoorie, & S. Mercer. (Eds.). *Student engagement in the language classroom*. Multilingual Matters, 241-259.

Khajavy, G. H., & Aghaee, E. (2022). The contribution of grit, emotions and personal bests to foreign language learning. *Journal of Multilingual and Multicultural Development*, 1-15.

Lee, J. S. (2022). The role of grit and classroom enjoyment in EFL learners′ willingness to communicate. *Journal of Multilingual and Multicultural Development, 43*(5), 452-468.

Li, J., King, R. B., & Wang, C. (2022). Profiles of motivation and engagement in foreign language learning: Associations with emotional factors, academic achievement, and demographic features. *System, 108*, 102820.

Luan, L., Hong, J. C., Cao, M., Dong, Y., & Hou, X. (2020). Exploring the role of online EFL learners′ perceived social support in their learning engagement: a structural equation model. *Interactive Learning Environments*, 1-12.

Solhi, M., Derakhshan, A., & Ünsal, B. (2023). Associations between EFL students' L2 grit, boredom coping strategies, and emotion regulation strategies: A structural equation modeling approach. *Journal of Multilingual and Muiticultural Development, 1-20.*

Sun, W., Shi, H., & Yan, Y. (2023). Contributions of Ideal L2 Self, Grit, and Boredom to Engagement in an EFL Context: A Structural Equation Modeling Approach. *The Asia-Pacific Education Researcher*, 1-12.

Tang, X., Wang, M. T., Guo, J., & Salmela-Aro, K. (2019). Building grit: The longitudinal pathways between mindset, commitment, grit, and academic outcomes. *Journal of youth and adolescence, 48*, 850-863.

Teimouri, Y., Plonsky, L., & Tabandeh, F. (2022). L2 grit: Passion and perseverance for second-language learning. *Language Teaching Research, 26*(5), 893-918.

Yu, X., & Ma, J. (2024). Modelling the predictive effect of enjoyment on willingness to communicate in a foreign language: the chain mediating role of growth mindset and grit. *Journal of Multilingual and Multicultural Development*, 1-18.

Zhao, X., & Wang, D. (2023). Grit, emotions, and their effects on ethnic minority students' English language learning achievements: A structural equation modelling analysis. *System, 113*, 102979.

Adoption Analysis of AIGC Tools by Art Students Using an Extended Technology Acceptance Model

Chenglin Yang[1,2], Chikin Lam[1], Qingyang Xu[1], Shujing Jiang[1], Tao Tan[1], Yue Sun[1,*]
[1] Faculty of Applied Sciences, Macao Polytechnic University, 999078, Macao SAR, China
[2]Anhui Broadcasting Movie and Television College, 231041, Hefei, Anhui, China
[*]Corresponding author

Abstract: *The rapid evolution of computer technology has significantly driven the expansion of generative art, leading to an increased prevalence of generative art tools among art students. This study investigates the widespread acceptance of generative art tools within the art student community by employing an extended model derived from the Technology Acceptance Model (TAM). The objective is to provide practical insights aimed at enhancing the adoption of generative art tools. The research collected data from 434 art students, utilizing quantitative analysis through partial least squares structural equation modeling. In addition to traditional TAM factors such as perceived usefulness and perceived ease of use, this study explores the interplay of computer self-efficacy, professional background, art appreciation, creativity, quality of generated images, level of learning, and acceptance. Ongoing efforts will refine the framework for increased applicability among art students in future research endeavors.*
Keywords: Technology Acceptance Model, Generative Art Tools, Computer Self-efficacy, Creativity

1. Introduction

With the evolution of computer-assisted education, today's educational model and learning styles have significant changes, particularly with the introduction of Generative Adversarial Networks (Goodfellow et al., 2014) and the advancement large language model. The acquisition of knowledge has become more convenient. For art students, the integration of generative art tools has transformed the learning process. As generative art tools progressively replace traditional art skills, the cultivation of artistic thinking and creativity takes on heightened importance.

The combination of art and technology is a crucial element in the development of the art field. In the realm of art education within schools, the question emerges on how to bolster students' enthusiasm for technology and effectively instill the ability to seamlessly combine artistic sensibility with the rational thinking of technology in their artworks. While the Technology Acceptance Model (TAM) serves as a framework for elucidating and predicting people's acceptance of information technology (Davis, 1989), existing research reveals a scarcity of technology acceptance tests specifically for art students. Hence, this study aims to explore students' acceptance of generative art tools during art courses by extending the TAM.

Our data collection involved 434 art students, employing partial least squares structural equation modeling employed for quantitative analysis. Beyond conventional factors like perceived usefulness and perceived ease of use, this research delves into the intricate relationships between variables such as computer self-efficacy, professional background, level of study, art appreciation, creativity, quality of work, and acceptance. The overarching goals of this research are to present a viable solution for art students to seamlessly integrate technology into their education, identify factors influencing technology acceptance to enhance its adoption among art students, and provide insights for the development of cross-disciplinary approaches in art.

2. Literature Review

2.1. Generative Art Tools

Generative art is a relatively new term used to refer to artworks that can be automatically generated using computer algorithms or computer programs (Nairat et al., 2020). According to Paul (2016), any artistic practice process in which an artist uses a computer program, natural language processing, machine, or other system with some degree of autonomy to set in motion something that contributes to the completion of a work of art can be called generative art. Therefore, a generative art tool is a medium that contributes to a work of art.

However, the research found that the use of generative art tools is rarely mentioned in the art classroom. Although some artists (Dehlinger, H., 2020) argue that machines are incapable of conceiving art. When ideas are used as the design focus of a generative system, it leads to aesthetic events. It is also recognized that accepting computers as part of art making to explore uncharted territories is desirable. Therefore, we will discuss generative art tools just from the perspective of art education, where generative AI has many applications in the field of education, with significant benefits in a number of areas, including instructional design (Dickey & Bejarano, 2023), creation of instructional materials (Leiker et al., 2023), and educational evaluation (Ilieva et al., 2023). Additionally, in the field of art education, since the proposal of Generative Adversarial Networks, there have been developments in generative pencil drawing (Jin, 2019), generative Monet-style oil painting (Manandhar et al., 2023), generative Chinese landscape painting (Xue , 2021), and many other image style migration techniques and methods that are important for the learning of art students in higher education institutions.

2.2. Technology Acceptance Model

Technology Acceptance Model (TAM) insists that a user's behavioral intentions to utilize technology are determined by how beneficial and easy they believe the technology to be (Davis, 1989). "The extent to which a person believes that using a particular system will improve his or her job performance" is the definition of perceived usefulness, while "the extent to which a person believes that using a particular system will be effortless" is the definition of perceived ease of use. The TAM has been widely applied in the field of educational technology, such as: MOOC systems (Al-rahmi, 2019), VR systems (Barrett, 2020), gamified learning platforms (Vanduhe, 2020). In addition, the TAM establishes the roles of perceived usefulness and perceived ease of use. It is thought that these two factors—perceived usefulness and perceived ease of use—have a direct impact on perceived usefulness, which in turn influences user attitude. Furthermore, Al-rahmi (2019) demonstrated that perceived compatibility, trialability, complexity, relative advantage, and observability all positively influence how useful and easy something is considered to use, which in turn influences behavior intention to use and attitude toward it.

3. Proposed Model and Hypothesis

3.1. Technology Acceptance Model (TAM)

TAM is one of the most common theories used to test the acceptance of technology by user groups and has been used in numerous theoretical studies (Lai, 2017). This research aims to used TAM investigating the acceptance of art students towards the use of generative art tools for creative work. Compared with the traditional TAM model, we set the external variables and named it xTAM. It is able to analyze the characteristics of generative art tools through a variable specific of art students.

3.2. Hypothesis

The hypotheses of this study were derived from the xTAM mentioned in **Figure 1**. The relationship between these factors was incorporated into the model to investigate the acceptance of generative art tools by art students. Perceived

Usefulness (PU), Perceived Ease of Use (PEOU), Attitude towards Use (A) and Actual Use (U) were used as the basic variables. Four external variables were derived from the literature review and analysis of previous research: art appreciation (AA), computer self-efficacy (CSE), system quality (Q) and creativity (C).

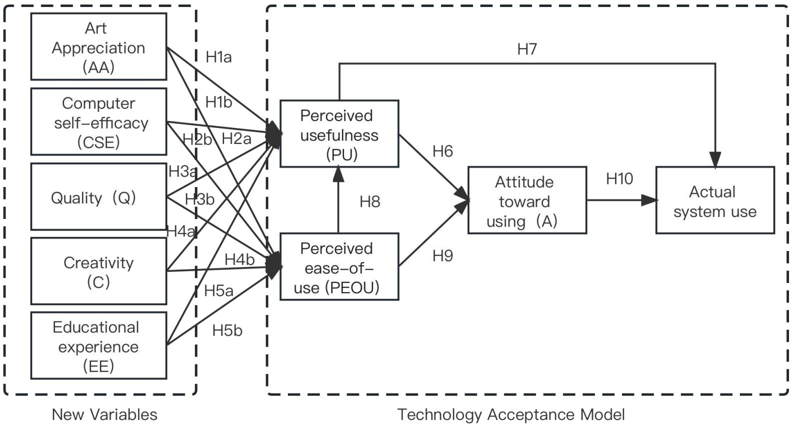


Figure 1. xTAM model and Hypothesis.

3.2.1. Art Appreciation (AA)

Art appreciation, often termed aesthetic awareness, is commonly acknowledged as a subjective realm (Schabmann et al., 2015). It is widely recognized that individual perception and cognition play a pivotal role in the assessment of art. Moreover, existing evidence suggests that professional knowledge can influence one's preferences in art (Gardner et al., 1975). In the context of generative art tools, art students who engage with such tools exhibit a propensity to value the images generated. It is imperative to delve into the correlation between this specific variable within the artistic domain and the acceptance of technology. This connection can be viewed as the interplay between user expertise and technology acceptance. From this perspective, we posit the following hypothesis:

H1a: AA has a positive effect on users' perceived usefulness of generative art tools.

H1b: AA has a positive effect on users' perceived ease of use of generative art tools.

3.2.2. Computer Self-efficacy (CSE)

The term of computer self-efficacy describes how people feels about their capacity to employ particular computer skills to carry out tasks related to computers (Afari et al., 2023). According to Loar (2018), computer self-efficacy is linked to favorable learning processes and results, such as intention to use the computer and perceptions of its utility and usability. In light of this, we put out the following theory:

H2a: CSE has a positive effect on users' perceived usefulness of generative art tools.

H2b: CSE has a positive effect on users' perceived ease of use of generative art tools.

3.2.3. Quality(Q)

The integrity of a system encompasses multifaceted dimensions while the quality of content produced by the system undergoes continuous evolution with technological advancements. Through drawing insights from m-learning research, it becomes evident that elements such as the quality of educational content, content design, interactivity, functionality, and user interface design significantly influence users' Perceived Usefulness and Perceived Ease of Use. This study narrows its focus to the quality of content generated by generative art tools. The following hypothesis are proposed:

H3a: Q has a positive effect on users' perceived usefulness of generative art tools.

H3b: Q has a positive effect on users' perceived ease of use of generative art tools.

3.2.4. Creativity (C)

Artistic creativity encompasses the comprehensive psychological qualities necessary for the creation of artworks . These qualities primarily involve artistic observation, artistic sensitivity, artistic imagination, and artistic communication ability(Gao, 2024). Recognized as a pivotal component of the art education process, AIGC can better play with and fulfil the creator's ideas. The quality of the work produced is determined by the creator's level of creativity. In the context of this research, significant attention is dedicated to examining the impact of artistic creativity on students' utilization of generative art tools. From this perspective, the following hypothesis is proposed:

H4a: C has a positive effect on users' perceived usefulness of generative art tools.

H4b: C has a positive effect on users' perceived ease of use of generative art tools.

3.2.5. Educational experience (EE)

Educational experience mainly refers to the background of students' previous education, as seen in previous studies, experience is one of the factors to be measured by TAM and belongs to users' personal characteristics (Al-nuaimi & Al-emran, 2021), in our study, educational experience mainly measures drawing experience and disciplinary background of use, and from this point of view, we propose the following hypothesis:

H5a: EE has a positive effect on users' perceived usefulness of generative art tools.

H5b: EE has a positive effect on users' perceived ease of use of generative art tools.

3.2.6. Perceived ease-of-use (PEOU)、Perceived usefulness(PU) and Attitude toward using (A)

Perceived usefulness refers to the extent to which an individual believes that a new technology can improve his or her efficiency (Lee & Lehto, 2013). Meanwhile, perceived ease of use refers to the extent to which an individual accepts that a new technology can be easily adopted without spending significant time learning it (Vanduhe et al., 2020). Concurrently, perceived ease of use has an impact on users' perceived usefulness and attitude towards use, which ultimately affects actual use, and the ease of use and complexity of a generative art tool may be critical to the actual use of the tool; therefore, we propose the following hypothesis:

H6 Users' perceived usefulness of generative art tools will positively influence their attitudes towards tools.

H7 Users' perceived usefulness of generative art tools will positively influence their actual use of tools.

H8 Users' perceived ease of use of generative art tools will positively influence their perceived usefulness of tools.

H9 Users' perceived ease of use of generative art tools will positively influence their attitudes towards tools.

H10 Users' attitudes towards the use of generative art tools will positively influence their actual use of tools.

4. RESEARCH METHOD

4.1. Questionnaire development

In alignment with the research objectives, this study employed a quantitative research questionnaire to empirically assess the formulated hypotheses. The questionnaire was systematically distributed among students specializing in art-related disciplines, encompassing both specialized art institutions and arts programs within comprehensive universities. Prior to participating, explicit consent was secured from the respondents, ensuring the confidentiality of their responses. It was explicitly communicated that participants' answers would be utilized exclusively for academic research purposes. Simultaneously all survey respondents willingly agreed to partake in the study, with their responses being strictly employed for academic objectives.

The questionnaire, specifically crafted for testing the research model and hypotheses, includes demographic information about the participating art students. Comprised of 32 questions, the questionnaire draws inspiration from previous research studies (Yang et al., 2022; Faqih & Jaradat, 2021; Luo & Du, 2022; Shen et al., 2022; Al-adwan et al., 2023). The questions cover a wide range of domains, including perceived usefulness, perceived ease of use, attitudes, practical use, art appreciation, computer self-efficacy, quality, and creativity. Given the questionnaire's adaptability, respondent convenience, and the potential for quantifiable results, a Five-point Likert scale was employed in this study. Respondents were prompted to express their opinion on a scale ranging from strongly disagree to strongly agree.

4.2. Data collection

Table 1 presents demographic information about the respondents from 10 universities in Mainland China and one university in Macau, selected as the study samples. Questionnaire collection spanned from October 2023 to November 2023. A total of 638 questionnaires were distributed, yielding 434 valid responses. Analysis of the respondent data reveals that a significant majority (80.88%) demonstrated familiarity with the generative art tool, while a smaller proportion (19.12%) reported a lack of comprehension or understanding regarding its functionality and applications.The survey participants were mostly female, comprising 70.74% of the total. The majority of respondents fell within the 18-25 age range and represented three levels of education: vocational, undergraduate, and postgraduate.

Table 1. Demographic characteristics of the respondents.

Category	Sub-category	Frequency(N=434)	Percentage%
Gender	Male	127	29.26
	Female	307	70.74
Age (years)	<18	4	0.92
	18-21	259	59.68
	22-25	170	39.17
	>26	1	0.23
Education Level	Diploma	214	49.31
	Undergraduate	195	44.93
	Postgraduate	25	5.76
Understanding the Generative Art Tool	Yes	351	80.88
	No	83	19.12
Total Participants		434	100.00

4.3. Data analysis

Drawing upon empirical data and the research context, we employed the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique for model development. In contrast to alternative modeling methodologies (Al-adwan et al., 2023; Peng et al., 2023), PLS-SEM stands out as a versatile and robust approach, characterized by more lenient prerequisites regarding sample size and data distribution. Its appropriateness is particularly evident in our research, showcasing unique advantages for conducting exploratory studies. For data analysis, we utilized Smart-PLS software. In the initial phase of the project, the model undergoes a comprehensive evaluation, encompassing assessments of internal consistency, convergent validity, and discriminant validity. Once the acceptability of the data is confirmed in this preliminary step, the study progresses to apply the structural model for the validation of our prior hypotheses.

5. Results

5.1. Preliminary data analysis

To substantiate the proposed latent factor structure against observed data, we employed the Smart-PLS 4.0 tool to conduct Confirmatory Factor Analysis (CFA). **Table 2** meticulously outlines the specific metrics concerning the reliability and validity of the questionnaire. It is worth nothing that the reliability assessment, measured by Cronbach's alpha for all items, consistently exceeded the critical threshold of 0.7 (except for the item related to creativity). The Composite Reliability(CR) coefficient achieved the recommended value of 0.7 (Hair, 2009). Additionally, the factor loadings for each observed item surpassed 0.7 (except for C2), underscoring the strong reliability in the composite measurements and affirming the overall robustness of the composite reliability.

Regarding convergent validity (Bagozzi & Yi, 1988), the Average Variance Extracted (AVE) for each dimension in this study surpassed the threshold of 0.5. Furthermore, discriminant validity was meticulously assessed. The diagonal values consistently surpassed the correlation coefficients with other potential constructs, affirming that the data within the discriminant validity matrix confirm significant distinctions between potential constructs. This corroborates the efficacy of the measurement instrument in adeptly distinguishing among diverse potential constructs (**Table 3**).

Table 2. Reliability and validity of all variables.

Items	Factor loadings	Mean	Percentages of the participant's answer to the items				
			Item 1	Item 2	Item 3	Item 4	Item 5
Perceived convenience (CSE) AVE=0.645 CR=0.879 alpha=0.82							
CSE1	0.769	3.190	5.3	8.8	55.9	21.3	8.6
CSE2	0.816	2.965	7.7	13.9	57.3	16.5	4.6
CSE3	0.778	2.849	10.2	17.4	54.5	13	4.9
CSE4	0.848	2.817	9	19	57.1	10.9	3.9
Perceived convenience (Q) AVE=0.854 CR=0.921 alpha=0.831							
Q1	0.941	2.993	7	11.1	61.9	15.5	4.4
Q2	0.906	2.893	7.9	16	59.9	11.4	4.9
Perceived convenience (AA) AVE=0.595 CR=0.814 alpha=0.701							
AA1	0.852	3.049	6.5	9	62.9	16.2	5.3
AA2	0.730	3.318	2.6	4.6	60.8	22.5	9.5
AA3	0.726	3.190	2.8	8.6	62.4	19.3	7
Perceived convenience (EE) AVE= 0.653 CR=0.850 alpha=0.735							
EE1	0.842	3.148	4.6	10.7	57.1	20.4	7.2
EE2	0.803	3.123	4.6	11.8	57.3	19	7.2
EE3	0.778	3.077	3.5	13.5	61.5	15.1	6.5
Perceived convenience (C) AVE=0.611 CR=0.741 alpha=0.492							
C1	0.979	3.371	1.6	5.1	59.2	22.7	11.4
C2	0.514	3.148	2.6	10.7	64	14.8	7.9
Perceived convenience (EOU) AVE= 0.684 CR=0.867 alpha=0.775							
PEOU1	0.799	3.030	6.7	11.4	61.5	13	7.4
PEOU2	0.830	2.926	8.6	15.8	55.9	13.9	5.8
PEOU3	0.851	3.074	5.3	10.9	61	16.5	6.3
Perceived convenience (PU) AVE=0.764 CR=0.951 alpha=0.938							
PU1	0.852	3.225	4.6	7.7	56.1	23.7	7.9
PU2	0.868	3.255	5.1	5.8	56.4	23.9	8.8
PU3	0.869	3.067	7.7	9.5	57.1	20	5.8
PU4	0.905	3.086	8.4	7.9	57.8	18.8	7.2
PU5	0.883	3.060	7.9	9.5	58.2	17.4	7
PU6	0.866	3.262	7	5.8	51.3	26	10
Perceived convenience (A) AVE=0.861 CR=0.949 alpha=0.919							
A1	0.908	3.346	4.9	4.6	52.9	26.2	11.4
A2	0.938	3.118	8.1	6.7	58.2	19	7.9
A3	0.938	3.174	7.2	6	57.8	20.2	8.8
Perceived convenience (USE) AVE=0.903 CR=0.949 alpha=0.893							
USE1	0.949	3.246	5.3	6	56.4	23.2	9
USE2	0.952	3.260	5.3	6.7	55.7	21.1	11.1

Table 3. Discriminant validity.

	A	AA	C	CSE	EE	EOU	PU	Q	USE
A	0.928								
AA	0.618	0.771							
C	0.124	0.317	0.782						
CSE	0.658	0.659	0.243	0.803					
EE	0.361	0.630	0.559	0.550	0.808				
PEOU	0.480	0.534	0.192	0.528	0.503	0.827			
PU	0.856	0.644	0.124	0.623	0.389	0.552	0.874		
Q	0.694	0.736	0.099	0.712	0.430	0.488	0.708	0.924	
USE	0.753	0.609	0.170	0.554	0.374	0.409	0.708	0.599	0.951

5.2. Measurement model

Following a satisfactory assessment of the measurement model, the subsequent phase involves the examination of the structural model. PLS-SEM served as the primary method for data analysis in this study, with BootStrap employed for estimating the T-value associated with the path coefficient. The Coefficient of Determination (R^2) was utilized to gauge the overall model fit, measuring the model's ability to elucidate the observed variables. R^2 values were deemed significant if exceeding 0.20 (Shiau et al., 2020). **Figure 2** illustrates the structural model of the study, depicting the path coefficients between variables and the R2 values for the dependent variables.

In terms of predictive efficacy, the influences of CSE, Q, AA, EE, and C on PEOU resulted in an R^2 value of 0.377, indicating that these variables collectively accounted for 37.7% of the variability in PEOU. This explanatory capacity is considered moderately substantial. Additionally, the explanatory capacity of five factors (CSE, Q, AA, EE, C, and PEOU) in elucidating the variance in PU reached 58.3% ($R^2 = 0.583$), signifying a considerable level of explanatory power. Finally, while the total variance explained in A is 73.3% ($R^2 = 0.733$) concerning PU and PEOU, USE explains the total variance of 58.2% ($R^2 = 0.582$) in PU and A. These explanatory powers are recognized as substantial.

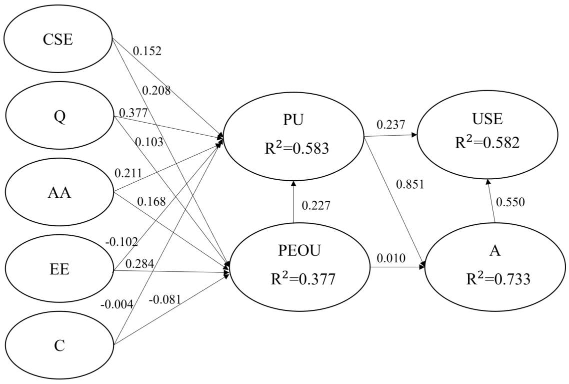


Figure 2. Structural model.

5.3. Hypotheses testing

Following the establishment of a satisfactory level of reliability and validity in the measurement outcomes, a systematic hypothesis test was conducted, and the significance of the path coefficients (β) was assessed in **Table 4**. The results indicate positive and significant effects of art appreciation on perceived usefulness (β = 0.211, p = 0.000) and perceived ease-of-use (β = 0.168, p = 0.034), supporting H1a and H1b. Similarly, the relationships of computer self-efficacy with perceived usefulness (β = 0.152, p = 0.004) and perceived ease-of-use (β = 0.208, p = 0.018) were positive and significant, supporting H2a and H2b. Quality (β = 0.377, p = 0.000) positively impacts perceived usefulness but does not show a positive impact on perceived ease-of-use (β = 0.103, p > 0.05). Therefore, H3a is confirmed while H3b is rejected.

However, regarding the role of curiosity, the results indicate that the direct influence of curiosity on both perceived usefulness (β = -0.004, p > 0.05) and perceived ease-of-use (β = -0.081, p > 0.05) are found to be insignificant, suggesting that H4a and H4b are not supported. In addition, educational experience (β = -0.102, p > 0.05) fails to demonstrate a positive impact on perceived usefulness, but it (β = 0.284, p = 0.000) exhibits a positive influence on perceived ease-of-use, thereby rejecting H5a but supporting H5b. Moreover, perceived ease-of-use (β = 0.227, p = 0.000) has a positive impact on perceived usefulness, and perceived usefulness (β = 0.237, p = 0.000) has a positive impact on actual system use, thus H7 and H8 are supported. Finally, both perceived ease-of-use (β = 0.010, p = 0.001) and perceived usefulness (β = 0.851, p = 0.000) have a positive impact on attitude toward using, and it (β = 0.550, p = 0.000) exhibits significant effects on actual system use, indicating that H6, H9, and H10 respectively are supported.

Table 4. Results of paths.

Paths	β	T-value	P-value	f^2	Support?
H1a: AA -> PU	0.211	3.645	0.000	0.035	yes
H1b: AA -> PEOU	0.168	2.117	0.034	0.015	yes
H2a: CSE -> PU	0.152	2.889	0.004	0.022	yes
H2b: CSE -> PEOU	0.208	2.370	0.018	0.029	yes
H3a: Q -> PU	0.377	5.852	0.000	0.115	yes
H3b: Q -> PEOU	0.103	1.402	0.161	0.006	no
H4a: C -> PU	-0.004	0.342	0.732	0.000	no
H4b: C -> PEOU	-0.081	1.160	0.246	0.007	no
H5a: EE -> PU	-0.102	0.605	0.545	0.010	no
H5b: EE -> PEOU	0.284	3.612	0.000	0.056	yes
H6: PU -> A	0.851	26.598	0.000	1.886	yes
H7: PU -> USE	0.237	19.331	0.000	0.036	yes
H8: PEOU -> PU	0.227	3.910	0.000	0.077	yes
H9: PEOU -> A	0.010	3.370	0.001	0.000	yes
H10: A -> USE	0.550	6.984	0.000	0.193	yes

6. Discussion and conclusions

In the realm of art education, the use of generative art tools to enrich learning is increasingly prevalent among art students (Hutson & Robertson, 2023). Within this context, students not only express heightened concerns about the creation of artworks but also for the time investment in this process. Consequently, this study expands the TAM by incorporating external variables such as computer self-efficacy, professional background, art appreciation, creativity, quality of generated images, and the level of learning. The proposed TAM tailored for art majors using generative art tools emphasizes the specific abilities of art perception, a dimension relatively underexplored in previous studies.

The study's findings align with research hypotheses, confirming the consistency of relationships between perceived ease of use, perceived usefulness, attitude toward use, and actual use (Barrett et al., 2023; Yoon & Kim, 2007). However, the anticipated role of creativity in influencing the connection between perceived ease of use and perceived usefulness is not supported. This suggests that, in the context of generative art tools, users do not consider originality a pivotal factor since these tools generate images based on dataset training, ensuring their inherent originality. Notably, the quality of generated images significantly influences perceived usefulness, a rationale rooted in art students' inclination towards high-quality visuals owing to their fine art foundation. Furthermore, the positive effect of the user's learning background on perceived ease of use is explicable by the cognitive reliance inherent in perceived ease of use, wherein exposure to relevant knowledge provides users with cognitive cues.

This study serves as a valuable guide for art education seeking to leverage generative art tools for learning and teaching purposes. The perceived usefulness emerges as a pivotal determinant influencing users' sustained utilization of generative art tools. Enhancing the ease of use in these tools is crucial, as it not only augments their utility but also positively shapes user attitudes, fostering a greater willingness to continue their usage. The study supports collaboration between art instructors and generative art tool developers to understand students' attitudes and perceptions. This collaboration facilitates the optimization of tool design, leading to enhanced services and improved product quality, thereby promoting greater ease of use. Art instructors are encouraged to incorporate art appreciation classes to broaden students' understanding and acceptance of diverse artistic styles. Additionally, teaching staff should cultivate students' art appreciation skills to yield more meaningful outcomes when using generative art tools. Developing students' proficiency in utilizing these tools and encouraging exploration for new inspirations is essential for their enhanced creative output. This study encourages educators to guide students in brainstorming their ideas with generative art tools (Dillon & Brown, 2010), fostering a close embrace of new technologies for the effective fusion of art and technology. For developers, tailoring content to users' cognitive capacities and needs, alongside timely updates to datasets, is vital for enhancing the efficacy and diversity of generated images. In terms of ease of use, developers should optimize the generation process, reducing the time required to produce an image and thereby enhancing the practical utility of the tool.

7. Limitations

While this study contributes valuable theoretical and practical insights, it is essential to acknowledge its limitations and improve further . The study exclusively relied on an extended TAM, while future researchers are encouraged to explore the integration of TAM with other relevant models. This collaborative approach has the potential to yield more comprehensive and nuanced findings. Furthermore, the examination of the generative art tool acceptance was broadened to encompass all art students. Future studies could benefit from a more focused scope, specifically delving into the acceptance dynamics among painting or design students, as they likely constitute the primary users of generative art tools within the realm of art education. Further more, narrowing the scope in this manner can provide a more targeted and detailed understanding of acceptance patterns within specific art disciplines.

8. References

Afari, E., Eksail, F. A. A., Khine, M. S., & Alaam, S. A. (2023). Computer self-efficacy and ICT integration in education: Structural relationship and mediating effects. *Education and Information Technologies*, 1-17.

Al-adwan,A.S., Li,N., Al-adwan,A., Abbasi,G.A., Albelbisi,N.A. ,& Habibi, A.(2023).“Extending the Technology Acceptance Model (TAM) to Predict University Students’ Intentions to Use Metaverse-Based Learning Platforms”. *Education and Information Technologies,28*(11),15381-15413.https://doi.org/10.1007/s10639-023-11816-3

Al-nuaimi,M.N. ,& Al-emran M.(2021).Learning management systems and technology acceptance models: A systematic review. *Education and Information Technologies,26*(5),5499-5533.https://doi.org/10.1007/s10639-021-10513-3）

Al-Rahmi, W. M., Yahaya, N., Alamri, M. M., Alyoussef, I. Y., Al-Rahmi, A. M., & Kamin, Y. B. (2021). Integrating innovation diffusion theory with technology acceptance model: Supporting students’ attitude towards using a massive open online courses (MOOCs) systems. *Interactive Learning Environments, 29*(8), 1380-1392.

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the academy of marketing science, 16,* 74-94.

Barrett, A., Pack, A., Guo, Y., & Wang, N. (2023). Technology acceptance model and multi-user virtual reality learning environments for Chinese language education. *Interactive Learning Environments, 31*(3), 1665-1682.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.

Dehlinger,H.(2020).Generative Art.*Journal of Mathematics and the Arts,14*(1-2),33-36.https://doi.org/10.1080/17513472.2020.1729058

Dickey, E., & Bejarano, A. (2023). A Model for Integrating Generative AI into Course Content Development. arXiv preprint arXiv:2308.12276.

Dillon, S., & Brown, A. (2010). The educational affordances of generative media in arts education. In INTED 2010-International Technology, *Education and Development Conference-Conference Proceedings* (pp. 005311-005320). International Association of Technology, Education and Developmnet.

Faqih, K. M., & Jaradat, M. I. R. M. (2021). Integrating TTF and UTAUT2 theories to investigate the adoption of augmented reality technology in education: *Perspective from a developing country. Technology in Society, 67*, 101787.

Paul, C. (2016). A companion to digital art.

Gao, B., Xie, H., Yu, S., Wang, Y., Zuo, W., Zeng, W. (2024). Exploring User Acceptance of Al Image Generator: Unveiling Influential Factors in Embracing an Artistic AIGC Software. In: Zhao, F., Miao, D. (eds) AI-generated Content. AIGC 2023. *Communications in Computer and Information Science,* vol 1946. Springer, Singapore. https://doi.org/10.1007/978-981-99-7587-7_17

Gardner, H., Winner, E., & Kirchner, M. (1975). Children’s concep-tions of the Arts. Journal ofAesthetic Education, 9, 60–77.

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. *Advances in neural information processing systems, 27*.

Hair, J. F. (2009). Multivariate data analysis.

Hutson, J., & Robertson, B. (2023). Exploring the Educational Potential of AI Generative Art in 3D Design Fundamentals: A Case Study on Prompt Engineering and Creative Workflows. *Global Journal of HUMAN-SOCIAL SCIENCE: A Arts & Humanities-Psychology, 23*(2).

Jin, Y., Li, P., Wang, W., Zhang, S., Lin, D., & Yin, C. (2023). GAN-based pencil drawing learning system for art education on large-scale image datasets with learning analytics. *Interactive Learning Environments, 31*(5), 2544-2561.

Lai, P. C. (2017). The literature review of technology adoption models and theories for the novelty technology. *JISTEM-Journal of Information Systems and Technology Management, 14*, 21-38.

Lee, D. Y., & Lehto, M. R. (2013). User acceptance of YouTube for procedural learning: An extension of the Technology Acceptance Model. *Computers & Education, 61*, 193-208.

Leiker, D., Gyllen, A. R., Eldesouky, I., & Cukurova, M. (2023, June). Generative AI for Learning: Investigating the Potential of Learning Videos with Synthetic Virtual Instructors. *In International conference on artificial intelligence in education* (pp. 523-529). Cham: Springer Nature Switzerland.

Loar, E. A. (2018). Computer self-efficacy revisited. *Journal of Instructional Research, 7*, 55–59. https://doi.org/10.9743/JIR.2018.4

Luo, Y., & Du, H. (2022). Learning with desktop virtual reality: Changes and interrelationship of self-efficacy, goal orientation, technology acceptance and learning behavior. *Smart Learning Environments, 9*(1), 1-22.

Manandhar, S., Naikodi, S., VL, M. V., & AN, M. Z. (2023). Generating Monet Style Images Using DCGAN Based CycleGAN.

Nairat, M., Nordahl, M., & Dahlstedt, P. (2020). Generative comics: a character evolution approach for creating fictional comics. *Digital Creativity, 31*(4), 284-301.

Peng,M.Y. , Xu,Y. ,& Xu , C.(2023).Enhancing students’ English language learning via M-learning: Integrating technology acceptance model and S-O-R model.*Heliyon,9*(2),e13302.https://doi.org/10.1016/j.heliyon.2023.e13302

Schabmann,A. , Gerger,G. , Schmidt,B.M. , Wögerer,E. , Osipov,I. ,& Leder , H.(2015).Where Does It Come From? Developmental Aspects of Art Appreciation.*International Journal of Behavioral Development,40*(4),313-323.https://doi.org/10.1177/0165025415573642

Shen, S., Xu, K., Sotiriadis, M., & Wang, Y. (2022). Exploring the factors influencing the adoption and usage of Augmented Reality and Virtual Reality applications in tourism education within the context of COVID-19 pandemic. *Journal of hospitality, leisure, sport & tourism education, 30,* 100373.

Shiau, W. L., Yuan, Y., Pu, X., Ray, S., & Chen, C. C. (2020). Understanding fintech continuance: perspectives from self-efficacy and ECT-IS theories. *Industrial Management & Data Systems, 120*(9), 1659-1689.

Vanduhe,V.Z. , Nat,M. ,& Hasan , H.F.(2020).Continuance Intentions to Use Gamification for Training in Higher Education: Integrating the Technology Acceptance Model (TAM), Social Motivation, and Task Technology Fit (TTF).*IEEE Access,8*,21473-21484.https://doi.org/10.1109/ACCESS.2020.2966179

Xue, A. (2021). End-to-end chinese landscape painting creation using generative adversarial networks. *In Proceedings of the IEEE/CVF Winter conference on applications of computer vision* (pp. 3863-3871).

Yang, F., Ren, L., & Gu, C. (2022). A study of college students' intention to use metaverse technology for basketball learning based on UTAUT2. *Heliyon, 8*(9).

Yoon, C., & Kim, S. (2007). Convenience and TAM in a ubiquitous computing environment: The case of wireless LAN. *Electronic Commerce Research and Applications, 6*(1), 102-112.

Investigating the Impact of Digital Storytelling-based Online Flipped Learning on EFL Learners' Willingness to Communicate

Bowen Jing[1], Huiqi Fan[1], Lin Luan[1*]
[1] Beijing University of Posts and Telecommunications
[*] luanlin@bupt.edu.cn

Abstract: *Learners' communicative intention serves as a determinant of second language acquisition (SLA). Digital storytelling (DST), which provides learners with multimodal resources for digital narration, constitutes an innovative approach for language learning. Despite the importance of DST in language instruction, scant attention has been paid to the role of DST in promoting English as a foreign language (EFL) learners' willingness to communicate (WTC) within a online flipped learning context. To fill this gap, a mixed-method research was conducted to explore the influence of DST-based online flipped learning approach on EFL learners' WTC. Firstly, a quasi-experiment was performed with a total of 69 participants being randomly assigned to the experimental (the DST-based online flipped learning) and comparison (the online flipped learning) groups. Secondly, a semi-structural interview was carried out. The quantitative results demonstrated that the experimental group outperformed the comparison group in terms of WTC. The interview also reflected EFL learners' positive attitude towards DST-based online flipped learning approach. Therefore, this study offered pedagogical implications for optimizing L2 speaking instruction in the post-COVID era.*
Keywords: digital storytelling (DST), willingness to communicate (WTC), online flipped learning, EFL learners

1. Introduction

The post-pandemic era has accelerated the prevalence of online flipped learning as an innovative approach of language instruction. Along with the benefits of online flipped learning, concerns about decreased in-class engagement and insufficient communication opportunities emerge simultaneously (Luan et al., 2023). Among all language competence, willingness to communicate (WTC) serves as one of the most pivotal facilitators of non-native speakers' second language development (Huang, 2023). Therefore, it is imperative to incorporate other effective instructional designs into online flipped learning so as to improve the language teaching quality. According to previous scholars (e.g. Fu et al., 2022), digital storytelling (DST) which provides multimodal resources for digital narration, unleashes the potential of enhancing EFL learners' oral proficiency. As a result, DST might serve as a suitable solution for EFL learners' inadequate communicative practice in conventional online flipped learning.

2. Literature Review

2.1. Digital Storytelling in EFL Education

Digital storytelling (DST) involves the process of creating topic-centered stories which can be recorded for playback and self-evaluation, with students as storytellers and multimedia elements (e.g. text, music, image) as digital resources (Robin, 2008). With the advancement of educational technologies, integrating DST into language instruction has gained increasing attention of researchers. DST empowers EFL learners' speaking, listening, reading and writing (Fu et al., 2022) by providing personalized learning experiences, real-life interactions and peer collaboration (Hava, 2021). Therefore, DST facilitates EFL learners' language competence required in the 21st century (Huang, 2023).

2.2. EFL Learners' Willingness to Communicate

Willingness to communicate (WTC) is defined by MacIntyre et al. (1998) as "a readiness to enter into discourse at a particular time with a specific person or persons, using L2" (p. 547). Specifically, WTC can be further conceptualized at both trait and situational levels (Öz et al., 2015). The trait level WTC refers to learners' stable communication propensity without fluctuations across different context. The situational level WTC, in contrast, is regarded as a situation-specific construct with dynamic variation in different learning settings. Based on well-established WTC model (e.g. Luan et al., 2023), the current study focused on the situated dimension of WTC, proposing individuals' intention to initiate or involve in English communications within a specific online flipped learning context.

2.3. Digital Storytelling for EFL Learners' Willingness to Communicate

A myriad of research has investigated the impact of DST on EFL learners' communicative capacity in diverse learning contexts (e.g. Fu et al., 2022; Huang, 2023). For instance, Huang (2023)'s study reveals that students in DST group benefit from learner-centered affordance and thus outperform non-DST group in WTC within traditional classroom setting. However, the effect of DST on EFL learners' WTC in the online flipped context, a technology-rich environment, remains under-explored. Therefore, it is worthwhile to verify DST-based online flipped learning approach as an effective way to improve EFL learners' WTC. The following two questions will be addressed in this study:

(1) Compared with the conventional online flipped learning approach, can the DST-based online flipped learning approach enhance EFL learners' WTC?

(2) What are EFL learners' opinions on the two different learning approaches?

3. Method

3.1. Research Context and Participants

This study was conducted in a college English course at a comprehensive university in Chinese mainland. A total of 69 first-year undergraduate students (42 males, 27 females) were recruited and randomly assigned to either the experimental (DST-based online flipped learning approach, 36 students) or the comparison (online flipped learning approach, 33 students) group. Then, participants from both groups were further divided into mini-groups with 4 to 5 members. All of the participants own similar English proficiency and the teaching content is identical in both experimental and comparison groups so as to eliminate the distraction of irrelevant variables.

3.2. Instruments

This research employed two instruments: English WTC questionnaire and semi-structural interview. The English WTC questionnaire was revised from Öz et al. (2015)'s well-developed survey in the form of five-point Likert scale ranging from 1 (Strongly Disagreed) to 5 (Strongly Agreed) .The questionnaire gauged EFL learners' WTC from two dimensions: willingness to engage in English communication (5 items. e.g. I'm willing to interact with others about the quality of DST products) and self-perceived English communicative competence (5 items. e.g. I'm capable of asking for clarification of the DST requirements) The items were presented in Chinese for participants' better comprehension. The revised questionnaire owned desirable consistency reliability with Cronbach's $\alpha = 0.92$. A semi-structural interview was also applied to evaluate participants' perceptions of the two different instructional methods.

3.3. DST Activity Design

Figure 1 illustrates the three-stage procedure of DST activity. For preparation, the mini-group members selected a topic from the three given options (i.e. society, beautiful scenery and campus life), brainstormed the storyline, and then collected topic-related materials. During the production stage, participants gathered, ordered and edited the DST elements. They recorded the digital story and made constant modification of details. On the post-production stage, students uploaded their DST artifacts to the Learning Management System (LMS) for peer feedback and evaluation.

Figure 1. Procedure of the DST activity

3.4. Research Procedure

The quasi-experiment lasted for 16 weeks, with two 45-minute classes each week. During the 1st and 2nd weeks, both experimental and comparison groups were invited to fill in WTC pre-questionnaire and trained how to conduct online flipped learning on the LMS. In addition, the experimental group was also taught the method and process of creating DST product. From the 3rd to 14th week, both of the two groups watched the same topic-related videos on LMS for flipped learning. But the distinction was that the participants in experimental group produced DST creation around certain topic and shared it via LMS while students in comparison group only involved in class discussions and receive feedback from teachers. In the last two weeks, WTC post-questionnaire was distributed to all participants. Moreover, 10 students from each group were randomly selected for interview.

3.5. Data Collection and Analysis

Firstly, one-way analysis of covariance (ANCOVA) was performed in SPSS to explore the impact of two different learning patterns on EFL learners' WTC. Secondly, thematic analysis of the interview was also operated via Nvivo software to gauge students' opinions on both of the DST-based and conventional online flipped learning approaches.

4. Results

4.1. Quantitative Results

According to descriptive statistics, both of the two learning modes enhanced students' WTC with the post-test score (Experimental Group: Mean = 3.98, SD = 0.57; Comparison Group: Mean = 3.58, SD = 0.75) higher than pre-test score (Experimental Group: Mean = 3.22, SD = 0.84; Comparison Group: Mean = 3.19, SD = 0.70). However, the ANCOVA results reflected a significant difference between the experimental and comparison groups in terms of WTC post-test scores (η^2= 0.11, F = 6.36, p = 0.01<0.05). The above experimental data indicated that the DST-based online flipped learning approach outperformed conventional online flipped learning in improving EFL learners' WTC.

4.2. Results of Interview

Table 2 reflects the thematic analysis results of the interview. After coding students' responses to interview questions, three themes emerged, revealing students' positive attitude towards both of the two learning styles. However, students holding the three positive perceptions in experimental group outnumbered comparison group, which meant that from students' perspective DST-based online flipped learning outperformed conventional flipped learning approach in terms of improving learners' communicative confidence, peer interaction as well as learning motivation.

Table 2 . Thematic analysis of the semi-structured interview

Themes	The number of students mentioned	
	DST-based flipped learning	Conventional flipped learning
Improving communicative confidence	8	5
Increasing interactive opportunities	9	4
Promoting learning motivation	10	7

5. Discussion and Conclusion

This study has explored the influence of DST-based flipped learning approach on EFL learners' WTC via quasi-experiment. Both of the quantitative and qualitative results demonstrated that DST-based flipped learning approach exerted positive impacts on students' WTC, congruent with Fu et al. (2022) and Hava (2021)'s statement that DST creates abundant opportunities for interaction and provides authentic context for meaningful communication, which activates reticent EFL learners' motivation to express themselves and communicate with others in public.

Pedagogical implications are also offered in the current study. As DST-based online flipped learning facilitates students' oral proficiency, instructors are recommended to incorporate DST as an effective implementation of technology-enhanced task-based language learning (TETBLT) into flipped classroom (Luan et al., 2023) to develop learners' English communicative skills in the post-COVID era. However, this research is limited in several aspects. Firstly, the current research only verified DST as a solution for poor oral proficiency. So follow-up studies are encouraged to explore the impact of DST on other language skills, such as reading and writing. Secondly, the short experiment duration may engender novelty effects. Therefore, further in-depth longitudinal analysis is required.

Acknowledgements

This research was supported by the Teaching Reform Projects of Beijing University of Posts and Telecommunications (Grant number 2022Y013 and 2023ZD08).

References

Fu, J. S., Yang, S. H., & Yeh, H. C. (2022). Exploring the impacts of digital storytelling on English as a foreign language learners' speaking competence. *Journal of Research on Technology in Education, 54*(5), 679-694.

Hava, K. (2021). Exploring the role of digital storytelling in student motivation and satisfaction in EFL education. *Computer Assisted Language Learning, 34*(7), 958-978.

Huang, H. T. D. (2023). Examining the effect of digital storytelling on English speaking proficiency, willingness to communicate, and group cohesion. *Tesol Quarterly, 57*(1), 242-269.

Luan, L., Yi, Y., Hwang, G. J., Dong, Y., Jing, B., & Liu, J. (2023). Facilitating EFL learners' willingness to communicate amidst the pandemic: a digital storytelling-based online flipped learning approach. *Innovation in Language Learning and Teaching*, 1-16.

MacIntyre, P., Dörnyei, Z., Clément, R., & Noels, K. (1998). Conceptualizing willingness to communicate in a L2: A situational model of L2 confidence and affiliation. *The Modern Language Journal, 82*(4), 545‒562.

Öz, H., Demirezen, M., & Pourfeiz, J. (2015). Willingness to communicate of EFL learners in Turkish context. *Learning and Individual Differences, 37*, 269-275.

Robin, B. R. (2008). Digital storytelling: A powerful technology tool for the 21st century classroom. *Theory into practice, 47*(3), 220-228.

A VR-assisted Language Learning Approach to Improve EFL Learner's Willingness to Communicate

Huiqi Fan[1], Bowen Jing[1], Yanqing Yi[1], Lin Luan[1*]
[1]Beijing University of Posts and Telecommunications, China
[*]luanlin@bupt.edu.cn

Abstract: *Willingness to communicate (WTC) has been recognized as a prerequisite for successful foreign or second language learning. With the advancement of digital technologies, virtual reality (VR) has witnessed growing application in language learning. However, the impact of VR on EFL learners' WTC has so far been insufficiently investigated. To fill the gap, this study set out to explore the potential of a self-developed VR platform for improving Chinese EFL learners' WTC and exploring their perceptions of VR-assisted English learning approach. Seventy college students were randomly assigned into experimental and comparison groups. Data collection comprised WTC questionnaires and semi-structured interviews. The quantitative results demonstrated that the use of VR exerts a significant impact on EFL learners' WTC. Analyses of interviews revealed that VR players enjoyed interacting with virtual objects and characters, which helped ease their anxiety and motivate them to communicate in the target language.*
Keywords: virtual reality, willingness to communicate, EFL learners, VR-assisted language learning approach

1. Introduction

For English as foreign language (EFL) learners, it is of great significance for them to improve communication or speaking skills for language learning. However, due to insufficient time and opportunities to speak and practice in English (Hung et al., 2023) or learning anxiety, lack of confidence and fear of making mistakes (Tai & Chen, 2020), EFL learners are disinclined to communicate with classmates and teachers in English. Therefore, it is necessary to find effective approaches to facilitate EFL learners' willingness to communicate. Virtual reality (VR) is gaining popularity for enhancing linguistic competencies, especially speaking skills (Park & Hanna, 2022). However, the potential contribution of VR on EFL learners' WTC still remain unclear. Therefore, the present study set to investigate the impact of VR on Chinese college EFL learners' WTC and their perceptions of the use of VR for English learning.

2. Literature Review

2.1. VR and EFL Education

VR is 'a highly interactive, computer-based, multimedia environment in which the user becomes a participant with the computer in a "virtually real" world' (Pantelidis, 1993). The fascinating features that make VR technologies so popular within educational settings include their ability to create immersive and authentic learning environments (Yu Ju Lan, 2020) and provide interactive opportunities for interpersonal communication (Yeh et al., 2021). The rapid development of VR in recent years has resulted in increasing attention from researchers and educators in EFL education (Barrett et al., 2020). For example, Hassani et al. (2016) employed VR to investigate non-native English language learners' speaking and listening skills. The results indicated that the virtual environment was effective for improving their oral proficiency. Moreover, Ebadi and Ebadijalal (2020) found that VR tools were helpful as it enabled learners to have comfortable and enjoyable interactions and encouraged them to practice speaking in a safe and relaxed environment. However, it should be noted that so far VR research has been mainly focused on English linguistic competences, such as speaking (Hassani et al., 2013), listening (Tai & Chen, 2021) and other aspects, yet little is known about its impact on EFL learners' WTC.

2.2. WTC in L2 Learning

L2 WTC refers to "a readiness to enter into the discourse at a particular time with a specific person or persons, using an L2" (MacIntyre et al., 1998). Students who possess a high level of WTC are more likely to engage L2 communication and become autonomous language learners without seeking help from teachers and peers, which in turn improve their communication skills (Reinders & Wattana, 2014). With the advancement of digital technologies, recent studies have been conducted to investigate EFL learners' WTC with the use of digital games (Reinders & Wattana, 2014), computer-mediated communication (Buckingham & Alpaslan, 2017), intelligent personal assistants (Tai & Chen, 2020) and other technologies. However, the relationship between EFL learner's WTC and VR is still insufficiently investigated. Therefore, the research questions in this study were proposed as follows:

(1) Does VR-assisted learning approach significantly promote EFL learners' willingness to communicate?

(2) What are the EFL learners' perceptions of VR-assisted English learning?

3. Method

3.1. Research Context and Participants

The study enrolled seventy sophomores (65.7% male, aged 18-21) from a comprehensive university in Chinese mainland who were attending a college English course to enhance their overall English proficiency especially speaking skills. They all have at least 6 years of formal English education and passed the College English Test Band 4. All participants were randomly divided into either the experimental (VR players, N=35) or the comparison group (video watchers, N=35) .

3.2. Instruments

3.2.1. The VR learning platform

A self-developed VR platform named *Situational English in Virtual Reality* (Figure 1) was employed in the study. By simulating major scenarios and check-in procedures at the international airports, the platform centered on the practical use of English in learners' everyday life as well as the enhancement of their communication skills.

Figure 1. The self-developed Situational English in Virtual Reality platform.

3.2.2. WTC in English questionnaire

The WTC in English questionnaire was adapted from Luan et al. (2023). The adapted version is a 15-item scale with two dimensions. The first section included five items concerning students' willingness to communicate in English (e.g. I talk to other VR players about a quest assignment). The second section consisted of ten items exploring students' state of self-perceived communicative competence in a VR learning environment (e.g. I feel nervous about using English while participating in VR activities). The items are measured with 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5) and presented in Chinese.

3.2.3. Semi-structured interviews

Semi-structured interviews were carried out to gather more in-depth insights on the participants' perceptions toward the impact of VR on their WTC and English learning. Three interview questions are as follows: (1) Did you find VR activities helpful in terms of facilitating communication in English? (2) What were your favorite parts of the VR experiment that promote WTC? (3) How did you feel about VR for English learning? Students' native language, Chinese, was used through the whole interviewing process to get clear and comprehensive replies.

3.3. Research Procedure

This study lasted for six weeks, with two 45-minute classes each week. All participants completed a background questionnaire and the WTC questionnaire in the first week. In week two, all the participants were introduced to the operation of Moodle platform. In addition, the VR group was informed of the basic instructions about the operation of the VR platform. Starting from week three, VR players did learning activities on the VR platform, while the video watchers learned the same content by watching instructional videos on personal computers. In week six, the post-test WTC questionnaire was administered to all participants. Moreover, eight students, four from each group, were chose to attend the semi-structured interviews based on convenience sampling. The interviews were conducted through Tencent Meeting for around 20 minutes each, which were audio-recorded and later transcribed for qualitative analysis.

3.4. Data Analysis

First, one-way analysis of covariance (ANCOVA) was conducted on SPSS 25.0 to explore the impact of VR-assisted learning approach on learners' WTC in English. Second, the thematic analysis method was used to analyze participants' responses to the semi-structured interviews with the help of NVivo 11.0.

4. Results

4.1. Quantitative Results

ANCOVA was conducted to investigate whether the use of the desktop VR platform has an impact on participants' WTC. We considered students' pretest scores as a covariate. Levene's test of the homogeneity of variance with regard to students' WTC was also performed before conducting the ANCOVA analysis, which indicated that there exists no significant difference in variances (p =0.16>0.05). Both groups have improvement in their WTC on the post-test questionnaire. However, a statistically significant difference was found in WTC between the two groups, $F=4.65$, $p = .04$. Given the value of the partial eta squared of .07, it can be concluded that the use of desktop VR has a significant impact on the participants' WTC in English.

4.2. Results of Interviews

The most prominent findings regarding experimental groups' perceptions of using the desktop VR were that it improves the L2 WTC and English proficiency of these EFL participants. The majority of participants were excited and motivated during the experimental process. Students also argued the strength of VR in providing a less anxious English learning environment. For instance, student VR-03 claimed: "*I liked participating in VR activities, because its relaxed atmosphere helped me practice speaking without the fear of being judged by classmates.* Moreover, the overwhelming VR players indicated that their English vocabulary knowledge has been enhanced, and they were more willing to apply what they had learned in the virtual platform to the real world. However, some VR players indicated that some technical issues had distracted their attention.

5. Discussion and Conclusion

The study investigated the impact of a VR platform on Chinese EFL learners' WTC. The findings revealed that the VR is a beneficial tool to improve the WTC performance of EFL learners, which corroborated that of Ebadi and Ebadijalal (2020). Besides, the majority of VR players held a positive attitude towards the use of VR-assisted English learning. They also felt more confident and less anxious when learning in the virtual reality environments. The findings also aligned with the suggestion to provide a stress-free atmosphere for learners (Kang, 2005), in which they could have ample opportunities to interact with virtual characters to practice the target language (Tai & Chen, 2020).

This study also has some limitations. First, the sample size was relatively small with 70 second-year students from one single university. Future research is encouraged to recruit larger group members with more diverse backgrounds. Secondly, technical issues such as unstable internet connection sometimes occurred, resulting in data losses. Therefore, technical experts are advocated to optimize the VR platform. Thirdly, the current study only lasted for six weeks, so longitudinal experiment can be conducted to gain further understanding about the impact of VR on EFL learners' WTC.

Acknowledgements

This research was supported by the Teaching Reform Projects of Beijing University of Posts and Telecommunications (Grant number 2022Y013 and 2023ZD08).

References

Barrett, A., Pack, A., Guo, Y., & Wang, N. (Joanne). (2020). Technology acceptance model and multi-user virtual reality learning environments for Chinese language education. *Interactive Learning Environments*, 1–18.

Buckingham, L., & Alpaslan, R. S. (2017). Promoting speaking proficiency and willingness to communicate in Turkish young learners of English through asynchronous computer-mediated practice.

Ebadi, S., & Ebadijalal, M. (2020). The effect of Google Expeditions virtual reality on EFL learners' willingness to communicate and oral proficiency. *Computer Assisted Language Learning*, 1–25.

Hassani, K., Nahvi, A., & Ahmadi, A. (2013). Design and implementation of an intelligent virtual environment for improving speaking and listening skills. *Interactive Learning Environments*, *24*(1), 252–271.

Hung, S.-T. A., Chen, W.-J., & Chien, S.-Y. (2023). Virtual reality is not always a cure-all: evidences from a quasi-experiment of EFL business speaking courses. *Interactive Learning Environments*, 1–17.

Kang, S.-J. (2005). Dynamic emergence of situational willingness to communicate in a second language. *System*, *33*(2), 277–292.

Yu Ju Lan. (2020). *Immersion, interaction, and experience-oriented learning: Bringing virtual reality into FL learning*. *24*(1), 1–15.

Luan, L., Yi, Y., Hwang, G.-J., Dong, Y., Jing, B., & Liu, J. (2023). Facilitating EFL learners' willingness to communicate amidst the pandemic: a digital storytelling-based online flipped learning approach. *Innovation in Language Learning and Teaching*, 1–16.

MacIntyre, P. D. (2017). An overview of language anxiety research and trends in its development. *New insights into language anxiety: Theory, research and educational implications*, 11-30.

Macintyre, P. D., Clement, R., Dornyei, Z., & Noels, K. A. (1998). Conceptualizing Willingness to Communicate in a L2: A Situational Model of L2 Confidence and Affiliation. *The Modern Language Journal*, *82*(4), 545–562.

Pantelidis, V. S. (1993). VR in the classroom. *Educational Technology*, *33*(4), 23–27.

Park, Hanna. (2022). Effects of Virtual Reality-based English Learning on Korean University Students' Speaking Ability. *Multimedia-Assisted Language Learning*, *25*(4), 93-119.

Reinders, H., & Wattana, S. (2014). Affect and willingness to communicate in digital game-based learning. *ReCALL*, *27*(1), 38–57.

Tai, T.-Y., & Chen, H. H.-J. (2020). The impact of Google Assistant on adolescent EFL learners' willingness to communicate. *Interactive Learning Environments*, 1–18.

Tai, T.-Y., & Chen, H. H.-J. (2021). The Impact of Immersive Virtual Reality on EFL Learners' Listening Comprehension. *Journal of Educational Computing Research*, *59*(7), 1272-1293.

Yeh, H.-C., Tseng, S.-S., & Heng, L. (2020). Enhancing EFL students' intracultural learning through virtual reality. *Interactive Learning Environments*, 1–10.

Developing an AI-enhanced Video Drama-Making Learning System to Support EFL Learners in Authentic Contexts

Yi-Fan Liu [1*], Muhammad Irfan Luthfi [2,4], Wu-Yuin Hwang [2, 3]
[1] National Academy for Educational Research, New Taipei, Taiwan.
[2] Graduate Institute of Network Learning Technology, National Central University Taiwan.
[3] Department of Computer Science and Information Engineering, National Dong Hwa University, Taiwan.
[4] Department of Electronics and Informatics Engineering Education, Universitas Negeri Yogyakarta, Indonesia
[*] yifan.liu.tw@gmail.com

Abstract: *This study presents an AI-enhanced Video Drama-Making Learning System designed to improve English as a Foreign Language (EFL) learning. Leveraging advanced Artificial Intelligence (AI) technologies such as video-to-text recognition, GPT-generated sentences, grammar checking, and Text-to-Speech (TTS), the system offers an engaging and comprehensive approach to language learning. Implemented on the Android platform, it allows students to create video dramas in authentic contexts, enhancing their speaking and writing skills. An evaluation involving sixty-three university students revealed the system's effectiveness, as assessed by the Technology Acceptance Model (TAM). The findings demonstrate the system's usability, usefulness, and positive influence on learners' attitudes towards technology, highlighting its potential as a valuable tool in EFL education. Despite its overall success, some technical issues indicate a need for further refinement, especially in user interface and system compatibility across different Android versions. This study contributes to technology-enhanced language learning, underscoring the importance of integrating AI in educational contexts.*

Keywords: AI-Enhanced Learning, English as a Foreign Language, Video Drama-making, Authentic Context, Technology in Education

1. Introduction

This study explores how AI can make learning English as an EFL more effective. AI gives learners personalized and interactive ways to learn, making it easier for them to understand and use the language (Chapelle 2018, 2019; Chen et al. 2021; Hwang et al. 2023). Adding drama-making to EFL helps students participate more actively and be more creative, which improves their language skills (Lee 2017; Angelianawati 2019; Dunn & Stinson 2011).

Learning English in real-life situations or authentic contexts is important. It helps students apply what they learn in practical ways, remember better, and understand cultural aspects of the language (Manabe et al. 2023; Richards 2005; Gilmore 2007). Our study develops a system for creating AI-enhanced video dramas on Android phones. This system combines AI with drama activities in real-life settings. It uses technologies like video-to-text recognition, GPT for creating sentences, grammar checking, and TTS to give students a whole learning experience (Luthfi et al. 2023; Al-Jarf 2022).

The two main goals of this study are to see how well the app helps in learning EFL and to find out what students think about this AI-enhanced learning system. Understanding how influential and popular the system is among EFL learners is essential. Our work adds to the growing area of using technology to help learn languages. It shows new ways to learn EFL and discusses the benefits and challenges of using AI systems in education.

2. AI-enhanced video Drama-Making Learning System

The AI-enhanced Video Drama-Making Learning System is a new tool designed to help students learn English by writing and speaking in real situations. This system uses advanced technology to let students make and interact with video dramas, improving their English in a practical setting (Figure 1).

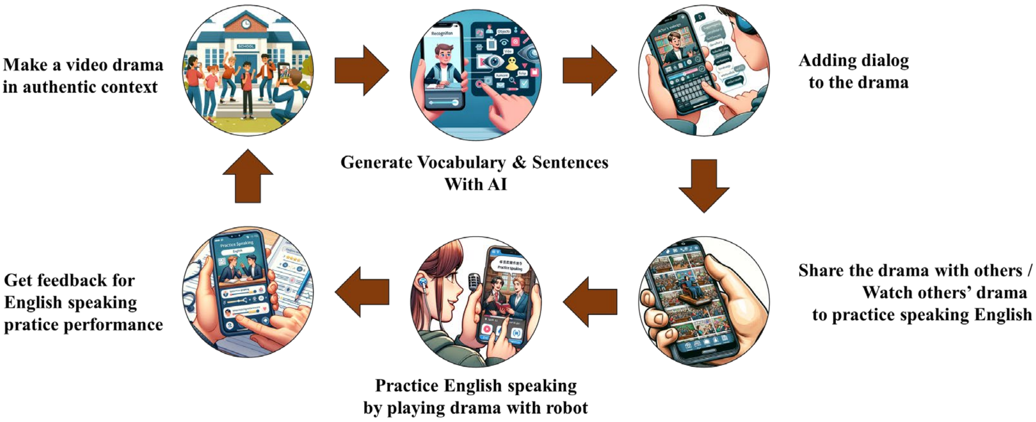
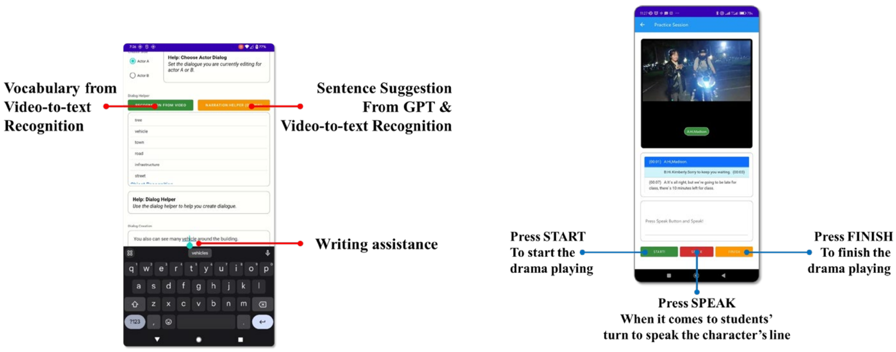


Figure 1. Learn Writing and Speaking with an AI-enhanced video Drama-Making Learning System

Core to the system is the drama-making feature (Figure 2A), where students create video dramas by first recording videos and then using video-to-text recognition to transcribe the content into text, providing a rich vocabulary and context for drama creation. Furthermore, the system incorporates a GPT model that uses this text to suggest sentences, aiding in writing improved dialogues and fostering student creativity by encouraging original sentence construction without relying on copy-pasting.



(A) (B)

Figure 2. Speaking practice with the robot

The speaking practice feature is another essential part of the system (Figure 2B). Here, students can actively engage with dramas made by their peers. They watch these dramas and can choose roles to participate in the dialogues. This feature not only helps them understand different ways of storytelling but also allows them to practice speaking English by participating in the dialogues.

The system uses Google Video Intelligence for video-to-text recognition and GPT-3.5 for sentence suggestions. It also includes a Google keyboard for writing help, Google TTS for text-to-speech, and the Speechace API for feedback on spoken English.

This system is a significant step forward in using technology to learn languages. It combines creating video dramas with advanced technology to support students in developing their writing and speaking skills in English while encouraging creativity and teamwork.

3. Analysis of AI-enhanced video Drama-Making Learning System Performance

3.1. Testing Methodology

The testing methodology involved automated scripts to simulate user interactions and system responses. These scripts were executed across different device configurations and Android versions to ensure a broad assessment. Key aspects such as video-to-text recognition, dialogue writing assistance, and speech interaction capabilities were tested. The methodology also included stress tests to evaluate system performance under high usage conditions.

Table 1. Setting for AI-Enhanced Video Drama-Making Learning System Performance Testing

Settings	Description
Environment	Performed using Android Studio's integrated testing tools and automation software
Version	Tested across four different Android operating system versions (10 to 13)
Scenario	Included video-to-text recognition accuracy, dialogue writing assistance, grammar-checking effectiveness, and the system's response time.

3.2. Criteria for Success or Failure:

The criteria for determining the success or failure of each test were clearly defined. A test was successful if the system performed the expected task accurately and within a reasonable timeframe, without any errors or significant performance lags. Failures were categorized based on specific issues, such as 'Element not found,' 'Timeout while locating element,' or 'Internal error.' Each failure category provides insights into potential areas for system improvement, whether in interface design or backend processing.

3.3. Result of System Performance Testing

Out of 26 tests on the AI-enhanced video drama-making system, 21 were successful, indicating reliable performance with an average test time of 64.22 seconds across various Android versions. While primary functions like video-to-text conversion, dialogue assistance, and speech practice were effective, six tests failed due to technical issues related to system design and Android compatibility. These results underscore the system's overall efficacy in most tasks but also highlight the need for improvements in its interface and backend architecture, with ongoing advancements in AI expected to further enhance its capabilities in educational settings.

4. Analysis of Students' Perception Toward AI-enhanced video Drama-Making Learning System to Support EFL Learners in Authentic Contexts

The effectiveness of this application was evaluated using the TAM, a questionnaire administered to sixty-three students. The TAM questionnaire is structured into four dimensions: Perceived Ease of Use, Perceived Usefulness, Attitude Toward Using Technology, and Behavioral Intention to Use Technology (Table 2).

Table 2. Summary of Students' Perceptions of the AI-Enhanced Video Drama-Making Learning System

Dimension	Findings	Mean Score
Perceived Ease of Use	Students found the system easy to learn and use, indicating its user-friendly interface and straightforward operation.	3.97 - 4.19
Perceived Usefulness	The system was considered beneficial for improving English skills, especially in writing and speaking, reflecting its practical utility in language learning.	3.89 - 4.05
Attitude Towards Using Technology	Students had a positive attitude towards the system, appreciating its benefits and expressing a favorable view on using it for language learning.	3.98 - 4.05
Behavioral Intention to Use Technology	Students were strongly inclined to use the system regularly in their learning and to recommend it to others, demonstrating their engagement and endorsement.	3.78 - 4.02

Based on the results of the analysis, the AI-enhanced video drama-making learning system received positive evaluations from students, demonstrating its potential as an effective tool for EFL learning in authentic contexts. The system's user-friendly design, practical utility in language skill enhancement, and alignment with learners' educational goals were particularly noteworthy.

5. Conclusion

the study's AI-enhanced Video Drama-Making Learning System shows significant potential in enhancing EFL learning in authentic contexts. Integrating advanced AI features like video-to-text recognition, GPT-generated sentences, grammar checking, and TTS, it offers a multifaceted learning environment. The system proved effective in various tests, although some areas require further improvement. Student feedback was overwhelmingly positive, reflecting its ease of use, usefulness, and the positive impact on learning English. This system stands as a testament to the transformative power of AI in language education, emphasizing the importance of ongoing development and user-focused design. Future research should continue to refine these technologies, expanding their capabilities and assessing their long-term impact on language acquisition and motivation.

Acknowledgments

I extend my gratitude to the reviewer, advisors, the High Interaction in Multimedia Lab team, the Research Assistants in Video-to-Text Recognition, and the EFL Study group.

References

Angelianawati, L. (2019). Using drama in EFL classroom. Journal of English Teaching, 5(2), 125-134.

Al-Jarf, R. (2022). Text-to-speech software for promoting EFL freshman students' decoding skills and pronunciation accuracy. Journal of Computer Science and Technology Studies, 4(2), 19-30.

Dunn, J., & Stinson, M. (2011). Drama and second language learning. Routledge.

Chapelle, C. A. (2018). Artificial intelligence for language learning: The state of the art. Language Teaching, 51(4), 496-534.

Chapelle, C. A. (2019). Technology and second language learning. Wiley.

Chen, X., Zou, D., Cheng, G., & Xie, H. (2021, July). Artificial intelligence-assisted personalized language learning: Systematic review and co-citation analysis. In 2021 International Conference on Advanced Learning Technologies (ICALT) (pp. 241-245). IEEE.

Gilmore, A. (2007). Authentic materials and authenticity in foreign language learning. Language Teaching, 40(2), 97-118.

Lee, S. (2017). Impact of the integration of drama in EFL teaching: A multi-case study of young learners' classrooms (Doctoral dissertation, University of Warwick).

Luthfi, M. I., Wardani, R., & Septiyanti, N. D. (2023). Development of an Android-based cultural heritage map app. Elinvo (Electronics, Informatics, and Vocational Education), 8(1), 103-112.

Manabe, K., Hwang, W. Y., & Chuang, Y. W. (2023). English learning enhanced by collaborative contextual drama in an authentic context. Interactive Learning Environments, 31(7), 4490-4506.

Richards, J. C. (2005). Communicative language teaching today. Cambridge University Press.

Students' Engagement in Seeking and Accepting ChatGPT Feedback in Essay Writing: A Study of Second Language Learners at Varying Proficiency Levels

Hong Cheng [1], Hongyang Liu[1], Yuting Xu[1], Chao Gao[1], Juejia Yang[1], Miao Jia[1], You Su [1*]
[1]Beijing University of Posts and Telecommunications
*suyou@bupt.edu.cn

Abstract: *In the field of second language learning, an increasing amount of research has been conducted on different sources of feedback and their effects on writing. However, few investigations have explored the potential impact of ChatGPT in providing feedback support during the writing process. This study adopted a case study approach to examine the utilization of ChatGPT as a feedback tool in academic English writing based on the analysis of human-computer interaction and interview data. The findings reveal distinct metacognitive strategies and characteristics among learners at different proficiency levels. High-proficiency learners exhibit a critical perception of ChatGPT feedback, focusing on advanced vocabulary use during the monitoring phase. Moderate-proficiency learners demonstrate discerning perception, balancing attention across planning, monitoring, and evaluation stages. Low-proficiency learners heavily rely on ChatGPT feedback, particularly during the planning phase. These findings provide valuable insights for enhancing second language writing instruction.*

Keywords: EFL writing, ChatGPT feedback, metacognitive strategies, students' engagement

1. Introduction

In recent years, the emergence of generative large language models, such as ChatGPT, has sparked discussions among researchers regarding their impact on second language writing and instruction (Mohamed, 2023; Rudolph, Tan, & Tan, 2023). Leveraging deep learning and natural language processing techniques, ChatGPT is capable of providing high-quality and real-time feedback, offering personalized guidance and suggestions to students. It showcases unique advantages in evaluating and guiding deep features by demonstrating its proficiency in semantic comprehension, content analysis, and creative thinking (Guo & Wang, 2023). As a result, ChatGPT possesses the potential to facilitate significant advancements in students' English writing proficiency.

Previous research has primarily focused on examining the applications and explorations of AWE or ChatGPT in providing feedback during the writing evaluation stage (e.g.(Chang, Li, Huang, & Whitfield, 2021; Guo & Wang, 2023; Wang et al., 2020)). However, there is a lack of empirical research on the role of ChatGPT in providing feedback support during the whole writing process.

Most empirical studies have categorized second language learners' writing strategies and cognitive processes as metacognitive strategies (Teng & Zhang, 2016; Yan & Kou, 2020), which encompass three stages: planning, monitoring, and evaluation. And for the learners' engagement during the three stages of metacognitive strategies, current research has reached a consensus that learners' engagement in the learning process involves three dimensions, behavioral engagement, cognitive engagement, and affective engagement (Han, 2017; Su, Ren, & Song, 2022; Tian & Zhou, 2020). These dimensions of learner engagement are dynamically interconnected and positively correlated with second language acquisition and learning outcomes (Han, 2017; Tian & Zhou, 2020). Learners' second language performance and writing assimilation are influenced by individual difference variables, such as second language proficiency (Shintani & Ellis, 2015). However, few investigations have been conducted to explore whether EFL students with different proficiency levels exhibit differences in engaging with seeking for and accepting ChatGPT feedback.

As ChatGPT continues to permeate the field of education, it is of significance to examine and verify the potential effects of providing ChatGPT feedback support during the writing process for students at different proficiency levels.

Therefore, this study examined and verified the potential effects of providing ChatGPT feedback support during the writing process for students at different proficiency levels. The following three research questions were addressed:

(1) How do EFL learners at different English proficiency levels engage with ChatGPT feedback in different phases of writing (i.e., planning, monitoring, evaluation)?

(2) How do EFL learners at different English proficiency levels adopt ChatGPT feedback in different phases of writing (i.e., planning, monitoring, evaluation)?

(3) How do EFL learners at different English proficiency levels formulate their uptake strategies?

2. Method

2.1. Research context

This experiment recruited three university students of high, medium and low level as experimental participants, and a certain amount of compensation was given to participants after the completion of the experiment. This experiment was mainly divided into two parts: writing and interviewing. First, participants needed to complete an IELTS essay on the argumentative genre within one hour with the assistance of ChatGPT. The experiment was completed on a computer provided by the experimenter, and with the participants' consent, the whole process was recorded for subsequent analysis. Secondly, after the writing experiment was completed, the experimenter conducted an interview with each participant for about 40 minutes to explore the interaction between the participant and ChatGPT as well as the participant's ideas and writing plans for these three aspects, mainly in terms of planning, monitoring, and evolution of writing.

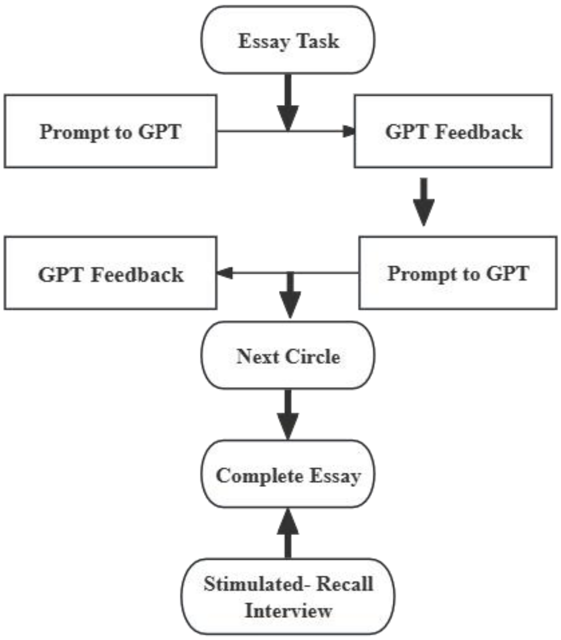


Figure 1. Essay Task Process Map.

2.2. Participants

In order to investigate the interaction status of students with different English proficiency levels with ChatGPT, students with high, medium, and low proficiency levels were recruited for this experiment. The three participants in this experiment came from three different majors in two different universities (see Table 1 for participant information). They took the IELTS and a nation-wide College English Test, and their English proficiency levels ranged from high to low.

Table 1. Demographic information of participants.

	Gender	Major	English Level	Frequency of Writing by GPT
participant 1	Male	Sinology	IELTS 8.5	occasionally
participant 2	Male	Telecommunications Engineering with Management	CET-6 565	frequently
participant 3	Female	Fintech	CET-4 450	normally

2.3. Data collection

The experimental data consisted of prompts entered into the GPT by the three participants during a one-hour writing session and the feedback given by the GPT based on the requirements of the prompts. After obtaining the experimenter's consent, the entire writing process was recorded on video. Experimental data also included participants' attitudes toward the feedback and the degree of critical adoption. After each participant's writing task, the researchers also conducted stimulus recall interviews lasting approximately 40 minutes to understand the reasons why participants decided whether or not to incorporate the feedback when revising their essays. The researcher scrutinized all feedback and revisions made during the composition task and selected those stimuli representative of learners' decision-making in taking up or rejecting the feedback. Interviews were conducted in Chinese according to the preferences of the three participants and were audio-recorded with their consent.

2.4. Data analysis

Data analysis consisted of analysis of the coding of the three students' prompts interacted with GPT, and analysis of the adoption rate of GPT feedback at each stage for the three students based on video recordings, as well as analysis of stimulus recall interview data.

The coding of the prompts entered during the interaction with ChatGPT was performed by two coders. After detailed coding rules were established and training was provided, the two coders independently coded the prompts used by the three participants during their writing process. The internal reliability measured by Cohen's Kappa reached 0.86, indicating an acceptable level of agreement.

The participants' writing process was first scrutinized on the videotaped screen, and each participant's interaction with the GPT pairs was categorized into three phases: planning, monitoring, and evolving. Then, whether the GPT feedback in these three stages was utilized by the participants was investigated, and the adoption rate of the feedback in the three stages as well as the overall adoption rate of the participants at different levels were counted.

In addition, the researchers conducted comprehensive coding of the writing process and the absorption strategies in the stimulus recall interviews for each of the three participants to explore the attitudes and strategies of students with different English proficiency levels towards the use of GPT feedback. The coding was divided into first-order coding and second-order coding, with first-order coding being a generalized description of the participants' strategies, and second-order coding categorizing and integrating the first-order coding to summarize the common features of multiple first-order codes of the same type in order to analyze the participants' subjective mental states.

3. Results

During the process of utilizing ChatGPT for writing assistance, students with varying levels of English proficiency show discernible disparities in learner engagement across the stages of planning, monitoring, and evaluation. These disparities encompass behavioral engagement, cognitive engagement, and affective engagement. Behavioral engagement is mainly evidenced by the frequency and distribution of students’ acquisition of GPT feedback. Cognitive engagement pertains to how students employ metacognitive strategies during their interactions with GPT to facilitate adoption and revision behaviors. Affective engagement, on the other hand, encapsulates students' emotional and attitudinal perception of GPT feedback when utilizing it for English writing support. These disparities are influenced by individual difference variables and carry significant implications for the observed variations.

3.1. Analysis of behavioral engagement based on acquisition of GPT feedback

This section provides insights into the first research question in relation to learners’ engagement with ChatGPT and acquisition of GPT feedback.

Table 2. Encoding categories for prompts.

	planning		**monitoring**					**evaluation**		**sum**
	content	outline	content		organization	language		citation	editing	——
	——	——	variety	accuracy	coherence	word	grammar	——	——	——
high	1	0	1	0	0	24	1	2	1	30
mid	2	2	2	2	1	1	1	1	3	15
low	4	1	3	4	0	1	1	1	2	17

In terms of visual frequency of interaction, the high-proficiency learner engaged most frequently with GPT, with a total number of 30, placing a significant emphasis on advanced vocabulary use, especially in the phase of monitoring. In contrast, the learner with medium proficiency, who has interacted with ChatGPT approximately 15 times, showed no obvious differences in the engagement across the three stages. However, the low-proficiency learner, who has interacted with ChatGPT 17 times, exhibited a stronger focus on engagement, particularly on content, in the phase of planning and monitoring writing.

During the planning stage of writing, the high-proficiency learner had fewer interactions with ChatGPT, signaling greater autonomy and ability to independently formulate ideas and structure his writing. Conversely, the low-proficiency learner interacted frequently with GPT during the planning stage. She relied more heavily on the generated structure and viewpoints from GPT, demonstrating a higher degree of dependence and a lack of critical thinking abilities.

When it comes to the phase of monitoring, the high-proficiency learner prioritized utilizing GPT to obtain feedback and guidance on language quality and accuracy. The high-proficiency student engaged in frequent interactions with GPT during this stage, accounting for 80% of the total interactions, to acquire vocabulary information and utilize advanced lexical choices. While the medium-proficiency learner paid balanced attention to the content, organization and language during this stage. In comparison, the low-proficiency learner demonstrated less involvement in this stage but exhibit a higher level of recognition and acceptance of ChatGPT’s feedback.

In the evaluation stage, the high-proficiency learner focused on editing, revising, and correctly citing references. The medium-proficiency learner devoted attention to editing during the evaluation stage. However, low-proficiency learner concentrated more on modifications related to word count limitations. They affirm the overall content generated by ChatGPT without conducting in-depth evaluation and revisions.

3.2. Analysis of cognitive engagement based on adoption of GPT feedback

The second research question was addressed in this section by presenting the percentage of GPT feedback adoption for each writing phase.

Table 3. Adoption rate of ChatGPT feedback

	planning		monitoring					evaluation		sum
	content	outline	content		organization	language		citation	editing	——
	——	——	variety	accuracy	coherence	word	grammar	——	——	——
high	25%	——	100%	——	——	87.5%	100%	50%	100%	73.68%
mid	0%	50%	100%	100%	100%	100%	100%	100%	66.7%	73.33%
low	60%	100%	75%	75%	——	100%	100%	66.7%	66.7%	66.67%

The high-proficiency student displayed a minimal adoption rate of 25% during the planning stage, indicating his diminished dependency on GPT and a heightened level of autonomy in constructing the overall writing framework. However, his adoption rate for word usage during the monitoring stage was remarkably high at 87.5%, indicating that the high-proficiency student primarily sought GPT's assistance for surface-level feedback, such as the utilization of advanced vocabulary and language optimization.

The medium-proficiency student manifested a comparatively lower adoption rate of GPT feedback during the planning stage, suggesting a greater dependence on his own planning skills for the overall conceptualization of his writing. However, in subsequent monitoring and evaluation stages, there was a noticeable increase in the propensity to adopt GPT feedback, highlighting a primary dependence on GPT for content assessment, final revisions, and refinement.

The low-proficiency student demonstrated a notable elevation in the adoption rate of GPT feedback throughout all the stages, particularly in the planning phase. This signifies her significant dependence on GPT for idea generation and essay structure construction, thereby underscoring a deficiency in her writing autonomy and critical consciousness.

3.3. Analysis of affective engagement based on uptake strategies

The last research question related to how learners formulate uptake strategies and their affective engagement with GPT feedback was addressed here. The results revealed the dynamic perception and affective engagement of learners at different proficiency levels. Their interactive and uptake strategies and dynamic perception, arranged in order of their second language proficiency, are presented as follows: Learner 1 (high-proficiency); Learner 2 (medium-proficiency); and Learner 3 (low-proficiency).

3.3.1. Learner 1: A high-proficiency learner with a critical perception of ChatGPT feedback, focusing on advanced vocabulary use, especially in the phase of monitoring.

The high-proficiency learner possessing critical thinking could integrate his specific requirements into well-defined inquiries and then effectively incorporate the received feedback.

The high-proficiency student considered complete dependence on ChatGPT as meaningless, and he relied on his own knowledge and critical thinking for textual structure, reasoning, and content organization. He commented,

> *"I feel somewhat uncomfortable writing an entire article using ChatGPT because it doesn't feel like my own writing. I prefer taking control of the overall direction of the article myself."*

The high-proficiency student primarily perceived ChatGPT just as an electronic dictionary. Therefore, his adoption strategy mainly manifested in the aspect of using advanced vocabulary during the phase of monitoring, as observed from the interviews:

> *"The primary role of ChatGPT in writing for me, is to serve as an electronic dictionary."*

He conveyed a positive recognition of the advanced vocabulary generated by ChatGPT in accordance with the provided prompts,

> *"I find ChatGPT quite successful in terms of adjusting and substituting advanced vocabulary. Many of the*

word replacements are particularly apt. In this regard, I have a considerable level of trust in its capabilities."

In comparison to ChatGPT, he expressed a greater sense of trust in the feedback provided by human beings for his compositions,

> *"In my opinion, the assistance provided by ChatGPT is not as specific and trustworthy as that offered by high-achieving peers or experienced teachers."*

3.3.2. Learner 2: A medium-proficiency learner with a discerning perception of ChatGPT feedback, paying balanced attention to the stages of planning, monitoring and evaluation.

The medium-proficiency learner adopted a comprehensive strategy when interacting with ChatGPT, paying balanced attention to the stages of planning, monitoring, and evaluation. He relied on ChatGPT to generate ideas and structures, while also critically evaluating its feedback and selectively adopt it.

He leveraged ChatGPT to generate the overall framework of his writing and expressed a certain level of affirmation towards its output. He commented,

> *"Regarding the efficacy of ChatGPT-generated content, I find that it performs well in producing well-structured frameworks for a complete writing."*

However, he also pointed out that some of ChatGPT ' s viewpoints lacked originality and did not meet his expectations, suggesting a need for further editing,

> *"The thought process of ChatGPT tends to be rigid, lacking novelty, and some viewpoints are not directly relevant to the topic, thus not quite meeting my expectations. Consequently, manual intervention is required to make necessary adjustments."*

He could employ ChatGPT to refine the content of the article, consciously filtering information and identifying flaws in logical coherence and vocabulary choice, and then prompting necessary modifications.

He also conveyed a preference towards manual revision of the article, recognizing the necessity of employing human research to compensate for the limitations of ChatGPT,

> *"I prefer human feedback because ChatGPT's language style may become more homogeneous. Additionally, ChatGPT fails to provide sufficient and comprehensive information, thus requiring manual search for supplementation."*

3.3.3. Learner 3: A low-proficiency learner with heavy dependence on ChatGPT feedback, particularly on content in the phase of planning and monitoring writing.

The low-proficiency learner exhibited a significant dependence on ChatGPT for content generation and structural organization during the writing process. She widely embraced the suggestions and feedback provided by ChatGPT in the phase of planning and monitoring writing, often regarding it as her primary source for the whole generation and organization. However, she displayed a limited capacity for critical thinking and subjective agency in her approach.

This learner based her opinion of this article on the information provided by ChatGPT. She commented,

> *"ChatGPT provided explanations for two contrasting viewpoints, and after glancing over those sub-arguments, I made the decision to adopt the opposing stance."*

She held the opinion that the preliminary quality of the essay generated by ChatGPT is satisfactory, so she just edited the composition according to the overall logic and structure provided by ChatGPT.

Despite acknowledging the lack of originality in most viewpoints generated by ChatGPT, she refused to subjectively introduce new perspectives. Instead, she directly evaluated and selected from the viewpoints generated by ChatGPT,

> *"The majority of viewpoints generated by ChatGPT are often general and commonly used."*

Her overall affective engagement in using ChatGPT to assist with English writing was positive, and she expressed affirmation and trust in the content generated by ChatGPT,

> *"I feel that I can't reach that level in my own writing, and ChatGPT's summaries and elaborations of*

sub-arguments are well-written and can be directly used.";

"After glancing at the translated content generated by ChatGPT, I find it quite fluent and the vocabulary generated by ChatGPT is quite advanced for me.";

For the later evaluation phase, she expressed trust in both ChatGPT and teacher feedback, leaning more towards seeking feedback from ChatGPT or the teacher rather than peer feedback.

4. Discussion and Conclusion

This study examined the different performance exhibited by high, medium, and low proficiency students when assisted by GPT in English argumentative essay writing. Based on metacognitive strategies, the writing process was divided into three stages: planning, monitoring, and evaluation, while learner engagement was categorized as behavioral engagement, cognitive engagement, and affective engagement. The research findings revealed varying levels of engagement among students of different proficiency levels across the three writing stages. The high proficiency student demonstrated the highest levels of autonomy and critical awareness. He primarily utilized GPT during the monitoring stage to obtain mainly surface-level feedback on language quality and accuracy, with a focus on advanced vocabulary use. The medium proficiency learner presented a discerning perception of ChatGPT feedback, paying balanced attention to the stages of planning, monitoring and evaluation. In contrast, the low proficiency student exhibited heavy dependence on GPT, primarily focusing on the planning stage content to form the body of her essay. This study holds significant implications for incorporating GPT as an auxiliary tool in foreign language writing and instruction.

ChatGPT shows potential in assisting students with English writing, however, we must also acknowledge the potential challenges and ethical considerations when using such tools for educational purposes. Firstly, educators need to recognize the limitations of these tools, which may have deficiencies in language quality, cultural sensitivity, and creativity, thereby impacting students' autonomy and innovativeness. Over-reliance on these tools may result in a lack of initiative and critical thinking skills in students' language learning process. Educators should consider these tools as supplementary aids, combining them with traditional teaching methods to encourage students' active participation in the writing process and foster their autonomous learning abilities. And it is important to guide students to critically evaluate and adapt to the feedback provided by these tools, rather than blindly accepting it. Additionally, privacy and data security issues are crucial aspects that educators need to address. Ensuring the protection of students' personal information and academic work is of utmost importance when using AI-based feedback tools. Educators should adhere to appropriate privacy policies and implement data protection measures to safeguard students' rights and privacy.

Therefore, the integration of AI-based feedback tools like ChatGPT into language teaching requires prudent consideration. Educators should take into account both the potential and limitations of tools like ChatGPT comprehensively, as well as ethical and privacy concerns. Based on these considerations, educators can flexibly introduce such intelligent feedback tools in the classroom, aiming to maximize students' language learning and writing abilities while maintaining their motivation and autonomy.

Future research should focus on enhancing critical thinking and creativity among low proficiency students while using GPT as a supportive tool. Furthermore, studying the long-term effects of GPT usage on students' language and writing abilities would provide valuable insights for educational practices. It is also important to expand the sample size, diversify the genres of writing, and compare the roles of peer feedback, teacher feedback, and GPT feedback in the writing process to address the limitations of this study.

Acknowledgements

This study was supported by College Students Innovation and Entrepreneurship Training Program (202309018) and Postgraduate Teaching Reform Projects (2023Y037; 2022Y022) of Beijing University of Posts and Telecommunications.

References

Chang, T.-S., Li, Y., Huang, H.-W., & Whitfield, B. (2021). Exploring EFL Students' Writing Performance and Their Acceptance of AI-based Automated Writing Feedback. 2021 2nd International Conference on Education Development and Studies, 31–35. Hilo HI USA: ACM.

Guo, K., & Wang, D. (2023). To resist it or to embrace it? Examining ChatGPT's potential to support teacher feedback in EFL writing. Education and Information Technologies.

Han, Y. (2017). Mediating and being mediated: Learner beliefs and learner engagement with written corrective feedback. System, 69, 133–142.

Mohamed, A. M. (2023). Exploring the potential of an AI-based Chatbot (ChatGPT) in enhancing English as a Foreign Language (EFL) teaching: Perceptions of EFL Faculty Members. Education and Information Technologies.

Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? Journal of Applied Learning and Teaching, 6(1), 342–363.

Shintani, N., & Ellis, R. (2015). Does language analytical ability mediate the effect of written feedback on grammatical accuracy in second language writing? System, 49, 110–119.

Su, Y., Ren, J., & Song, X. (2022). The effects of group awareness tools on student engagement with peer feedback in online collaborative writing environments. Interactive Learning Environments, 1–17.

Teng, L. S., & Zhang, L. J. (2016). A Questionnaire-Based Validation of Multidimensional Models of Self-Regulated Learning Strategies. The Modern Language Journal, 100(3), 674–701.

Tian, L., & Zhou, Y. (2020). Learner engagement with automated feedback, peer feedback and teacher feedback in an online EFL writing context. System, 91, 102247.

Wang, E. L., Matsumura, L. C., Correnti, R., Litman, D., Zhang, H., Howe, E., … Quintana, R. (2020). eRevis(ing): Students' revision of text evidence use in an automated writing evaluation system. Assessing Writing, 44, 100449.

Yan, L., & Kou, H. (2020). A Study on the Influence of Metacognitive Strategies on EFL (English as a Foreign Language) Writing for College Students. Korean Association For Learner-Centered Curriculum And Instruction, 20(8), 1–23.

An Evaluation of Co-regulation Strategies in Computer-mediated Collaborative Writing: Scale Development and Validation

Zeting Yuan[1], You Su[1*], Haizhen Guo[1], Miao Jia[1]
[1] Beijing University of Posts and Telecommunications
[*] suyou@bupt.edu.cn

Abstract: *The employment of co-regulation strategies (CRS) is a critical factor for learners' performance in the collaborative learning environment. Although a burgeoning body of research has investigated the effects of CRS on the collaborative writing process and product, limited studies explored its underlying construct, and there were few tools available to measure learners' CRS in the online collaborative writing environment. This study aimed to validate a newly developed CRS instrument for assessing English language learners' utilization of co-regulated learning strategies in computer-mediated collaborative writing. A total of 471 undergraduate students from a university in Northern China participated in the study. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted to evaluate the reliability and validity of the instrument's factor structure. The study validated that the multi-component structure with six correlated factors was acceptable to assess students' employment of co-regulation strategies in the context of computer-mediated collaborative writing. Results along with their implications are further discussed.*
Keywords: co-regulation strategies (CRS), computer-mediated collaborative writing, scale development

1. Introduction

The rapid growth of digital technologies has dramatically changed the ways and forms we write and influenced the instructional practices of L2 writing (Hyland, 2021). As an effective pedagogical task, computer-mediated collaborative writing has been widely employed in L2 classrooms during the last decade (Zheng & Warschauer, 2017). It refers to the online writing activity in which students co-construct and co-revise texts through synchronous and asynchronous interaction and negotiations afforded by these technology tools (Zhang et al., 2021). Previous studies have documented multiple advantages of incorporating technology tools into collaborative writing (Elola & Oskoz, 2010; Storch, 2012).

Despite the potential benefits of computer-mediated collaborative writing, effective collaboration and satisfactory outcomes are not always guaranteed (Li & Kim, 2016). In reality, using such tools can create unpleasant collaborative experiences for learners, including extra cognitive, motivational, and behavioral burdens on the writing process (Kennedy & Miceli, 2013). Considering the positive association between the employment of regulatory skills and better learning performance in collaborative settings (DiDonato, 2013), it would be of significance to investigate how learners utilize regulatory strategies while writing collaboratively. However, after reviewing the relevant literature, available scales on co-regulated learning are still scarce, especially in the area of L2 writing. Therefore, this study attempted to develop an instrument for assessing students' employment of co-regulation strategies in the setting of computer-mediated collaborative writing.

2. Literature Review

2.1. Computer-Mediated Collaborative Writing

Collaborative writing refers to a learning activity in which two or more students work together throughout the writing process to produce one single text (Storch, 2013). With the advent of digital technologies allowing "synchronous and asynchronous communication capacity" (Luppicini, 2007, p.142), the integration of computer-mediated communication in collaborative writing has gained wide popularity in L2 classrooms (Zhang et al., 2021). Previous studies have identified multiple benefits of online collaborative writing, including enhancing audience awareness (Li, 2018; Storch, 2012), improving writing performance (Abrams, 2019), and boosting students' sense of community and writing motivation (Miceli et al., 2010).

As collaborative writing is characterized by equality and mutuality (Storch, 2013), students' deployment of regulatory strategies becomes a critical factor for effective collaboration. Multiple studies have demonstrated that individuals' regulatory behaviors were conducive to fostering their motivation and confidence in the writing process and promoting writing proficiency (Lam, 2014; Teng & Zhang, 2019). However, previous studies have focused primarily on the utilization of regulatory strategies in individual writing, with little attention paid to the context of computer-mediated collaborative writing. There is thus a pressing need to further explore how group members regulate their collaborative writing mediated by computer.

2.2. Co-regulation Strategies

According to Järvelä et al. (2016), co-regulation occurs when peers support one another's participation and learning in collective activities behaviorally, cognitively, and motivationally. From a socio-cognitive perspective, the term co-regulation emerged to indicate the process in which individuals in a learning group as self-regulating agents use strategies to socially regulate each other's learning (Volet et al., 2009). In this process, group members ask each other questions, prompt one another, and evaluate the group's progress to achieve co-regulation (Chan, 2012).

Previous scholars have underscored the pivotal role of co-regulation in collaborative learning tasks, indicating the positive association between co-regulation strategies and successful collaboration (Ucan & Webb, 2015). More recently, plenty of research on co-regulation has been conducted to improve learners' academic performance in collaborative learning (e.g., Durak & Uslu, 2023; Teng & Huang, 2021). Although there is growing consensus on the critical role of co-regulation for effective collaborative learning, research into assessing co-regulation strategies is a relatively new area. As researchers have called for further understanding of the theoretical nature of co-regulated learning (Chan, 2012), it is imperative to go beyond a blanket categorization of co-regulation skills and to locate specific co-regulation strategies deployed in collaborative learning.

2.3. Developing a Multidimensional Scale for Evaluating Co-regulation Strategies

Previous researchers have developed several questionnaires to evaluate co-regulation strategies in collaborative learning environments. However, to the best of our knowledge, it was found that most of them primarily focus on a single factor, with greater emphasis on metacognitive or cognitive regulation processes (e.g., DiDonato, 2013; Garrison & Akyol, 2015; Lin; 2018). Considering the multi-faceted nature of co-regulation, a uni-component structure may be insufficient for a more nuanced observation of the internal construct of co-regulation strategies(Hadwin et al., 2017; Järvelä et al., 2016). As a result, discussions about co-regulation strategies may need to extend to multiple regulation processes, such as behavioral regulation and motivational regulation.

Recent studies tend to take a multi-component perspective to gain a more comprehensive understanding of students' diverse co-regulated learning experiences. For instance, Su et al., (2023) developed the Co-Regulated Strategies Questionnaire (CRSQ) to investigate L2 learners' co-regulated learning process in five dimensions: co-planning, co-monitoring, co-evaluation, effort-regulation, and help-seeking. Although the CRSQ exhibits the multi-dimensional construct of co-regulation, it doesn't include the strategy of help-giving in the discussion. Co-regulation is characterized by reciprocal conversation exchanges and interdependent regulatory behaviors, which necessitates an equal examination of help-seeking and help-giving (Backer et al., 2015). In addition, the Co-Regulated Strategies for Learning Questionnaire (CRSLQ) developed by Olakanmi (2016) is another robust tool for assessing learners' co-regulated learning in the setting of science education. Nevertheless, since co-regulation processes are greatly contextualized (Hadwin et al., 2017), the CRSLQ may not be applied to the specific learning context of computer-mediated collaborative writing. Therefore, this study aimed to develop a multi-dimensional questionnaire to comprehensively measure students' use of co-regulation strategies during online collaborative writing.

2.4. Research Questions

To achieve the aims of the research, two research questions were put forward:

(1). What are the key dimensions of co-regulation strategies in the context of computer-mediated collaborative writing?

(2). Is the newly developed scale a valid tool for evaluating the construct of co-regulation strategies in the context of computer-mediated collaborative writing?

3. Methodology

3.1. Participants

The current study involved 471 Chinese students (341 males and 130 females) at a university in northern China, who were selected randomly from five intact classes of the College English Course. The participants were first-year and second-year undergraduate students and were aged approximately between 19-20. As the university is a technological university, there were more male participants in this study.

3.2. Learning Activity

The College English Course was a 16-week language course that was taught by one single instructor to enhance students' English reading and writing skills. In the eighth week, the computer-mediated collaborative writing activity was introduced and implemented as an extracurricular assignment. The participants were randomly divided into groups of three to four students and required to complete three argumentative writing tasks in total, each of which extended over three weeks. HDwiki, a wiki platform, was employed in this study to provide an online collaborative writing environment. To promote students' collaboration, QQ chatrooms were established for student writers to have full discussions on the tasks.

3.3. Instrument

In this study, a self-reported questionnaire named the Co-regulation Strategies Questionnaire (CRSQ) was developed and applied to examine student writers' use of co-regulation strategies during online collaboration. The items and factors of the CRSQ were developed under the guidance of the questionnaire developed by Su et al. (2023). The original five sub-scales with a total of 20 items were maintained in the CRSQ. In addition, a new sub-scale named help-giving was included in the newly developed instrument as help-giving is one of the critical factors of successful collaboration (Huang & Law, 2023). The final CRSQ consisted of 26 items in the format of a 5-point Likert scale, which has been categorized into six factors. Below are the descriptions of each factor:

(1) Co-planning (4 items): This factor involves students' planning, goal setting, or task division of the collaborative writing task.

(2) Co-monitoring (6 items): This factor deals with students' ongoing management of their understanding, progress, and performance during the collaborative writing task.

(3) Co-evaluation (4 items): This factor concerns how students assess their groups' performance in the collaborative writing tasks.

(4) Effort regulation (5 items): This factor refers to students' effort to persist when confronted with learning

obstacles or challenges.

(5) Help-seeking (3 items): This factor refers to how students obtain assistance from others to overcome challenges during collaborative writing.

(6) Help-giving (4 items): This factor refers to how students help others during collaborative writing.

3.4. Data Collection and Analysis

The survey was carried out in classroom settings by the instructor at the end of the course. Before responding to the CRSQ anonymously, all the participants were fully notified that they could withdraw from the research at any time without penalty. Regarding the process of data analysis, first, the collected data were randomly split into two halves for exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), respectively. Then, EFA was performed with one sample of 236 participants to clarify the factor structure of co-regulation strategies. Finally, CFA was conducted with another sample of 235 participants to examine the construct validity and model fit of the instrument.

4. Results

4.1. Results of Exploratory Factor Analysis

To clarify the factor structure of the CRSQ, EFA was employed with the method of principal component analysis and varimax rotation. Following the criteria of Stevens (2012), items with loadings weighted greater than 0.40 on the relevant factor and less than 0.40 on the non-relevant factors were retained in the finalized scale. As presented in Table 1, 21 items were kept and classified into six factors, accounting for 68.07% of the total variance. The six factorial dimensions were labeled as co-planning (4 items, $\alpha = 0.83$), co-monitoring (3 items, $\alpha = 0.80$), co-evaluation (3 items, $\alpha = 0.71$), effort regulation (4 items, $\alpha = 0.84$), help-giving (4 items, $\alpha = 0.78$), and help-seeking (3 items, $\alpha = 0.73$). The reliability coefficient for each sub-scale ranged from 0.71 to 0.84, with an overall Cronbach's alpha value of 0.90, suggesting satisfactory internal reliability of the scale.

4.2. Results of Confirmatory Factor Analysis

To cross-validate the factor structure extracted from EFA, confirmatory factor analysis (CFA) was conducted using the remaining half sample (n=235). Based on the findings of Hair et al. (2006), the results of CFA indicated an acceptable model fit with chi-square to degrees of freedom (x2/df) ratio = 2.37; Root Mean Square Error of the Approximation (RMSEA) = 0.077; Adjusted Goodness-of-Fit Index (AGFI) = 0.80; Comparative Fit Index (CFI) = 0.91; Goodness of Fit Index (GFI) = 0.85; Normed Fit Index (NFI) = 0.85; Incremental Fit Index (IFI) = 0.91; Tucker-Lewis Index (TLI) = 0.89. As presented in Table 2 and Figure 1, all factor loadings were higher than the 0.50 threshold (ranging from 0.59 to 0.82) and significant at $p < 0.001$, indicating connections between measurement items and their corresponding constructs. Additionally, the Cronbach's alpha coefficient for each factor ranged from 0.68 to 0.85, with an overall reliability coefficient of 0.93, demonstrating adequate internal consistency of these factors for measuring students' co-regulation learning strategies.

Table 1. Rotated factor loadings and Cronbach's alpha values for the six factors of co-regulated learning

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1: Co-planning, $\alpha = 0.83$, Mean = 3.16, SD = 0.78						
Co-planning 1	0.66					
Co-planning 2	0.66					
Co-planning 3	0.81					
Co-planning 4	0.84					

Factor 2: Co-monitoring, α = 0.80, Mean = 3.62, SD = 0.73						
Co-monitoring 1		0.74				
Co-monitoring 2		0.84				
Co-monitoring 3		0.64				
Factor 3: Co-evaluation, α = 0.71, Mean = 3.74, SD = 0.69						
Co-evaluation 1			0.82			
Co-evaluation 2			0.77			
Co-evaluation 3			0.56			
Factor 4: Effort regulation, α = 0.84, Mean = 4.05, SD = 0.60						
Effort regulation 1				0.79		
Effort regulation 2				0.72		
Effort regulation 3				0.78		
Effort regulation 4				0.81		
Factor 5: Help-giving, α = 0.78, Mean = 3.17, SD = 0.75						
Help-giving 1					0.71	
Help-giving 2					0.55	
Help-giving 3					0.74	
Help-giving 4					0.72	
Factor 6: Help-seeking, α = 0.73, Mean = 3.43, SD = 0.78						
Help-seeking 1						0.76
Help-seeking 2						0.79
Help-seeking 3						0.73

Note. Overall reliability coefficient: 0.90; total variance explained: 68.07%

5. Discussion and Conclusion

The current study developed and validated a scale to measure the co-regulation strategies employed during collaborative writing mediated by computers. The EFA and the CFA results confirmed a 6-component scale with 21 items about three co-regulatory processes: metacognition, motivation, and social behavior. Regarding the metacognitive domain of co-regulation strategies, there are co-planning, co-monitoring, and co-evaluation. The motivational co-regulation process only includes the strategy of effort regulation. Help-giving and help-seeking are specified as the social behavioral strategies of co-regulation.

Table2. The CFA results of CRSQ

Construct and measurement items	Factor loading	t-value	AVE	CR	Alpha value	Mean	S.D.
Co-planning (CP)	——	——	.57	.84	.84	3.44	.81
CP 1#	.63	——				3.70	.86
CP 2	.78	9.67***				3.41	1.04
CP 3	.81	9.89***				3.44	1.00
CP 4	.79	9.70***				3.20	1.03
Co-monitoring (CM)	——	——	.57	.80	.79	3.69	.80
CM 1#	.79	——				3.69	.96
CM 2	.78	12.21***				3.57	1.02
CM 3	.70	10.91***				3.80	.86

Co-evaluation (CE)	——	——	.44	.70	.68	3.93	.64
CE 1#	.59	——				4.15	.72
CE 2	.74	7.96^{***}				3.94	.85
CE 3	.65	7.38^{***}				3.69	.89
Effort regulation (ER)	——	——	.52	.81	.81	4.19	.52
ER 1#	.75	——				4.20	.59
ER 2	.61	10.73^{***}				4.23	.67
ER 3	.74	8.78^{***}				4.08	.72
ER 4	.78	10.92^{***}				4.23	.65
Help-giving (HG)	——	——	.58	.84	.84	3.45	.81
HG 1#	.77	——				3.33	.95
HG 2	.67	10.21^{***}				3.57	.97
HG 3	.79	12.39^{***}				3.45	.94
HG 4	.80	12.45^{***}				3.43	1.01
Help-seeking (HS)	——	——	.65	.85	.85	3.57	.93
HS 1#	.79	——				3.65	1.05
HS 2	.82	12.74^{***}				3.54	1.05
HS 3	.81	12.51^{***}				3.53	1.10

Total alpha: .93

Note: $^{***}p < .001$

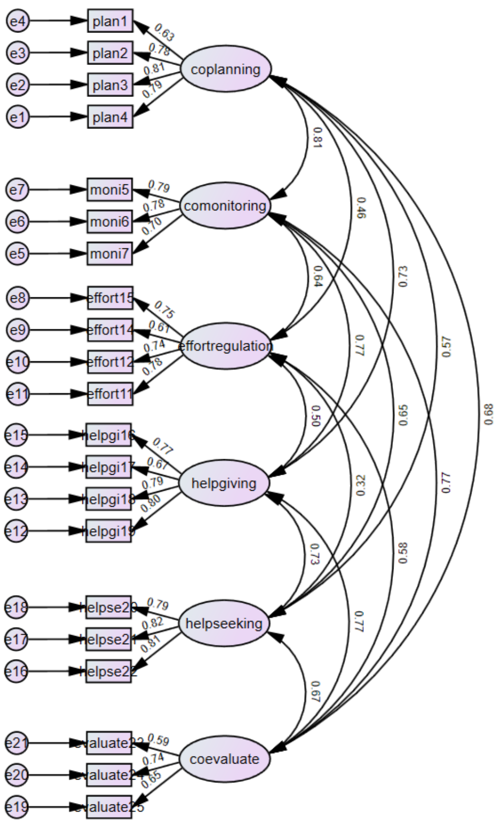


Figure 1. The CFA results of CRSQ

The newly developed CRSQ has high validity and reliability scores. Therefore, it could serve as a useful framework to conceptualize L2 writers' employment of co-regulation strategies. The research findings have several implications.

Theoretically, the current study enhances the understanding of co-regulation's multi-faceted nature by characterizing co-regulation strategy as a six-dimension structure. There is a general paucity of multi-component instruments for assessing co-regulation strategies, which may mar a more nuanced and comprehensive observation of the internal construct of co-regulation learning strategies. Therefore, the six-component scale developed in this scale provides a useful means to capture diverse categories of co-regulation strategies.

Practically, this scale could be applied to measure student writers' employment of co-regulation strategies from different aspects. Consequently, the instrument can help students improve their awareness of utilizing co-regulation strategies and cultivate a habit of using them during collaborative writing. While the questionnaire does not list co-regulation strategies exhaustively, the assessing process may let students become more willing to deploy these strategies to achieve their learning goals.

Pedagogically, the CRSQ could serve as an insightful tool for L2 teachers to evaluate important aspects of students' learning engagement during computer-mediated collaborative writing. The results may guide the teachers in refocusing their teaching practices to help student writers utilize co-regulated learning strategies efficiently.

There are several limitations of the present study that can be informative for future research directions. First, self-reported survey results might still be insufficient to provide a full interpretation of learners' use of co-regulation strategies in reality. Future studies could consider using multiple methods for data collection (e.g., stimulated recall after completing a task, interviews, etc.). Second, the participants in the study were college students in China and most of them were male. It is recommended that more research should be conducted in different socio-cultural contexts to generalize the findings of the present study. Third, future studies can further the understanding of co-regulation strategies by including second-order factors in the discussion.

Acknowledgments

This research is funded by the National Social Science Fund of China (Grant No. 23BYY161).

References

Abrams, Z. I. (2019). Collaborative writing and text quality in Google Docs. *Language Learning & Technology*, *23*(2), 22–42.

Chan, C. K. K. (2012). Co-regulation of learning in computer-supported collaborative learning environments: a discussion. *Metacognition and Learning*, *7*(1), 63–73.

De Backer, L., Van Keer, H., & Valcke, M. (2015). Exploring evolutions in reciprocal peer tutoring groups' socially shared metacognitive regulation and identifying its metacognitive correlates. *Learning and Instruction*, *38*, 63–78.

DiDonato, N. C. (2013). Effective self- and co-regulation in collaborative learning groups: An analysis of how students regulate problem solving of authentic interdisciplinary tasks. *Instructional Science*, *41*(1), 25–47.

Durak, H., & Nilüfer Atman Uslu. (2023). Group regulation guidance through agile learning strategies: empowering co-regulation, transactive memory, group cohesion, atmosphere, and participation. *Educational Technology Research and Development*, *71*(4), 1653–1685.

Elola, I., & Oskoz, A. (2017). Writing with 21st century social tools in the L2 classroom: New literacies, genres, and writing practices. *Journal of Second Language Writing*, *36*, 52–60.

Garrison, D. R., & Akyol, Z. (2015). Toward the development of a metacognition construct for communities of inquiry. *The Internet and Higher Education*, *24*, 66–71.

Hadwin, A. F., Järvelä, S., & Miller, M. (2017). Self-regulation, co-regulation, and socially shared regulation in collaborative learning environment. In D. H. Schunk, & J. A. Greene (Eds.). Handbook of self-regulation of learning and performance (2nd ed.). New York: Routledge

Huang, K., & Law, V. (2022). Help Seeking from Peers in an Online Class: Roles of Students' Help-seeking Profiles and Epistemic Beliefs. *Educational Technology & Society*, *25*(3), 1–14.

Hyland, K. (2021). Teaching and researching writing (4 ed.). New York: Routledge.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2006). *Multivariate data analysis*. Pearson Education.

Järvelä, S., Malmberg, J., & Koivuniemi, M. (2016). Recognizing socially shared regulation by using the temporal sequences of online chat and logs in CSCL. *Learning and Instruction*, *42*, 1–11.

Kennedy, C., & Miceli, T. (2013). Inpiazzaonline: exploring the use of wikis with beginner foreign language learners. *Computer Assisted Language Learning*, *26*(5), 389–411.

Lam, R. (2014). Understanding EFL Students' Development of Self-Regulated Learning in a Process-Oriented Writing Course. *TESOL Journal*, *6*(3), 527–553.

Lin, J.-W. (2018). Effects of an online team project-based learning environment with group awareness and peer evaluation on socially shared regulation of learning and self-regulated learning. *Behaviour & Information Technology*, *37*(5), 445–461.

Li, M., & Kim, D. (2016). One wiki, two groups: Dynamic interactions across ESL collaborative writing tasks. *Journal of Second Language Writing, 31*, 25–42.

Luppicini, R. (2006). Review of computer mediated communication research for education. *Instructional Science*, *35*(2), 141–185.

Miceli, T., Murray, S. V., & Kennedy, C. (2010). Using an L2 blog to enhance learners' participation and sense of community. *Computer Assisted Language Learning*, *23*(4), 321–341.

Olakanmi, E. E. (2016). Development of a questionnaire to measure co-regulated learning strategies during collaborative science learning. *Journal of Baltic Science Education*, *15*(1), 68–78.

Stevens, J. P. (2012). Applied multivariate statistics for the social sciences. Routledge.

Storch, N. (2012). Collaborative writing as a site for L2 learning in face-to-face and online modes. In G. Kessler, A. Oskoz, & I. Elola (Eds.), Technology across writing contexts and tasks. San Marcos, TX: CALICO

Storch, N. (2013). *Collaborative Writing in L2 Classrooms*. Multilingual Matters.

Su, Y., Liang, J.-C., Zheng, C., & Tsai, C.-C. (2023). Co-regulation strategies and their associations with writing self-efficacy in a computer-mediated collaborative writing setting. *Journal of Second Language Writing*, *59*, 100972.

Teng, L. S., & Zhang, L. J. (2019). Empowering learners in the second/foreign language classroom: Can self-regulated learning strategies-based writing instruction make a difference? *Journal of Second Language Writing*, *48*, 100701.

Teng, M. F., & Huang, J. (2021). The effects of incorporating metacognitive strategies instruction into collaborative writing on writing complexity, accuracy, and fluency. *Asia Pacific Journal of Education*, 1–20.

Ucan, S., & Webb, M. (2015). Social Regulation of Learning During Collaborative Inquiry Learning in Science: How does it emerge and what are its functions? *International Journal of Science Education*, *37*(15), 2503–2532.

Volet, S., Summers, M., & Thurman, J. (2009). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction*, *19*(2), 128–143.

Zhang, M., Gibbons, J., & Li, M. (2021). Computer-mediated collaborative writing in L2 classrooms: A systematic review. *Journal of Second Language Writing, 54*, 100854.

Zheng, B., & Warschauer, M. (2017). Epilogue: Second language writing in the age of computer-mediated communication. *Journal of Seco nd Language Writing, 36,* 61–67.

Engaging Online Students in Hands-on Activities During Blended Synchronous Learning

Wang Qiyun [1*], Quek Choon Lang [2], Wen Yun [3] and Chin Yi Jie [4]
[1, 2,3,4] National Institute of Education, Nanyang Technological University, Singapore
[1] Co-Director, Centre for Research and Development in Learning, Nanyang Technological University, Singapore
[*] qiyun.wang@nie.edu.sg

Abstract: *Blended synchronous learning (BSL) is commonly used to deliver lectures. There are challenges in engaging online students when they are doing hands-on activities. In this study, two groups of students took a course lasting 13 weeks. This course heavily involved hands-on activities. 3-4 students attended the course from home using video conferencing in each session. Some strategies were applied to engage them during the sessions. The purpose of the study was to explore how to effectively engage online students in hands-on activities and their perceptions of the strategies used. Results showed that having a teaching assistant, peer feedback, back-channel communication, clear audio, and two-device setups helped engage online students in hands-on activities. Implications for teachers and researchers are suggested.*

Keywords: Blended synchronous learning, Hands-on activity, Engagement, Online learning

1. Introduction

Blended synchronous learning (BSL) is an instructional approach that enables the instructor to teach both online and face-to-face (f2f) students simultaneously (Wang et al., 2023). It has been widely adopted in many institutions (Raes et al., 2020), especially after the Covid-19 pandemic (Detyna et al., 2023; Wang et al., 2023). The benefit it entails has not only shed new light on the disadvantaged students who had no access to class. It allowed more students from other places to join institutions facing low student enrollment (Raes et al., 2020). Also, courses taught by specific faculty can now be held with students of a different discipline, especially from another campus (Raes et al., 2020). However, studies have shown that the engagement level of online students is often lower than that of f2f students (Hayes & Tucker, 2021). Therefore, engaging online students in a BSL environment is a challenge.

Furthermore, engaging online students in hands-on activities in the BSL setting is much more challenging. Issues raised included limited interaction and a lack of student's readiness for hands-on learning (Zha & He, 2021). Also, May et al. (2023) fully transited their hands-on lab for engineering courses online. Their students experienced unfamiliarity with the online lab technology, which led to poorer self-regulation. This dilemma highlighted the potential difficulty in integrating hands-on content within the BSL setting. Nevertheless, hands-on activities remain crucial as they help to proof concepts, apply knowledge and skills, and increase students' self-efficacy (Ho et al., 2016). The purpose of this study was, therefore, to explore how to engage online students in hands-on activities while taking courses from other sites by following the BSL approach.

2. Conceptual Framework

The engagement of online students is often affected by many factors including the instructor, learner, content, technology, and environment (Wang et al., 2023). The instructor factor refers to the lecturers' techniques in engaging students. Effective strategies involve the instructor's enthusiasm and openness, using inclusive language, having a teaching assistant, and professional development (Wang & Huang, 2023). The instructor can increase student engagement with warm and frequent interaction. He/she can also closely look at the camera to maintain eye contact with online students. Furthermore, the instructor should be well prepared by simplifying the process to avoid being overwhelmed (Detyna et al., 2023). The presence of staff support, such as the teaching assistant, and attending training courses is also essential (McCaw et al., 2023).

The learner factor begins with individuals. Learning self-regulation methods like active planning, monitoring, and seeking help are recommended (Wang et al., 2023). Encouraging peer interaction among learners is also vital, as group activities are practical. For instance, constructive peer feedback often increases learner engagement (Lyu et al., 2023).

The content factors refer to learning tasks and activities. Effective content strategies include making learning content challenging (Lakhal et al., 2020), releasing learning materials early, and having students design artifacts. The learning content should be simple, motivating, and developed in tandem with the learner's ability. Earlier releases of learning materials also aid students in preparing better, which boosts their confidence (Shi et al., 2021). In addition, having students design artifacts is found to have high predicted effectiveness (Hadad et al., 2024).

Technology is a mediating tool that facilitates learning. Its function involves providing a platform for f2f and online students to interact (Bower et al., 2017). Simple technology can reduce cognitive overload (Allan & Bryden, 2023). The equity of education can be achieved with the right platform, which should include small breakout group sessions for peers to interact seamlessly (Mentzer et al., 2023)

The environment refers to the setting for the instructor and learners (Wang et al., 2023). This can cause distraction if mismanaged. For instance, students may join the BSL session at an unsuitable site, such as walking or riding a train (Allan & Bryden, 2023). This stipulates the need for clear rules to be set.

3. Methodology

3.1. The course

In this study, two groups of 25 and 26 adult learners aged 25 to 45 years were enrolled in the Master of Education programme at the National Institute of Education, Singapore. They were taught two authoring tools including web-based Articulate Rise and Windows-based Storyline for developing e-learning packages. Learning these tools involved heavy hands-on activities. Most sessions were conducted in a BSL mode, where a live demonstration involving step-by-step instructions on how to use the software tools was given to f2f and online students. This was followed by a hands-on self-exploration period for the participants. Students were later tasked to develop two artifacts as their final assignments using Articulate Rise and Storyline, respectively. This involved choosing a teaching topic and developing interactive e-learning packages that run for about 1-2 hours each. Lessons were held once a week, from 6pm to 9pm, over 13 weeks. Each student was allowed to attend some sessions online in a round-robin manner. These resulted in 3 to 4 online participants every week.

3.2. Strategies applied

For engaging online students, some specific strategies were applied. The instructor began each class with a warm introduction. A teaching assistant was present to monitor and coordinate the participation of the online students. Students were encouraged to plan, monitor, and seek help if needed. In some sessions, peer feedback was involved, in which 4-5 students formed a group and constructively evaluated individual artifacts. Furthermore, online students were encouraged to use back-channels to communicate with their peers. The class setup comprised two cameras: one ceiling for viewing the instructor and the other for the class overview. Two ceiling microphones were used for audio, while two front-facing screen projectors displayed the lesson content. Zoom was used as a video conferencing tool for the BSL sessions. The students' cameras were turned on during the BSL sessions. An overview of the strategies applied is shown in Table 1.

Table 1. Strategies used in the BSL environment

Instructor	-	Warm introduction / frequent interaction.
	-	Look at the camera while having appropriate eye contact with the class.
	-	Well prepared and avoid doing too much too quickly.
	-	Presence of Teaching assistant.
Learner	-	Self-regulated method of planning, monitoring, and seeking help for learning outcomes.
	-	Peer feedback.
	-	Back-channel platform (WhatsApp) and third-party app (Poll Everywhere).
Content	-	Learning content in tandem with student ability.
	-	Earlier release of learning materials.
	-	Student design artifact.
Technology	-	2 camera set-ups, one ceiling for instructor view, the other side camera for class view. (Video)
	-	2 ceiling microphones. (Audio)
	-	2 front-facing projector screens, one primary, the other subsidiary screen. (Projector)
	-	Use a clicker to control slides. (Slides)
	-	Selection of Zoom as an optimal platform with break out room. (Platform)
	-	Recommend using 2 device screens for hands-on learning. (Student devices)
	-	Online student to keep their camera turned on.
Environment	-	Quiet Room for online students.
	-	Ground rules in place for students not to join from unsuitable sites.

This study aimed to answer the following research question:

What are the students' perceptions of the strategies used in the course?

3.3. Data collection and analysis

To answer the research question, a survey, focus group discussions, and lesson observations were conducted. A 24-item survey (5-point Likert scale) was administered to all the students in the two groups. In the end, 19 students and 16 students responded. Three focus group discussions involving 11 participants were carried out. Survey data were analyzed using SPSS V28. The interview data from the focus group discussions were examined using a constant comparative analysis approach. Also, the teaching assistant took observation notes in class and shared the findings with the instructor weekly.

4. Results

4.1. Warm welcome and frequent interaction

The detailed survey results are attached in the appendix. The surveyed students agreed that paying close attention (M=4.03, SD=0.83), frequent interaction (M=4.15, SD=0.87), and prompt replies to questions by the instructor (M=4.21, SD= 0.95) helped engage them. Two interviewed students further echoed that these strategies made the sessions a better experience. As the student cited:

"I think the Professor did very well by repeating explanations and making online students understand." She added, *"These intentionally implemented tactics made me enjoy the BSL session very much."*

4.2. Teaching assistant

The students indicated that having a teaching assistant in class was beneficial (M=4.89, SD=0.47). Five students stated that it would be even better if the teaching assistant was well-versed in the teaching content. Especially for practical and hands-on learning of the software. A student said:

"I once attended another blended learning course. There, a few teaching assistants who knew their subject led the instruction during the workshop. Here, I think it is still feasible; the teaching assistant can float from one break-out room to another, guiding the students."

4.3. Design artifacts

Designing artifacts increased their engagement (M=4.19, SD= 0.83). One interviewed student reported:

"Creating our artifact was an effective strategy. As I knew I had to share my articulate artifact during the online presentation. This made me extremely engaged as the presenter."

4.4. Peer feedback

Six interviewed students consented that peer feedback was highly advantageous. As a participant mentioned:

"I think the peer feedback was useful, and the professor achieved his objective. Students had to pay attention while others were presenting. They need to listen carefully and provide feedback constructively." Also, another added, *"The peer feedback made me reflect on my artifact, while the constructive feedback gave me an idea of where I can improve."*

4.5. Back-channel communication

Six students in the focus group discussions mentioned they used back-channel platforms to interact with f2f students directly. For instance, a student said:

"It is interesting that the professor used Poll everywhere to check our emotional status. The selection of emoticons livens up the class." Another student commented: *"Yes, we use WhatsApp; for example, at the start of the class, if we cannot hear, we can inform the classmate, who informs the teaching assistant, and then the teacher."* An additional student also said*, "Yes, we use a back-channel, as we can add screenshots in my group WhatsApp."*

4.6. Two-device usage

Three students also reported that using two-device screens was helpful for hands-on activities as it made screen observation easier. A learner cited:

"We use two devices, an iPad and a computer, for class. The first screen is for the Zoom lecture, while the second is for hands-on activities."

4.7. Challenging hands-on activities

Though students reported little difficulties following the hands-on demonstration (M=4.13, SD=0.94), they stated that doing hands-on activities in the BSL environment was challenging. A student indicated:

"The moment I attended the BSL session for Articulate Rise (Hands-on), I immediately preferred the face-to-face classes. It is just that asking questions and waiting for answers can be difficult."

Lessons observations also confirmed that it was hard for students to find the right time to ask questions. This could be challenging if the instructor moved on to the next topic. Furthermore, if students missed or did not understand a step, progressing to the next steps became even more challenging, leading to more confusion.

4.8. Technical difficulties

Three students reported audio and visual issues during the BSL session. For instance, a student said:

"The Professor often walked out of the camera view during his lecture. But the issue was not so much of seeing Professor on screen; the more important thing is to be able to follow the voice."

5. Discussion

In this section, some useful strategies identified from the study, implications for teachers and researchers, and limitations are discussed.

5.1. Strategies

Teaching Assistant

Having a teaching assistant in class has emerged as an imperative strategy for BSL hands-on activities. The study identified the need for a teaching assistant to update and coordinate the BSL setting and be well-versed in the learning content. Li et al. (2022) indicated that the workload of the BSL instructor was not overwhelming due to the presence of a teaching assistant. Lakha et al. (2020) stated that the teaching assistant's ability and education are crucial for the BSL environment's success. They warned that the lack of skills from the teaching assistant can be worrying, especially for the online student. The results of this study would advocate for the teaching assistant to be very well-versed in the teaching subject so that he could respond to the queries directly. This would extend the benefit, as Bower et al. (2017) stated that engaging several teachers on a subject can bring a richer learning experience to the classroom.

Peer Feedback

It seemed that peer feedback was a useful strategy for BSL hands-on activities. Peer feedback is a conversing process in which students discuss performance and standards (Lyu et al., 2023). This benefits the students when they assume an active role in grading and learning (Lyu et al., 2023) while providing constructive feedback to their peers. However, the implementation of peer feedback often requires a structure. Lyu et al. (2023) indicated several characteristics the feedback process should consider. First, students are less likely to implement feedback if it is just a suggestion, as this may lack sufficient information to understand the feedback completely. They advocate that suggestions are more likely to materialize if they incorporate cognitive, emotional, and motivational factors. They further suggested that seeking clarification was essential for peer feedback to be useful.

Back-channel communication

Ross et al. (2011) describes a back-channel platform as an informal form of communication that ventures across the lecture room to encourage discussion among learners within the community. Hayes et al. (2021) claimed that for BSL to be successful, a back-channel platform needed to be introduced between online and f2f students. This could reduce the workload placed on the faculty and promote free conversations between students. They also emphasized the need to customize these back-channels appropriately to the students' needs. For instance, in their study, most of the overseas students from China were unfamiliar with apps like Facebook, WhatsApp, or Google Docs. Instead, they were inclined to use WeChat. These students took the initiative to use the tool to share class documents, which turned out to be beneficial for them.

Dual device set-up

The study found that many online students used a two-device setup for optimal hands-on learning experience in the BSL setting. This comprises a computer and an iPad. Students often use laptops for learning, which can be an issue for hands-on activities, as students must switch between the Zoom meeting window and the hands-on tool window. Hence, having an additional iPad for displaying the Zoom meeting is helpful. The ease of the dual monitors would relinquish the need for shuffling between windows.

Audio

Learners consistently prioritized audio over visual teaching. This finding supports previous researchers who reported audio as a critical component of BSL success (Detyna et al., 2023). The frequent sound disruption experienced during the BSL environment was cited in many studies. Wang and Huang (2023) reported in the systematic literature review that ten out of 33 authors encountered audio issues in their research. Raes et al. (2020) suggested that online students should receive the same audio quality as those in class. A strategy was to let the online students test the connection earlier so that they could resolve the technical issues, ensuring a seamless BSL experience.

5.2 Implications

The findings of the study have implications for teachers and researchers. Planning is crucial for a successful hands-on endeavor. Integrating strategies such as peer feedback, student design artifacts, and back-channel platforms has proven useful. While selecting the right platform for technology, simplicity is a crucial facilitator for heavy hands-on courses. As for the researcher, there is much room for improvement in the hands-on course within a BSL environment. Strategies specific to the hands-on approach require further investigation. For instance, monitoring students' hands-on activities is a area of research. The present study allowed students to observe the instructor's screen and occasionally required the online students to share theirs. Future research can further explore how the instructor can monitor every student's screen at a time.

5.3 Limitation and conclusion

This study had some limitations. The study involved a small class size and was conducted in a developed country with tertiary students. In addition, the study used a retrospective study method where students' perceptions were assessed at the end of the semester. More research can apply learning analytics to examine student engagement by analysing the data stored in the learning management system. In conclusion, this research reveals that effective strategies to engage online students in hands-on activities include teaching assistants, peer feedback, back-channel platforms, two-device setups, and clear audio.

References

Allan, G., & Bryden, S. (2023). Blended synchronous learning: Integrating remote and face-to-face learners. In P. Ferguson, B. Lacy, & R. Derrah (Eds.), *Learning from Students, Educating Teachers— Research and Practice*. JALT. https://doi.org/10.37546/JALTPCP2022-25.

Bower, M., Lee, M. J., & Dalgarno, B. (2017). Collaborative learning across physical and virtual worlds: Factors supporting and constraining learners in a blended reality environment. *British Journal of Educational Technology, 48*(2), 407-430.

Detyna, M., Sanchez-Pizani, R., Giampietro, V., Dommett, E. J., & Dyer, K. (2023). Hybrid flexible (HyFlex) teaching and learning: Climbing the mountain of implementation challenges for synchronous online and face-to-face seminars during a pandemic. *Learning Environments Research, 26*(1), 145-159.

Hadad, S., Shamir-Inbal, T., & Blau, I. (2024). Pedagogical strategies employed in the Emergency Remote Learning Environment during the COVID-19 pandemic: The tale of teachers and school ICT coordinators. *Learning Environments Research,* 1-24.

Hayes, S., & Tucker, H. (2021). Using synchronous hybrid pedagogy to nurture a community of inquiry: Insights from a tourism Master's programme. *Journal of Hospitality, Leisure, Sport & Tourism Education, 29,* 100339.

Ho, V. T., Nakamori, Y., Ho, T. B., & Lim, C. P. (2016). Blended learning model on hands-on approach for in-service secondary school teachers: Combination of E-learning and face-to-face discussion. *Education and Information Technologies, 21*, 185-208.

Lakhal, S., Mukamurera, J., Bédard, M. E., Heilporn, G., & Chauret, M. (2020). Features fostering academic and social integration in blended synchronous courses in graduate programs. *International Journal of Educational Technology in Higher Education, 17,* 1-22.

Li, X., Yang, Y., Chu, S. K. W., Zainuddin, Z., & Zhang, Y. (2022). Applying blended synchronous teaching and learning for flexible learning in higher education: An action research study at a university in Hong Kong. *Asia Pacific Journal of Education, 42*(2), 211-227.

Lyu, Q., Chen, W., Su, J., & Heng, K. H. J. G. (2023). Steps to implementation: The role of peer feedback inner structure on feedback implementation. *Assessment & Evaluation in Higher Education,* 1-14.

May, D., Morkos, B., Jackson, A., Hunsu, N. J., Ingalls, A., & Beyette, F. (2023). Rapid transition of traditionally hands-on labs to online instruction in engineering courses. *European Journal of Engineering Education, 48*(5), 842-860. https://doi.org/10.1080/03043797.2022.2046707

McCaw, C. T., Mendus, A., Boyer, A., Cameron, S., Leve, A., & Messer, R. (2023). From “Am I just too old for this?” To “Hey–I think I could do that!”: A collaborative self-study of the implementation of blended synchronous learning in initial teacher education. *Education and Information Technologies,* 1-29.

Mentzer, N. J., Isabell, T. M., & Mohandas, L. (2023). The impact of interactive synchronous HyFlex model on student academic performance in a large active learning introductory college design course. *Journal of Computing in Higher Education,* 1-28.

Raes, A., Detienne, L., Windey, I., & Depaepe, F. (2020). A systematic literature review on synchronous hybrid learning: Gaps identified. *Learning Environments Research, 23,* 269-290.

Ross, C., Terras, M., Warwick, C., & Welsh, A. (2011). Enabled backchannel: Conference Twitter use by digital humanists. *Journal of Documentation, 67*(2), 214-237.

Shi, Y., Tong, M., & Long, T. (2021). Investigating relationships among blended synchronous learning environments, students’ motivation, and cognitive engagement: A mixed methods study. *Computers & Education, 168,* 104193.

Wang, Q., & Huang, Q. (2023). Engaging Online Learners in Blended Synchronous Learning: A Systematic Literature Review. *IEEE Transactions on Learning Technologies. 17,* 594-607.

Wang, Q., Wen, Y., & Quek, C. L. (2023). Engaging learners in synchronous online learning. *Education and Information Technologies, 28*(4), 4429-4452.

Zha, S., & He, W. (2021). Pandemic Pedagogy in Online Hands-on Learning for IT/IS Courses. *Communications of the Association for Information Systems, 48*. https://doi.org/10.17705/1CAIS.04811

	Appendix: Survey results	*n*	Mean	SD
	1. How many sessions (s) did you participate in online (using Zoom) during the BSL sessions?	34	1.76	1.21
Instructor	2. The instructor paid close attention to us (online participants) during the BSL sessions	34	4.03	0.83
	3. The instructor frequently invited us (online) for contributions (e.g., comments, questions, or answers) during the BSL sessions.	34	4.12	0.81
	4. The instructor had frequent interactions with us in the BSL sessions	33	4.15	0.87
	5. The instructor addressed our concerns and/or questions promptly in the BSL sessions	34	4.21	0.95
	6. Having a teaching assistant in the classroom helped in notifying the instructor to address our concerns (e.g., posted to the chat box)	18	4.89	0.47
	7. I closely followed the instructor's presentations and demonstrations when I was online in the BSL sessions	34	4.24	0.96
Learner	8. I stayed focused during the BSL sessions	34	4.21	0.91
	9. I frequently interacted with the instructor during the BSL sessions	34	3.59	1.13
	10. I kept contact with classroom peers using other back-channels like WhatsApp during the instructor's presentations in BSL sessions.	34	3.85	1.11
	11. I could follow the instructor's demonstrations during the hands-on activities in BSL	32	4.13	0.94
	12. I was highly engaged during the hands-on activities	32	4.16	0.95
	13. I was highly engaged when I was sharing my artifact with my group mates	31	4.19	0.83
	14. I was engaged when others were sharing their artifacts with the class	32	4.16	0.88
	15. Giving peer feedback made me concentrate on peers' sharing	31	4.29	0.74
	16. The feedback received during peer feedback was helpful for improving the artefact	30	4.23	0.77
Content	17. The learning content of the course was relevant	32	4.47	0.62
	18. The learning content of the course were helpful	31	4.48	0.57
Technology	19. The authoring tools we learned in the course were useful	16	4.38	0.81
	20. I did not encounter technical difficulties in the BSL sessions using Zoom	32	4.22	1.04
	21. The session using Pear Deck (in Google Slides) was more engaging than the sessions using Zoom only	16	3.38	0.96
Environment	22. I was highly engaged in the BSL sessions	34	3.82	0.83
	23. I was equally engaged wherever in the classroom or at home in the BSL sessions	34	3.91	1.08
	24. My engagement level was lower when I was online than in the classroom in the BSL sessions	34	3.29	1.45

An investigation into the interplay between EFL learners' emotion regulation strategies with emotions and academic performance in an online collaborative academic reading project

Haizhen Guo[1], Miao Jia[1], Zeting Yuan[1] and You Su[1*]
[1]Beijing University of Posts and Telecommunications
[*]suyou@bupt.edu.cn

Abstract: *Technology-enhanced collaborative academic reading has been recognized as an effective approach to facilitating learners' understanding of texts, promoting knowledge co-construction, and enhancing their motivation. However, few studies have explored the emotional facet of learners despite various challenges they may encounter in such learning contexts. This study aimed to address this research gap by examining the interplay of emotion regulation (ER) strategies with emotions and academic performance among 61 Chinese college students participating in an online collaborative academic reading project. Data collection methods consisted of a vignette-based questionnaire and the rating of students' academic reports. The results revealed that:1) cognitive change could significantly predict positive emotions;2) attention deployment made significant predictions for the delivery manners dimension of performance. This study provides important insights into learners' emotional aspects in the online collaborative language learning environment and concludes with implications for future research.*

Keywords: emotion, emotion regulation, online collaborative academic reading

1. Introduction

Collaborative academic reading has been recognized as a promising approach to enhance EFL learners' understanding of an academic text and facilitate their language learning (Jin et al., 2022; Liu et al., 2021). Though many researchers move academic reading activities into online space, successful collaboration in an online learning context is not easy to achieve (Zhang et al., 2021). Compared with individual learning, students may encounter various social, cognitive, and motivational challenges in collaborative learning (Järvenoja & Järvelä, 2009; Mänty et al., 2023). To overcome these challenges, students' emotional states inevitably would be more complex and the ER strategies they adopt would be distinct from those in individual learning situations. Understanding students' emotions and the ER strategies they employ becomes crucial for optimizing learning outcomes. However, students' emotions and ER strategies and the impact of ER strategies on their positive emotions and performance have been under-researched in collaborative language learning contexts (Kukulska-Hulme & Viberg, 2018; Nguyen et al., 2021; Zhang et al., 2021). To address these research gaps, this study adopted a mixed method to examine the interplay between ER strategies with emotions and academic performance in an online collaborative academic reading project based on the following research questions:

RQ1: What predictive role do EFL learners' ER strategies play on their emotions in an online collaborative academic reading project?

RQ2: What predictive role do EFL learners' ER strategies play on their academic performance in an online collaborative academic reading project?

2. Method

2.1 Participants and context

Participants of the study were 61 second-year undergraduate students at a university who were enrolled in an *English for Academic Purposes* course at a university in northern China. Their ages ranged from 19 to 22 years old, and 48 of them were males. They were split up into groups of three to four to be involved in an online collaborative academic reading project. Students performed four roles including summarizer, writing skills specialist, passage person, and word master through *Feishu* (https://www.feishu.cn/en/).

2.2 Data collection and analysis

Three sources of data were collected to analyze and address the research questions. The first challenge survey consisted of three open questions for students to write down at least three challenges they had encountered in previous collaborative reading experiences. The top 19 most frequent challenges were designed into 19 vignettes of the second vignette-based questionnaire with three questions in each one: (1) What kinds of emotions would you experience in this situation? (2) What specific emotions would you feel in this situation? (3) What would you do to manage these emotions in this situation? The results of the first two questions were calculated to explore students' emotion types and specific emotions they felt in the 19 scenarios. Following Gross's process model (2015), the responses to the third question were analyzed thematically by two coders to determine the ER framework specific to this research context. According to four roles they played in reading circles, two authors scored students' academic presentations from 1 to 5 based on the three-dimension rubrics: content, structure and delivery manners. Then, the relationships between the students' emotions and ER strategies, ER strategies and performance were analyzed through correlation analysis by SPSS 26.0. Stepwise regression analysis was conducted to figure out the predictive power of ER strategies for emotions and performance.

3. Results

3.1. Descriptive results of emotion types, specific emotions and ER strategies students adopted

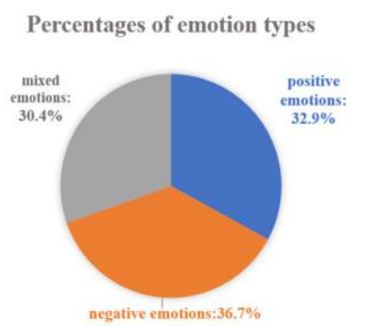


Figure 1. Percentages of emotion types

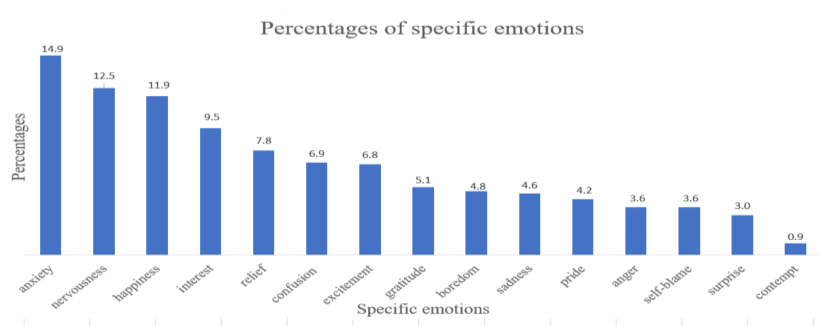


Figure 2. Percentages of specific emotions

Table 1. ER strategies framework and their numbers and percentages.

ER strategies	Task-related regulation	Response modification	Cognitive change	Attention deployment	Co-regulation	Situation modification	Total
Numbers.	162	238	255	153	304	140	1252
Percentages.	12.9	19.0	20.4	12.2	24.3	11.2	

To answer RQ1, this study primarily made a descriptive statistical analysis of students' emotion types, specific emotions and emotion regulation framework. As shown in figure 1, negative emotions (36.7%) was slightly more than positive (32.9%) and mixed emotions(30.4%). As shown in figure 2, anxiety, nervousness and happiness were the top three emotions students experienced among the fifteen specific emotions. Through a thematic analysis, this study identified a framework of ER strategies consisting of six strategy families and their frequency distribution (see table 1): cognitive change (20.4%), response modification (19.0%), attention deployment (12.2%), situation modification (11.2%), task-related regulation (12.9%) and co-regulation (24.3%). Co-regulation, cognitive change and response modification were the top three ER strategies students used in the online collaborative academic reading project.

3.2 The relationship between EFL learners' ER strategies and positive emotions

Table 2. Pearson correlations between ER strategies and positive emotions.

	Task-related regulation	Cognitive change	Response modification	Attention deployment	Situation modification	Co-regulation
PE	-.200	.372**	-.024	-.038	-.069	.081

Note: **p < .01.; PE：positive emotions

Table 3. Prediction of positive emotions by ER strategies.

Dependent variables	Predictor variables	B	S.E.	b	t	p
Positive emotions	Cognitive change	.406	.137	.372	2.974	.004**

B = Unstandardized regression coefficient; S.E. = Standard error of B; b = Standardized regression coefficient. **p < .01.

To explore the relationship between ER strategies and positive emotions, Pearson's correlation analyses was conducted and the results showed that cognitive change was significantly correlated with students' positive emotions (p<0.01, see table 2). To further test the predictive role of positive emotions by ER strategies, stepwise regression analysis was conducted and the pattern of results showed that cognitive change positively contribute of predicting positive emotions (see table 3).

3.3 The relationship between EFL learners' ER strategies and performance

Table 4. Pearson correlations between ER strategies and performance.

	Task-related regulation	Cognitive change	Response modification	Attention deployment	Situation modification	Co-regulation
Content	-.043	.101	-.172	.059	.146	.035
Structure	.067	.184	-.191	-.178	.125	.074
Delivery manners	-.085	.196	-.211	-.455**	.141	.121

Note: **p < .01.

Table 5. Prediction of performance by ER strategies.

Dependent variables	Predictor variables	B	S.E.	b	t	p
Delivery manners	Attention deployment	-.182	.050	-.455	-3.613	.001**

B = Unstandardized regression coefficient; S.E. = Standard error of B; b = Standardized regression coefficient. *p < .05.

To answer RQ2, Pearson's correlation analyses was conducted and table 4 showed the results that attention deployment was significantly related to the delivery manners dimension of performance (p<0.01). Then the study conducted Stepwise regression analysis to further evaluate the predictive power of the attention deployment for students' delivery manners dimension of performance. As shown in table 5, regression analysis revealed that attention deployment made significant predictions for delivery manners dimension of performance (p<0.01).

4. Discussions and conclusion

The results of the RQ1 indicated that learners experienced a few more negative emotions than the other two types. This finding is consistent with the Bielak & Mystkowska-Wiertelak (2020) who reported that negative emotions as dominant type among 539 Poland college EFL learners. Co-regulation has shown to be the most frequently used ER strategy in this study, followed by cognitive change and response modification. Co-regulation is an extension of Gross's (2015) process model of ER strategies, and it is in line with the socio-interactive characteristics of collaborative learning context (Linnenbrink-Garcia et al., 2011). Adopting co-regulation became popular in this context in that students could build an emotional zone of proximal development to scaffolding peers' emotional states (Liu &Yu, 2021). Furthermore, this study explored the relationship between students' ER strategies and their PE and found that the cognitive change and

PE were positively correlated and cognitive change could significantly predict the PE. This finding is consistent with Zhang et al. (2021) who found that cognitive change was capable of transforming the negative stimuli to be perceived as positive by participants. Cognitive change has been identified as one of the most common ER strategies by prior studies conducting in individual learning contexts, future researchs can direct their attention to the collaborative learning to explore the predictive power of ER strategies on their emotions in a larger sample size.

Concerning the RQ2, this study revealed attention deployment had negative correlation with delivery manners dimension of performance and the former made significant predictions for the latter. Attention deployment means students consciously allocating and adjusting their attention such as shifting their attention away from emotion-inducing events to the ones that help manage their emotions (Bielak & Mystkowska-Wiertelak, 2020; Liu & Yu, 2021). This finding can be attributed to the fact that some students' use of attentional deployment strategies might lead to their distraction during presentations, thereby adversely affecting their delivery performance. Overall, the findings stressed the significance of individual differences and the need for further exploration in understanding the intricate relationship between attentional deployment strategies and delivery manners performance.

Acknowledgement:

This study was supported by Postgraduate Teaching Reform Project of Beijing University of Posts and Telecommunications (2023Y037).

5. References

Bielak, J. & Mystkowska-Wiertelak, A. (2020). Investigating language learners' emotion-regulation strategies with the help of the vignette methodology. *System, 90,* 102208.

Gross, J. (2015). Emotion Regulation: Current Status and Future Prospects. *Psychological Inquiry*, *26*(1), 1–26.

Järvenoja, H., & Järvelä, S. (2009). Emotion control in collaborative learning situations: Do students regulate emotions evoked by social challenges? *British Journal of Educational Psychology*, *79*(3), 463–481.

Jin, T., Jiang, Y., Gu, M. M., & Chen, J. (2022). "Their encouragement makes me feel more confident": Exploring peer effects on learner engagement in collaborative reading of academic texts. *Journal of English for Academic Purposes*, *60*, 101177.

Kukulska-Hulme, A. and Viberg, O. (2018). Mobile Collaborative Language Learning: State of the Art, *British Journal of Educational Technology*, *49*(2), 207–218.

Linnenbrink-Garcia, L., Rogat, T. K., & Koskey, K. L. K. (2011). Affect and engagement during small group instruction. *Contemporary Educational Psychology*, *36*(1), 13–24.

Liu, C., & Yu, S. (2021). Exploring master's students' emotions and emotion-regulation in supervisory feedback situations: a vignette-based study. *Assessment & Evaluation in Higher Education*, *47*(7), 1101–1115.

Mänty, K., Järvenoja, H., & Törmänen, T. (2022). The sequential composition of collaborative groups' emotion regulation in negative socio-emotional interactions. *European Journal of Psychology of Education*, *38*(1), 203–224.

Nguyen, A., Hong, Y., Dang, B., & Nguyen, B. T. (2022). Emotional regulation in synchronous online collaborative learning: a facial expression recognition study learning. *The International Conference on Information Systems* (ICIS).

Xu, Q. (2021). Incorporating reading circles into a task-based EAP reading scheme. *ELT Journal*, *75*(3), 341–350.

Zhang, Z., Liu, T. & Lee, C.B. (2021). Language learners' enjoyment and emotion regulation in online collaborative learning. *System*, *98*, 102478.

The Predicting Effects of Online Co-regulation Strategies on EFL Learners' Attitude toward Collaborative Academic Reading: An Exploratory Study

Miao Jia[1], Haizhen Guo[1], Zeting Yuan[1], You Su[1*]
[1]Beijing University of Posts and Telecommunications
[*]suyou@bupt.edu.cn

Abstract: *This exploratory study examined the relationship between Chinese EFL learners' online co-regulation strategies and their attitudes toward collaborative academic reading activities. Data were collected through two questionnaires about learners' online co-regulation strategies and their attitudes toward collaborative academic reading activities among 67 university students in China. The findings demonstrated a positive correlation between students' co-regulation strategies and their attitudes. More interestingly, the stepwise regression analysis revealed that students' effort regulation significantly predicted all factors of students' attitudes toward collaborative academic reading. Students' co-planning positively explained their behavior, and co-monitoring emerged as a powerful predictor of self-efficacy for academic reading. Overall, this study highlighted the positive role of students' effort regulation, co-planning, and co-monitoring in explaining their attitudes toward collaborative academic reading, and the findings are expected to offer insights for both researchers and language teaching practitioners.*
Keywords: online co-regulation strategies, attitudes toward collaborative academic reading, online collaborative language learning, EFL

1.Introduction

Collaborative reading is a socially contextualized form of reading involving the joint construction of meaning and knowledge through text-based discussions (Kiili et al., 2012). Over the past two decades, there has been a notable shift in reading practices, moving from a primarily print-based experience to one predominantly situated in the digital environment (Thoms & Poole, 2017). However, online collaborative learning environments present additional challenges for students, leading to mixed or ambiguous attitudes toward collaborative reading activities (Su et al., 2019).

Co-regulation is defined as an interactive process where group members collectively regulate their joint learning by planning, monitoring, and evaluating to achieve a mutual objective (Chan, 2012). Co-regulation is considered crucial for successful collaborative learning (Ucan, 2015). Although previous studies have been conducted on co-regulation strategies in online collaborative writing environments (e.g. Su et al., 2023; Wang, 2019), empirical research on online collaborative academic reading environments is a relatively new area (Li et al., 2021).

In the last decade, an increasing amount of research has indicated the possible link between learners' co-regulation strategies and their attitudes toward online collaborative learning (e.g., Qiu, 2020; Yossatorn et al., 2022). Nevertheless, there is a scarcity of empirical explorations examining the role of co-regulation strategies in shaping students' attitudes toward collaborative learning in the context of online collaborative academic reading. Therefore, the present study addresses this research gap by investigating a sample of Chinese EFL students with experience in doing online literature circle activities. The corresponding research questions are presented as follows:

(1) What is the relationship between EFL learners' online co-regulation strategies and their attitude toward collaborative reading activities?

(2) What predictive roles do EFL learners' online co-regulation strategies play in their attitude toward collaborative reading activities?

2. Methods

2.1. Research Context and Procedures

The study aimed to explore the interconnection between Chinese EFL learners' co-regulation strategies and their attitude toward academic reading activities in an online learning environment. The participants in this study comprised 67 second-year undergraduate students (53.1% male, aged 18 to 21) , all possessing the same level of English proficiency. In this study, collaborative academic reading took the form of computer-assisted literature circles. The assessment of their co-regulation strategies and attitudes was conducted through questionnaire surveys.

2.2. Instruments

For this study, two questionnaires were developed: Online Co-Regulation Strategies (OCRS) and the Attitude toward Collaborative Academic Reading (ACAR). The OCRS questionnaire demonstrated high reliability, with an overall alpha reliability of 0.95. It contained five dimensions: co-planning, co-monitoring, co-evaluation, help-seeking, and effort regulation. The ACAR questionnaire exhibited strong reliability, with an overall coefficient of 0.97. It comprised four constructs (perceived usefulness, affection, behavior, and self-efficacy).

2.3. Data Analysis

To comprehend university students' attitudes toward online collaborative academic reading and their online co-regulation strategies, a descriptive statistical analysis of these two variables was initially performed. Then, the correlation between the finalized OCRS and ACAR factors was analyzed through Pearson correlation analysis. Moreover, stepwise regression was employed to further analyze the effect of students' online co-regulation strategies on their attitude toward collaborative academic reading.

3. Results

3.1. Descriptive Statistics

As indicated in Table 1, the mean scores of ACAR factors range from 4.06 to 4.26, indicating that students hold positive attitudes toward collaborative academic reading. Moreover, the means of OCRS factors fall within the range of 3.66 to 4.26, implying students' online co-regulation strategies are at a moderate level. Notably, the means for effort regulation and co-evaluation are slightly higher compared to co-planning, co-monitoring, and help-seeking. This suggests that students employed more effort regulation and co-evaluation strategies during collaborative academic reading activities.

3.2. Correlation Analysis

The Pearson correlation coefficient was employed to explore the relationship between students' online co-regulation strategies and their attitudes toward collaborative academic reading. As can be seen from Table 2, all factors of students' online co-regulation strategies are positively correlated with students' attitudes toward collaborative academic reading. Notably, the OCRS factor "Effort regulation" (r = 0.63-0.84, p < 0.01) demonstrated a stronger positive association with all dimensions of ACAR compared to the other OCRS factors (i.e., CP, CM, HS, CE).

Table 1. Descriptive results of students' online co-regulation strategies and their attitudes

	Min	Max	Mean	SD
Co-planning	1.25	5.00	3.90	0.84
Co-monitoring	1.17	5.00	3.66	0.75
Effort regulation	1.40	5.00	4.26	0.73
Help-seeking	1.25	5.00	3.71	0.94
Co-evaluation	1.00	5.00	4.15	0.77
Usefulness	1.00	5.00	4.17	0.96
Affection	1.00	5.00	4.06	1.02
Behavior	1.00	5.00	4.26	0.84
Efficacy	1.00	5.00	4.11	0.88

Table 2. Correlation coefficient between each factor of OCRS and ACAR

	Co-planning	Co-monitoring	Effort regulation	Help-seeking	Co-evaluation
Usefulness	0.41**	0.47**	0.63**	0.44**	0.56**
Affection	0.44**	0.45**	0.64**	0.44**	0.54**
Behavior	0.63**	0.59**	0.84**	0.54**	0.71**
Self-efficacy	0.60**	0.62**	0.82**	0.58**	0.67**

3.3. Stepwise Regression Analysis

The stepwise multiple regression was further conducted to explore to what extent the five components of OCRS predict the factors of ACAR. It is interesting to see that the OCRS factor "Effort regulation" makes significant predictions for all factors of the ACAR, indicating that students who exhibit greater perseverance when confronted with challenges are more likely to maintain a positive attitudes toward collaborative academic reading activities. The results also showed that "Co-planning" could only positively predict "Behavior" (B = 0.20, T = 2.50, p < 0.05). Besides, "Co-monitoring" had a significantly positive prediction for "Self-efficacy" (B = 0.22, T = 2.60, p < 0.05).

Table 3. Stepwise regression model for predicting students' ACAR

		B	*SE*	*β*	*T*	*R*
Usefulness	Effort regulation	0.83	0.13	0.63	6.50**	0.63
	Constant	0.64	0.55		1.16	
Affection	Effort regulation	0.89	0.13	0.64	6.70**	0.64
	Constant	0.26	0.58		0.45	
Behavior	Effort regulation	0.83	0.09	0.72	8.94**	0.85
	Co-planning	0.20	0.08	0.20	2.50*	
	Constant	-0.07	0.34		-0.21	
Self-efficacy	Effort regulation	0.83	0.10	0.69	8.16**	0.84
	Co-monitoring	0.26	0.10	0.22	2.60*	
	Constant	-0.36	0.37		-0.97	

4. Discussion and Conclusion

This study validated two questionnaires on students' online co-regulation strategies and their attitudes toward collaborative academic reading. The findings revealed effort regulation as the most positive predictor for all factors of students' attitudes toward collaborative academic reading. It indicates that learners who endeavor to persist in the face of obstacles or challenges encountered would have a more positive attitudes, which is in line with the results of previous studies (Floris et al., 2023). What's more, co-planning was found to be a significant predicator of behavior, illustrating the positive impact of students' planning on their perceived ability to execute a given task (Lai et al., 2018). The last but most interesting finding concerns that co-monitoring was a significant variable for explaining their self-efficacy. Previous studies have indicated the positive impacts of monitoring strategies on students' academic self-efficacy (Affuso et al., 2023). The present study extends such findings to the area of computer-mediated collaborative academic reading.

The study unveiled intricate connections between co-regulation strategies in computer-mediated collaborative academic reading and students' attitudes toward collaborative academic reading. Notably, more utilization of effort regulation, co-planning, and co-monitoring strategies emerged as predictors of students' positive attitudes toward academic reading. These findings propose that educators should explore effective methods to incorporate instruction with effort regulation, co-planning, and co-monitoring strategies within computer-mediated collaborative academic reading activities. For future research, more empirical studies are needed with surveys combined with qualitative analyses of students' collaborative academic reading processes and reading achievements to triangulate the results.

Acknowledgements

This research is funded by the National Social Science Fund of China (Grand No. 23BYY161).

References

Affuso, G., Zannone, A., Esposito, C., Pannone, M., Miranda, M. C., De Angelis, G., ... & Bacchini, D. (2023). The effects of teacher support, parental monitoring, motivation and self-efficacy on academic performance over time. European Journal of Psychology of Education, 38(1), 1-23.

Chan, K. K. (2012). Co-regulation of learning in computer-supported collaborative learning environments: A discussion. Metacognition and Learning, 7, 63-73.

Floris, M., Paganin, G., Guglielmi, D., & Mazzetti, G. (2023). Motivation is not enough: How career planning and effort regulation predict academic achievement. Current Psychology, 1-10.

Kiili, C., Laurinen, L., Marttunen, M., & Leu, D. J. (2012). Working on understanding during collaborative online reading. Journal of Literacy Research, 44(4), 448-483.

Lai, C., Hu, X., & Lyu, B. (2018). Understanding the nature of learners' out-of-class language learning experience with technology. Computer Assisted Language Learning, 31(1–2), 114–143.

Li, Y., Chen, K., Su, Y., & Yue, X. (2021). Do social regulation strategies predict learning engagement and learning outcomes? A study of English language learners in wiki-supported literature circles activities. Educational Technology Research & Development, 69, 917–943.

Qiu, X., & Lee, M. K. (2020). Regulated learning and self-efficacy beliefs in peer collaborative writing: An exploratory study of L2 learners' written products, task discussions, and self-reports. System, 93, 102312.

Su, Y., Li, Y., Liang, J. C., & Tsai, C. C. (2019). Moving literature circles into wiki-based environment: The role of online self-regulation in EFL learners' attitude toward collaborative learning. Computer Assisted Language Learning, 32(5–6), 556–586.

Su, Y., Liang, J. C., Zheng, C., & Tsai, C. C. (2023). Co-regulation strategies and their associations with writing self-efficacy in a computer-mediated collaborative writing setting. Journal of Second Language Writing, 59, 100972.

Thoms, J. J., & Poole, F. (2017). Investigating linguistic, literary, and social affordances of L2 collaborative reading. Language Learning & Technology, 21(1), 139–156.

Ucan, S., & Webb, M. (2015). Social regulation of learning during collaborative inquiry learning in science: How does it emerge and what are its functions?. International Journal of Science Education, 37(15), 2503-2532.

Wang, L. (2019). Effects of regulation on interaction pattern in web-based collaborative writing activity. Computer Assisted Language Learning, 35(1-2), 1-35.

Yossatorn, Y., Binali, T., Weng, C., & Awuor, N. O. (2023). Relating university students' online self-regulated English learning to motivational beliefs: a structural equation modelling analysis. Behaviour & Information Technology, 42(7), 888-903.

Developing Virtual Reality Learning Materials for Elementary Marine Education using the ASSURE Model

Yi-Shan Liu [1*], Ah-Fur Lai [2], Cheng-Ying Yang [3]
[1] Department of Computer Science, University of Taipei
[*]g11116005@go.utaipei.edu.tw
[2, 3] Department of Computer Science, University of Taipei
[2] laiahfur@gmail.com
[3] cyang@uTaipei.edu.tw

Abstract: *This study developed marine education virtual reality (VR) materials, employing the ASSURE model for instructional design. Utilizing the CoSpaces EDU platform, we designed an immersive VR escape room game that simulates a real marine environment. This VR allows students to become acquainted with Taiwan's marine society, culture, and resources, fostering an appreciation and awareness for the sustainable development of marine environments and resources. Expert evaluations have affirmed its effectiveness, and future teaching experiments will be conducted in elementary schools to verify its learning outcomes.*

Keywords: ASSURE model, E-Learning, Integrated Curriculum, Marine Education, Virtual Reality

1. Introduction

Taiwan, as a nation surrounded by the sea, boasts a diverse range of coastal topographies, geologies, and a wealth of marine life, including world-class coral reef ecosystems. The government has been actively promoting marine education through the release of relevant policies and the establishment of curricula, garnering widespread attention for marine education. The Ministry of Education's "National Ocean Policy White Paper," published in 2020, incorporates marine education into its critical agenda, aiming to construct an ecological, safe, and prosperous sustainable maritime nation. The twelve-year national basic education curriculum also integrates marine education (Twelve-Year National Basic Education Curriculum Guidelines, 2020) to enhance students' understanding of the sustainable development of the marine environment and resources.

This study utilized the CoSpaces EDU web platform to construct virtual reality learning materials, combined with an immersive escape room game, to simulate a realistic marine environment. This enables students to understand Taiwan's marine society, culture, and resources, and to strengthen their affinity for the ocean. The game in this VR is divided into three major levels, where students must unlock each level to become "Children of the Ocean." Based on the ASSURE model for instructional design, marine education is integrated into virtual reality (VR), aimed at guiding middle and high-grade elementary school students to value the concept of marine sustainable development and establish a foundational understanding of the sustainable development of the marine environment and resources.

2. Literature Review

Marine education has recently garnered global attention due to issues like global warming, extreme climate events, ocean pollution, and the depletion of marine resources. The methods of promoting marine education are varied, including role-playing, systematic teaching, competency education, and the integration of technology into curricula. These approaches underscore the importance placed on the philosophy and advancement of marine education, incorporating sustainable marine education into teaching activities to encourage positive student engagement and concern for marine issues. Consequently, this study aims to develop a more diverse range of marine education content, breaking through environmental limitations by employing gamification and digitalization. This will stimulate students' learning interests, offering teachers and students a wealth of vivid options, making marine knowledge more accessible and shareable. Such efforts will advance marine education and collectively protect our precious oceans.

With the advancement of technology products, Virtual Reality (VR) allows learners to interact with learning materials through the VR system. It provides learners with an immersive experience and offers opportunities for repeated practice, thereby providing a more realistic, flexible, and effective learning environment (Chen, Chen, & Li , 2022). Using VR as a learning technology provides students with a context for active learning. Users can freely decide where to go in the environment and can find additional information through the VR interface (Wu, Manabe, Marek, & Shu, 2021). Therefore, this study uses VR to provide students with a learning experience that encourages active exploration and interactive collaboration. It has rich extensibility, allows students to feel a sense of presence and immersion to explore different scenes and learning objects, and enhances learning effectiveness.

The ASSURE model of instructional design, proposed by Heinich, Molenda, Russell, and Smaldino in 2002, encompasses six steps: Analyze learners, State objectives, Select instructional methods, media, and materials, Utilize media and materials, Require learner participation, and Evaluate and revise. The ASSURE model is widely applied in education, integrating educational technology, generating interest and motivation through gamification, developing interactive course designs, and focusing on issue-based material creation to improve teaching practices and learning outcomes. Its goal is to enhance students' understanding and participation across various educational domains by incorporating interactive elements, multimedia resources, and learning activities, providing insights for future related material design. Therefore, this study, based on the ASSURE model, targets middle and high-grade elementary students, integrating virtual reality (VR) into marine education. We develop VR materials as teaching mediums, demanding active student participation in the learning process.

3. Research Method

This study first determined the research methodology and topic before confirming the research background and purpose. After reviewing relevant literature, the framework of the VR materials was studied and marine education VR materials were developed using the CoSpaces EDU web platform. Questionnaire surveys were conducted and experts were invited to evaluate the materials and provide suggestions for revisions. In the future, teachers can integrate these VR materials into elementary school science curricula and conduct teaching experiments. Related knowledge can also be delivered through the digital education process. The following is the research procedure, as shown in Figure 1.

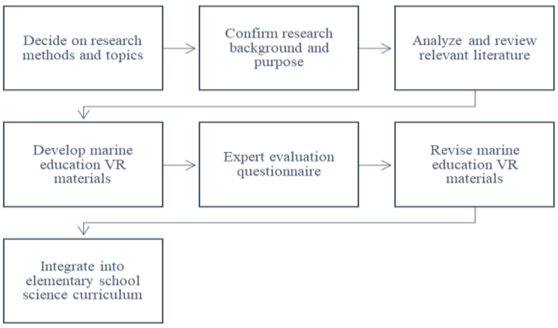


Figure 1. Research Procedure Flowchart.

The following points are the learning objectives: (1)Analyze Learner Characteristics: Targeting middle and high-grade elementary students with physical manipulation and logical computation abilities, we aim to engage them beyond anthropomorphic thinking. Thus, we employ escape room methods to captivate students, combining fun interactions and challenging learning experiences. (2)State Objectives: To establish students' understanding of the ocean through lively and interesting marine exploration using virtual reality technology. (3)Select, Modify or Design Materials: We use the

CoSpaces EDU platform to develop materials, providing a wealth of 3D models and scenes for an immersive experience of marine ecology and conservation issues. Materials are designed according to instructional goals and optimized based on feedback from experts and users. (4)Utilize Materials: Ensuring that instructional equipment, environments, and resources are prepared, we attract students' attention and resolve queries, encouraging proactive exploration and discovery to enhance learning motivation. (5)Require Learner Response: Student satisfaction and suggestions for the materials are collected through surveys to facilitate clear improvements and enhance material effectiveness. (6)Evaluate: Assessments include marine knowledge, conservation, ecology, and usability to confirm instructional effectiveness and further optimize materials.

The "VR Material Evaluation Questionnaire" developed in our laboratory encompasses five dimensions: "Learning Value," "Curricular Inspiration," "Interface Design," "Pre-assessment," and "Post-assessment." The overall questionnaire consists of 27 items with a Cronbach's Alpha value of .967, indicating a high reliability. A Cronbach's Alpha value above .80 is considered optimal, signifying very high reliability suitable for measurement purposes. Therefore, the scale of this study has high reliability and is appropriate for implementation, allowing for the evaluation of teaching materials.

Table 1. Cronbach's Alpha values for each dimension in the expert evaluation of marine education VR teaching

Dimension	Number of questions	Cronbach's Alpha
Learning Value	1-5	.879
Course Inspiration	6-9	.846
Interface Operation	10-16	.907
Pre-assessment	17-19	.873
Post-assessment	20-27	.945
Overall scale		.967

4. Research results

This study employs the CoSpaces EDU web platform for developing a virtual reality (VR) material of marine education. With the flourishing development of digital media, interactive elements in virtual spaces have enhanced the enjoyment of learning, making the overall materials more engaging. The marine education VR materials aim to direct students' attention to environmental issues and the protection of marine ecosystems by means of game-based learning. The first level, "Discovering Fantastical Marine Creatures," involves recognizing marine life and unlocking code locks. The second level, "Ocean Defense Battle," adopts a situational approach to collect marine debris and answer related questions to unlock doors. The final level, "Voyage to the Ocean – A Feast Journey," introduces Taiwan's famous fishing festivals and unique marine creatures, with interactive elements triggering the gateway for students to soar through the ocean. The developed VR material of this study is illustrated in Figures 2 to 4.

Figure 2. Marine Education VR Materials - Level One 'Finding Fantastic Marine Creatures

Figure 3. Marine Education VR Materials - Level Two 'Marine Defense War

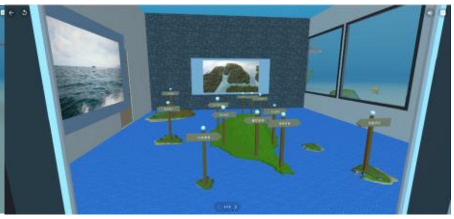


Figure 4. Marine Education VR Materials - Level Three 'Embarking on the Ocean - Feast Journey

Upon completion of the marine education VR materials, this study invited 33 experts for testing and evaluating it. The results were analyzed using descriptive statistics and a one-sample t-test (test value set at 3). The consolidated dimensional analysis results are presented in Table 2.

Table 2. Descriptive Statistics and One-Sample t-Test Summary of Expert Evaluation Results

Dimension	M	SD	$t_{(32)}$
Learning Value	4.45	.590	14.161^{***}
Course Inspiration	4.58	.482	18.779^{***}
Interface Operation	4.11	.737	8.673^{***}
Pre-assessment	4.22	.725	9.686^{***}
Post-assessment	4.49	.568	15.081^{***}

$^{***}p<.001$

After evaluation, experts have made suggestions for the marine education VR materials. This research has compiled the following three points of feedback:

(1) Objects within the level should not be purely decorative, such as the books on the bookshelf, which can be opened to view marine-related knowledge.

(2) When entering the level, the way to play is added to the operation mode description.

(3) The overall game design is thoughtful, with good intentions, and can interact with VR, which is a brand new experience for learners.

In summary, experts believe that this marine education VR curriculum holds significant educational value. They particularly emphasize its interactivity and the diverse learning scenarios, which enhance learning engagement and increase learning effect.

5. Conclusion

In this study, we developed a marine education VR material for elementary students using the ASSURE model. After evaluation, experts confirmed its effectiveness in enhancing learners' understanding of marine knowledge and conservation issues. The immersive VR technology provides a realistic experience, deepening comprehension of the ocean. Future teaching experiments will be conducted for examing its effect of VR in learners' attitudes, interests, and achievements, marine education sustainability concepts and emotional connections to ecological issues. These findings inform VR material development across disciplines.

References

Chen, C.-H., Chen, J.-H., & Li, Y.-W. (2022). Research Trends of Digital Media Design in Taiwan. *Journal of Chinese Economic Research, 20(1),* 19-31.

Luo, L.-X. (2018). Implementing competency-based marine education issues. *National Institute for Compilation and Translation, Electronic Journal of Educational Pulse, 13,* 1-5.

Wu, W.-C. V., Manabe, K., Marek, M. W., & Shu, Y. (2021). Enhancing 21st-century competencies via virtual reality digital content creation. *Journal of Research on Technology in Education, 55(3),* 388-410.

Ministry of Education (2020). Nation Ocean Policy White Paper.

Ministry of Education (2018). Curriculum Guidelines of 12Year Basic Education.

Using Whole-class Discussion to Promote Student Idea Evolution in a Blended Primary Science Lesson

Thi Thu Ha Nguyen, Lung-Hsiang Wong*, Peter Seow, Chew Lee Teo
National Institute of Education, Nanyang Technological University, Singapore
*lunghsiang.wong@nie.edu.sg

Abstract: *Student-Generated Ideas (SGI) is a socio-constructivist pedagogical approach that positions the development of student-generated ideas at the core of the learning trajectory alongside desired learning outcomes. This paper investigates the use of whole-class discussion as a pedagogical strategy to foster the evolution of SGIs in a blended primary science lesson in the Singapore context. Through a case study, we examine the design and implementation of a technology-enhanced SGI lesson, focusing on how students' ideas were generated and evolved, and the discursive practices employed by both the teacher and the students. Through qualitative data analysis, our findings uncover the richness of the SGIs, the teacher's adept orchestration of the discussion, the diverse cognitive processes exhibited by the students and the scaffolds employed by the teacher. The discussion extracts key design and enactment implications, which encompass, but are not limited to, the integral role of technology in supporting idea evolution beyond the lesson and the important role of the teacher in the effective use of whole-class discussion in SGI lessons.*

Keywords: Student-Generated Ideas (SGI), whole-class discussion, science teaching, computer-assisted learning

1. Introduction

Student-Generated Ideas (SGI) is a dynamic educational approach that positions student-generated ideas at the core of the learning trajectory (Wong et al., 2021; Lam et al., 2016). Emphasizing the pivotal role of eliciting ideas contributed by individual students or groups, SGI encourages diverse forms of student input, such as suggestions, questions, explanations, information, and artifacts that they bring to social learning environments, and extends the incorporation of these ideas both within the classroom and beyond, fostering a continuous advancement of these learning experiences. To achieve this objective, SGI promotes supportive learning settings, where students generate and evolve ideas, and draw conclusions as agentive and innovative participants, developing and fostering a habit of questioning and evaluating evidence in various learning contexts. Within this pedagogical framework, teachers' roles are shaped by their capacity to interpret and comprehend students' ideas and make informed decisions based on these evolving concepts.

This paper reports a case study, which was part of a larger intervention research project, to examine the role of whole-class discussion in fostering the development of SGIs within a blended primary science lesson in Singapore. The study outlines the design of the lesson flow and employs a qualitative approach to analyze the technology-supported classroom interactions, thereby distilling pedagogical considerations in designing and enacting this strategy in an SGI lesson. The role of technology in such an approach that places students' cognitive development in the center of the learning trajectory will also be examined. The study attempts to answer the following research questions: (1) How were the students' ideas generated and evolved? and (2) What were the discursive practices of the teacher and students?

2. Theoretical Background of Student-Generated Ideas

SGI pedagogical framework draws inspiration from various technology-enhanced socio-constructivist learning approaches, including seamless learning (Wong & Looi, 2011), knowledge building (Scardamalia, 2002), problem-based learning, maker, computational thinking, and others, which emphasize student-centered learning as both cognitive and social processes (Lam et al., 2016). This approach also aims to sensitize teachers to students' learning processes and interests (Goodson, 1998), avoiding the pure focus on reshaping or correcting students' perceptions to align with the established concepts within a particular discipline. Within the constructivist framework, SGI draws on the Conceptual Change Theory (Novak, 1977) to elucidate how individuals revise or transform their existing mental models, ideas, or understanding of concepts in response to new information, experiences, or educational interventions.

Central to conceptual change theory is the recognition that learners often hold misconceptions/ preconceptions (Novak, 1977) about certain concepts, even if those conceptions are inconsistent with canonical knowledge. Conceptual change occurs when learners encounter information or experiences that conflict with their existing mental models (Pintrich et al.,1993), prompting them to engage in a process of accommodation – re-evaluating and modifying their mental structures to align with the new information (Hewson & Hewson, 1984). This process may not occur instantly and can be influenced by the learner's cognitive readiness and motivation. Learning is not just a one-way transfer of information from teacher to learner; instead, it is important to address learners' existing ideas and misconceptions, and create opportunities for them to engage in the revision process. Hence, for a substantial paradigm shift, teachers need to ponder the nature of students' understandings and misconceptions, placing these aspects at the core of their teaching efforts (Goodson, 1998). Adhering to the existing teaching paradigm may perpetuate the concealed and superficial implementation of changing students' conceptions, treating their knowledge as if it could be effortlessly erased and replaced. Instead, teachers should regard students' 'raw' understandings not as shortcomings but as opportunities for individual or collaborative examination and reflection, thereby laying the foundation for transforming their concepts.

3. Whole Class Discussion and Classroom Interaction

Classroom interaction can be broadly categorized into authoritative and dialogic forms based on communicative function (Scott, 1998; Scott et al., 2005). The dialogic form of interaction, aligning with Bakhtin's concept of "internally persuasive discourse" and Van Zee and Minstrell (1997)'s "reflective discourse", was characterised by students' expression of their own thoughts and diverse perspectives. Authoritative talk, on the other hand, involves teachers sharing information, often in the form of factual statements, overviews, and instructional queries (Chin, 2007). While most scholars agree that a dialogic discourse would benefit students in collaboratively co-constructing knowledge (e.g., Wassermann, 2017), there were arguments that these two types of discourses should be flexibly incorporated in a "rhythm of the discourse" (Scott, 1998) to promote "productive disciplinary engagement" (Engle & Conant, 2002).

As teachers' discursive practices play a fundamental role in classroom talk, substantial research has investigated how teachers' questioning effectively leads to learning gains in students, in a process-product paradigm (e.g., Dantonio & Paradise, 1988) or in a socio-linguistics framework (e.g., Yip, 2004). The consensus was that teachers' questions in traditional lessons were generally information-seeking and aimed to evaluate students' knowledge (e.g., van Zee & Minstrell, 1997) while those in the constructivist lessons aimed for true dialogues, focusing on students' conceptual change by eliciting their ideas and engaging them in high-order thinking (Lemke, 1990). Such research on the teacher's productive discursive practices remains relevant with recent works such as Tang (2017) focusing on the meta-discourse of teachers, Chin (2006) detailing the types of teachers' feedback, and Chin (2007) and Soysal and Soysal (2022) proposing different typologies of teachers' questions. Studies which scrutinized the facilitation of whole-class discussions, however, were rare. Our study hopes to fill this gap, looking at the design, and the effectiveness of whole-class discussion as a pedagogical tool that helps develop SGI lessons.

4. Method

4.1. Research design and the context of the case study

This paper reports an exploratory case study to collect empirical data that would elucidate the fundamental principles of the SGI pedagogy. We collaborated with a science teacher and 37 consented fifth-grade high-progress students in a government school in Singapore. The teacher, Joe (pseudonym), had a decade of experience in teaching

Science at the Primary level. Joe described his students as possessing a solid foundational understanding of science knowledge, with the majority actively engaging in discussions and sharing their thoughts and ideas during lessons.

The study lasted five months in 2023. Initially, we conducted two one-hour professional development (PD) sessions with Joe and his colleagues in the Science department of the school to introduce the key concepts of the SGI pedagogy, and co-construct design and implementation principles for SGI lessons, such as (1) creating a well-connected learning space to support idea growth with the aid of technology, (2) focusing on idea improvement with student-generated questions and ideas, and (3) providing spontaneous teacher's scaffolding. Afterward, Joe and the research team co-designed and co-facilitated two blended lesson plans based on the SGI principles for the study. In this paper, we focus on the second SGI lesson on the topic of the dispersal methods of plants. The lesson design consisted of several learning activities; due to space constraints, we will focus on the segment of 28-minute whole-class discussion.

4.2. Lesson Design

The lesson was framed by a discussion question (DQ) set by Joe, "How did the plant get there on the top of the building?" By the end of the lesson, the students were expected to explain different plant dispersal methods. Yet they were not required to get to the same answer to the DQ. Padlet, an online e-sticky note tool, was employed as a virtual learning space to support students in idea sharing and evolution across classroom and home-based learning. The lesson flow is summarized as follows,

(1) Home-based pre-lesson activities: Joe posted the DQ and a real-life photo of a single plant growing on the top of a tall building on Padlet. The students posted their thoughts and questions related to the DQ, and then responded to each other's online posts.

(2) In-class lesson: Joe facilitated a 28-minute whole class discussion on the DQ. The students then worked in groups to discuss the possible characteristics of the seed/ the fruit of the plant, and post their group ideas on Padlet.

(3) Home-based follow-up activities: Joe provided two videos based on the student-posed questions arising during the discussion. The students posted their individual understanding on Padlet.

In what follows, the data analysis will uncover the generation of students' ideas during the whole-class discussion, examining both the discursive aspects of the teacher and the students.

5. Data Analysis and Findings

5.1. Research question 1: How were the students' ideas generated and evolved?

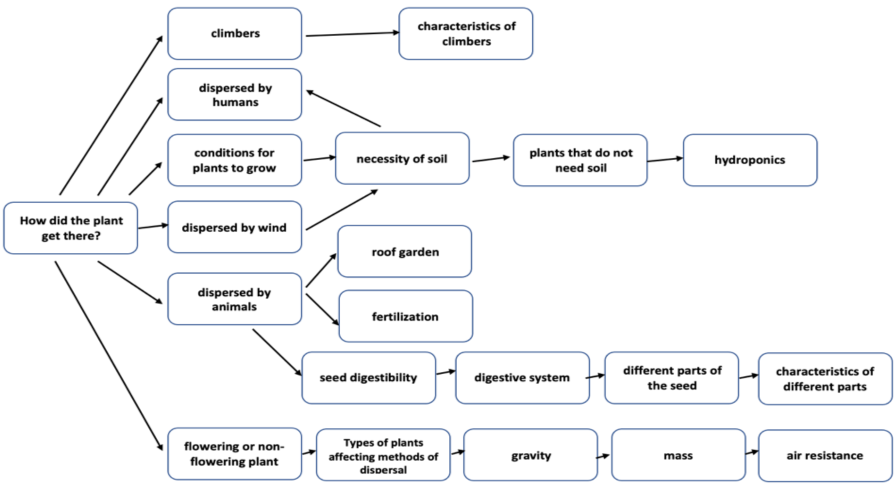


Figure 1. Student ideas brought up during the discussion

To answer research question 1, we first traced the themes brought up in the students' and teacher's responses to construct two diagrams of idea development of the entire discussion (Figures 1 and 2). While Figure 1 shows the diversity of the ideas brought up for discussion related to and developed from the initial discussion question, Figure 2 represents the engagement of students into the discussion. The purpose was to assess if the whole-class discussion was productive in generating students' ideas. In particular, Figure 1 represents different trajectories of idea development, which touched upon diverse scientific concepts such as digestive system, gravity, and mass. This example demonstrates how students generated ideas in the first trajectory:

S (Nis): *Are they climbers?*

T: *What are climbers?*

S (RD): *Plants with weak stems.*

S (LW): *This plant grows on a building, not a tree.*

S (SD): *This does not look like a climber.*

S (HY): *The stem is not too weak. Human planted it.*

The first trajectory involved a hypothesis that the plant might be a climber which started to climb its way up from the ground floor. This hypothesis led to a question about the characteristics of climbers. After some students recalled the characteristics of climbers, they compared them with the visual from the photo and no more ideas were further developed regarding the first hypothesis. Another hypothesis was raised (human planted it) and the students went on to discuss and develop that hypothesis. The arrows in the figure represent the connections among the ideas in such a way that the later idea was built up on the earlier one, which showed a process of collaborative idea evolution – the main objective of an SGI learning activity. Most of the threads in the figure consist of multiple responses built onto each other over time and these responses were relevant and stimulating for further discussions. This observation signals an assumption that students were listening and responding to one another's contributions with much thought.

Figure 2 summarizes the turns of the teacher and students that carried conceptual contents. Turns that functioned primarily as participation elicitation or disciplinary regulation were left out. The number in each box shows the sequence of the turn, with the student initials (of pseudonyms) in the brackets. The teacher's turns were without any initials. The arrows represent the causal relationship which can be translated as 'something leads to something'.

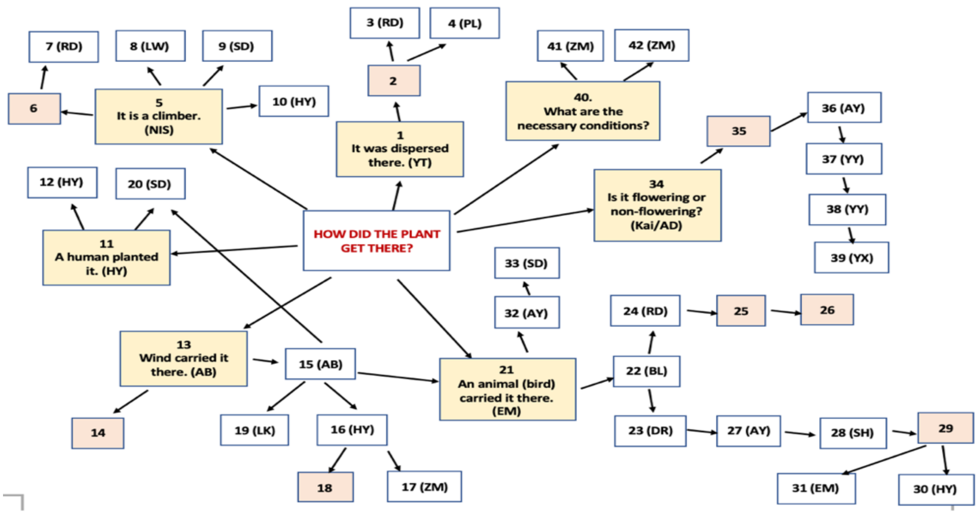


Figure 2. Students' engagement in idea generation

From the figure, we noticed that different students (19 out of 37) actively took part in the discussion and many of them contributed their ideas several times at different moments of the conversation; for example, HY (5 times), ZM (3 times), AY (3 times) and others. The linguistic data also showed that their contributions were substantial, expressed in long utterances and bringing up sophisticated content. One example is turn 31 (EM): "the covering of the seed should be quite hard, because if they want animals to disperse their seeds, the covering should be hard enough to go through the body of the animal".

Noticeably, Joe also brought up his ideas at different points, showing that he appeared an equal co-constructor of knowledge in this discussion. He did not just ask questions to facilitate the conversation, such as in turn 2 "What does 'dispersed' mean?" and turn 6 "What are 'climbers'?", but he also brought up discussion points such as in turn 25 "digested by whom? by human?" or turn 26 "would it be the same if the seeds were in the animal's body? are our digestive systems similar? is it possible that one is stronger than the other?".

Figures 1 and 2 apparently shows evidence of "productive disciplinary engagement" (Engle & Conant, 2002), as the students made substantial contributions to the topic under discussion, the ideas were coordinated, and they re-engaged and continued to be engaged in the topic over a long period of time (p.402).

5.2. Research question 2: What were the discursive practices of the teacher and the students?

To answer this research question, we worked on the transcript of the whole-class discussion and coded each of the turns on two layers (Table 1). On the first layer, we based ourselves on the triadic classroom sequence Initiation-Response-Feedback (IRF) (Lemke, 1990). On the second layer, we used open-coding to code the teacher's utterances and we used the revised Bloom's taxonomy (perception, conception and abstraction) (Soysal & Soysal, 2022) to code the students' utterances, bearing in mind the purpose of the classroom talk was to generate students' ideas. Thus, we wanted to see what role the teacher's utterance was doing in fulfilling this central purpose of the classroom talk.

Table 1. Example of data coding

		(I)	**(II)**
T	*Then, the question that she has was that, was there any soil there?*	I	Hypothesis Generating
S [AB]	*Maybe the soil was put there by some people.*	R	Abstraction: creating a hypothesis
T	*Ah, okay. She mentioned, she's not exactly sure if there was soil on top of the building. She just thought, she mentioned it could also be some people, go up to the top of the building, and pour some soil in there.*	F	Reporting/ revoicing
	Possible? Anyone has something to say? Yes? What? Ah, HY.	I	Soliciting Participation
S [HY]	*There must be some soil there. Cause if there's no soil, then the plant can't even grow there.*	R	Abstraction: supporting a hypothesis
T	*There must be some soil. If there's no soil, the plant can't even grow. Makes sense… makes sense…*	F	Repeating/ validation
	So what-	I	Eliciting Reasoning
S (ZM)	*Some plants, they can grow even without soil.*	R	Abstraction: evaluating
T	*Some plants, they can even grow without soil.*	F	Repeating

The result of the first layer coding showed that the classroom interactions clearly demonstrated the IRF pattern (Lemke, 1990), with Joe regaining the floor after each time a student gave a response. This pattern provided a clear structure for the discussion, and at the same time reflected orderliness and discipline; however, being well-structured, in this case, did not make the nature of the discourse more authoritative. In fact, Joe took control of the turn-taking but did not control the idea evolution process. A detailed examination of each turn within its contextual surroundings in layer two analysis would clarify this assertion.

5.2.1. The types of initiating questions that the teacher asked

We explored Joe's initiation questions as this discursive component played a crucial role in determining the nature of discourse during science instruction, influencing the type of cognitive processes that students engaged in as they co-constructed scientific meaning (Chin, 2007). Through the open coding process, there emerged the following types of questions used by the teacher (Table 2).

Table 2: Types of questions that the teacher asked

Question type	**%**	**Function**	**Examples**
1. Asking for Participation	15.79 %	encouraging students who haven't participated to share their thoughts	*Who has some thoughts on this?*

2. Asking for Alternative Perspectives	12.28 %	encouraging students to consider alternative viewpoints or explanations	*Agree or disagree? Or some of you have other thoughts?*
3. Asking for Existing Knowledge	7.018 %	seeking students' previous knowledge or ideas on the topic	*Have you seen plants that do not need soil to grow before?*
4. Asking for Clarification/ Elaboration	21.05 %	aimed at clarifying terms, concepts, or statements made by student	*What does the word disperse mean?*
5. Asking for Reasoning/ Evidence	15.79 %	prompting students to explain their reasoning or thought processes.	*Why do you say probably a person planted it there?*
6. Asking for Hypothesis Generation	26.32 %	prompting students to generate hypotheses or predictions.	*How in the first place was there soil on top of the building?*
7. Asking for Metacognition and Reflection	1.754 %	encouraging students to reflect on their thinking or the discussion	*So AH, after hearing from all your friends, what's your response?*

As evident from Table 2, Joe posed various types of questions to draw out students' ideas and stimulate constructive thinking. While question types 1 and 2 aimed to engage students and welcome different perspectives, the rest of the question types stimulated students' cognitive processes from perception (recalling and defining existing knowledge - type 3) to conception and abstraction (clarifying, explaining, reasoning, creating, and connecting knowledge - types 4, 5, 6 and 7). In particular, Joe's questions asking for hypothesis generation (type 6) accounted for a good proportion (26.32%), which expectedly contributed to students' generation of ideas. Also observed from the data, Joe often revoiced the questions raised by the students either earlier on the online platform or during the discussion, which cast himself more like a facilitator of the discussion than a powerful figure who questioned to assess students' knowledge, a typical feature of traditional classroom talk; for example, "so, AH's question was, even if it (the seed) is indigestible, as it goes through the digestive system of the animal, wouldn't the seed get so-called 'damaged' that it will not grow? Who has some thoughts on this?". We see Joe's attention to the students' questions highly productive as students' questions are valuable inputs in science learning, which help the teacher understand students' thinking process and possible gaps in conceptual knowledge (Chin & Osborne, 2008). Moreover, students tend to prefer exploring the questions that they themselves pose, which also arouses motivation, interest and even pride (Chin & Kayalvizhi, 2005).

5.2.2. The types of answers that the students gave

Table 3. Types of students' responses

Response type	**%**	**Description**	**Examples**
Perception (Lower cognitive level)	20.5%	Remembering, understanding (Defining terminology, recalling knowledge, observing)	*(Dispersed means) "carried"*
Conception (Mid cognitive level)	41.0%	Applying, analysing (Identifying and applying concepts in reasoning)	*I think the plant got there because the seeds of the plant got dispersed.*
Abstraction (Higher cognitive level)	38.5%	Evaluating, creating (Critical thinking and complex reasoning; creating hypothesis)	*So maybe a person could have just climbed up and plant the plant.*

Table 3 shows the proportions of the types of students' responses. Not surprisingly, their responses reflect a high degree of cognitive exercise with almost 80% of the responses falling in the mid and higher cognitive levels. Their responses demontrated deep thinking processes such as reasoning for an argumentation or creating a hypothesis. These results align well with the types of teachers' idea-triggering questions analyzed above, and also support the claims we made earlier on the diversified ideas that students brought up and developed, demonstrated in Figures 1 and 2.

5.2.3. The types of feedback that the teacher offered

Most of the time Joe either repeated, paraphrased, summarized or validated the students' ideas. At rare times, he quickly scaffolded the knowledge that they had learnt, e.g., "a hydroponics does not need soil to grow". There was no evaluation feedback, which involves assessing the correctness, accuracy, or quality of a student's response or work. Rather, validation feedback was found, which focused on acknowledging and affirming a student's contribution, regardless of whether it was completely correct or not. The main purpose of validation feedback was to create an encouraging learning environment and support an interactive – dialogic communication approach (Scott et al., 2005).

Apparently, the whole class-discussion showcased the dialogic nature of classroom discourse, with Joe asking various types of questions, stimulating and encouraging students' thinking and sharing. Joe actively invited and embraced students' ideas and inquiries, aiming to support their knowledge construction through inquiry-based learning. Notably, there was no trace of authoritative discourse, as Joe deliberately refrained from offering his viewpoint on the posed questions. The students, as a result, exhibited cognitive processes, indicating their active engagement in thought processes that not only enhanced their ideas but also transformed their understanding.

6. Discussion and Conclusion

The study's findings strongly support the notion that whole-class discussion serves as a potent pedagogical strategy for implementing SGI lessons, fostering the generation and evolution of ideas within a socio-constructivist learning context. The insights gained from this case study unveil several design strategies and implementation implications, highlighting the potential for leveraging whole-class discussions with technology-mediated activities before, during and after the session to enhance the SGI learning experience.

Regarding the design principle of "focusing on idea improvement" (Scardamalia, 2002), the discussion question posed to the students, in the first place, was intentionally open-ended and tied to real-life scenarios, deliberately devoid of a single correct answer. This approach aimed to encourage critical thinking and diverse perspectives among students. Secondly, students were afforded the flexibility to explore a variety of information sources before they participated in the whole-class discussion. Empowering students to take the lead in delving into theories on dispersal methods and leveraging real-life observations enriched their learning experience. Additionally, to "create a well-connected learning space to support idea growth", technology played a pivotal role in extending student idea development beyond physical boundaries, merging formal and informal learning experiences, across temporal and spatial dimensions (Wong & Looi, 2011). The Padlet forum also catered for different learning styles of the students, as some of them may feel more comfortable putting their thoughts in writing, or even visual texts, than speaking. In addition, Padlet allowed students to record and reflect on their idea development, which is believed to benefit their cognitive development.

In the enactment of SGI lessons, the study builds on Fuentes' (2011) argument in emphasizing the pivotal role of the teacher in fostering an environment conducive to collaborative learning and knowledge construction. The teacher in this case study adeptly facilitated discussions by employing a variety of thought-inducing questions, embracing different perspectives, steering away from evaluative judgments, acting as a knowledge co-constructor, and allowing for a more organic and student-driven exploration of ideas. Moreover, the teacher based himself on students' evolving ideas to make informed decisions on "spontaneous scaffolding" and continuous lesson design.

This exploratory case study has provided insights into the design, implementation, and effectiveness of whole-class discussion in the context of Student-Generated Ideas (SGI) learning, supported by the incorporation of technology. The study has elucidated the design and enactment strategies distilled from the lesson design and the qualitative data analysis of classroom interactions. The generalizability of findings and implications, however, is constrained by the focus on one single case. Future studies could delve into multiple cases across diverse contexts in order to refine and enhance the identified strategies and considerations.

Acknowledgments

This project is funded by MOE Education Research Funding (project ID: OER 17/21 WLH). Consent from the research participants was obtained based on ethics approval by Nanyang Technological University (IRB ref: IRB-2021-902).

References

Carlsen, W. S. (1991). Questioning in classroom: A sociolinguistic perspective. *Review of Educational Research, 61*(2), 157-178. https://www.jstor.org/stable/1170533

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International Journal of Science Education, 28*, 1315–1346.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44*(6). 815-843.

Chin, C., & Kayalvizhi, G. (2005). What do pupils think of open science investigations? A study of Singaporean primary 6 pupils. *Educational Research*, *47*(1), 107–126.

Chin, C., & Osborne J. (2008). Students' questions: a potential resource for teaching and learning science, *Studies in Science Education, 44*(1), 1-39. https://doi.org/10.1080/03057260701828101

Cohen, A., & Scardamalia, M. (1998). Discourse about ideas: Monitoring and regulation in face-to-face and computer-mediated environments. *Interactive Learning Environments, 6*(1-2), 93–113.

Dantonio, M., & Paradise, L.V. (1988). Teacher question-answer strategy and the cognitive correspondence between teacher questions and learner responses. *Journal of Research and Development in Education, 21*, 71–76.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*, 399–484.

Fuentes, S. Q. (2011). A lesson based on Student-Generated Ideas: A practical example highlighting the role of a teacher. *IUMPST: The Journal*. Vol 2 (Pedagogy).

Goodson, I. F. (1998). Towards an alternative pedagogy. In J. L. Kincheloe & S. R. Steinberg (Eds.), *Unauthorized methods: Strategies for critical teaching* (pp. 27-41). New York: Routledge.

Hewson, P. W., & Hewson, M. G. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science, 13*, 1-13.

Kincheloe, J. L., & Steinberg, S. R. (1998). Lesson plans from the outer limits: Unauthorized methods. In J. L. Kincheloe & S. R. Steinberg (Eds.), *Unauthorized methods: Strategies for critical teaching* (pp. 1-23). New York: Routledge.

Lam, R., Wong, L.-H., Gaydos, M., Huang, J., Seah, L. H., Tan, M., . . . Sandoval, W. (2016). Designing learning contexts using student-generated ideas. *Proceedings of International Conference of the Learning Sciences (ICLS) 2016* (pp.1090-1097), Singapore.

Lemke, J. L. (1990). *Talking science. Language, learning and values*. Norwood, NJ: Ablex.

Novak, J. D. (1977). *A theory of Education. Ithaca*. NY: Cornell University Press.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. *Liberal Education in a Knowledge Society, 97*, 67–98.

Scott, P. H. (1998). Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review. *Studies in Science Education, 32*, 45–80.

Scott, P. H., Mortimer E. F., & Aguiar, O. G. (2005). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Wiley InterScience*. DOI 10.1002/sce.20131

Soysal, Y., & Soysal, S. (2022). Exploring science teacher questions' influence on the students' talk productivity: A classroom discourse analysis approach. *Sage Open 2022*, 1-16. https://doi.org/10.1177/21582440221102433

Tang, K-S. (2017). Analyzing teachers' use of metadiscourse: The missing element in classroom discourse analysis. Wiley Online Library.

Van Zee, E. H., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education, 19*(2), 209–228.Wassermann, S. (2017). *The art of interactive teaching: Listening, responding, questioning*. New York and London: Routledge.

Wassermann, S. (2017). *The art of interactive teaching: Listening, responding, questioning*. New York and London: Routledge

Wong, L.-H., & Looi, C. K. (2011). What seams do we remove in mobile assisted seamless learning? A critical review of the literature. *Computers and Education, 57*(4), 2364-2381.

Wong, L.-H., Teo, C. L., Ogata, H., Song, Y., Wu, L., & Yu, F.-Y. (2021). Leveraging Student-Generated Ideas (SGI) to facilitate socio-constructivist learning and conceptual change: The roles of technology in SGI learning trajectories. *Proceedings of the 29th International Conference on Computers in Education* (Volume II, pp. 777-782), Bangkok, Thailand.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th Ed.). Los Angeles: SAGE

Yip, D.Y. (2004). Questioning skills for conceptual change in science instruction. *Journal of Biological Education, 38*, 76–83.

Effects of AI Functions in a Seamless Vocabulary Learning Environment for Young Learners

Yun Wen*, Xinyu Guo
First National Institute of Education, Nanyang Technological University, Singapore
* yun.wen@nie.edu.sg

Abstract: *While the potential benefits of AI in education have been widely acknowledged, there is a lack of research investigating how to leverage AI to promote language learning, especially among young learners. In this study, an AI-powered seamless vocabulary learning system – ARCHe – was designed and developed. The purpose of this paper is to report on the learning effectiveness of using ARCHe and explore the pedagogical affordances of AI to power seamless learning for young learners. The system has been implemented and evaluated in three government primary schools in Singapore, involving a total of 140 students and 6 teachers. The findings of the study indicate that the use of ARCHe significantly improves students' performance in Chinese character and vocabulary learning, regardless of their school contexts and prior language proficiency. Moreover, the results suggest that AI-enabled multimodal feedback may contribute to enhancing students' engagement in classroom-based collaborative learning activities. Given the absence of correlation among students' emotional engagement, Chinese language proficiency, and the quality and quantity of students' home-based work, future studies on AI-enhanced seamless learning, particularly those focusing on young learners, should delve into background variables that could impact students' learning engagement.*
Keywords: Seamless learning, Vocabulary learning, AI, Young leaners

1. Introduction

There is a growing recognition of the value of mobile-based language learning from the perspective of social constructivism, that extends language learning beyond the walls of the classroom to daily life (Hsu & Lin, 2022). In this sense, the notion of seamless learning, which highlights bridging separate learning contexts and better integrating everyday experiences with formal education, has received a boost in digital language learning (Godwin-Jones, 2018). Meanwhile, with the rapid development of Artificial Intelligence (AI), a thriving development direction of digital language learning has been to integrate mobile-based language learning and AI techniques (Li & Lan, 2022). More recently, Deep Neural Networks and big data have led to a significant development of AI in education. AI techniques, such as chatbot with natural language processing that enables communication between machine and individuals, or automatic speech recognition and automatic pronunciation evaluation, have been used to facilitate online language learning (Fu, Gu, & Yang, 2020).

On this premise, we developed an AI-powered seamless vocabulary learning system named ARCHe. The ARCHe-based learning activities were designed in alignment with the Chinese language curriculum for primary schools in Singapore. The purpose of this study is to investigate how diverse AI functions embedded in ARCHe impact students' learning engagement and, consequently, their performance in Chinese character and vocabulary learning. The study seeks to provide insights for learning designers, educational practitioners, and policy implementers, aiding them in understanding the potential of AI in language learning and its implementation in primary schools. Below are the two research questions to be addressed in the study.

RQ 1. To what extent does the seamless Chinese character learning powered by the ARCHe system help students improve their Chinese character learning?

RQ 2. How different perspectives of AI-powered ARCHe system affordances influence young students' learning engagement?

2. Literature Review

AI-enabled automatic feedback or recommendations are increasingly used to scaffold learning in mobile-based language learning environment (Li & Lan, 2022). For instance, Lee et al. (2023) developed an AI-powered learner-generated-context-based learning system to promote learning autonomy of secondary school students' English as foreign language learning. Hsu et al.'s study (2023) evidenced that Grade 3 English as foreign language learners could have greater development of self-regulation and lower learning anxiety while participating in the learning activity with AI-supported image recognition in terms of their behavioral data. Despite the potential benefits of AI-supported language learning, it has not discerned on its effectiveness on students' academic performance among all students (Wang, et al., 2023). Booton et al. indicated in their review study (2023), a scarcity of experimental research examining the specific impacts of mobile application features on language learning among young learners, despite some mobile app features demonstrating support for language learning aspects. While AI-enabled automatic feedback or recommendations are increasingly used to scaffold language learning, little is understood about how different AI features might affect language learning, particularly among young learners.

3. ARCHe-enabled Seamless Vocabulary Learning

The ARCHe system composes home-based individual activity and classroom-based collaborative activity. In the home-based activity, students are required to complete foundational tasks (1. character composition, 2. pronunciation, 3. handwriting, 4. speaking) and (2) creation tasks (forming words, taking photos of the surroundings, and creating sentences accordingly). In the classroom-based collaborative activity, students are asked to do scenario-based tagging and sentence-making as a group and peer review other groups' work.

The home-based individual activity includes foundational tasks and creation tasks. After logging into the system, students are proceeded to follow the instructions provided by ARCHe for the 4 steps of foundational tasks. They need to select appropriate radicals to compose the target Chinese character, select the correct character by the given Pin Yin, and handwrite and read out the target characters. The first and second steps of the activity are both multiple-choice questions. The design of the third and fourth steps is intended to assess and practice students in the handwriting of the target character and their ability to pronounce it correctly. In Step 3, ***the handwritten Chinese characters submitted by students can be automatically recognized and assessed by the system***. In Step 4, ***automatic feedback is provided based on the accuracy of students' pronunciation***.

Figure 1. The creation task of the home-based individual activity in ARCHe

Students will proceed to the creation task after completing the foundational task. The creation task requires students to create the individual artifacts in three steps (Figure 1). Firstly, students are required to form a short phase using the target character. Secondly, they need to upload an appropriate image for the character. It could be a drawing, photograph, or an image from the internet. Lastly, students are required to construct a sentence that contains the short phase under the picture's context.

Additionally, the ARCHe App designed for teachers can be used to monitor students' engagement in home-based individual activities. Another important function of the teacher's app is to approve the content of students' artifacts and automatically assess the quality of students' sentences. Before student artifacts are published on the forum, they must go through a teacher approval process. Meanwhile, the AI-powered ARCHe system ***automatically evaluates the students' sentences*** and provides recommended scores to teachers. Then, teachers decide to either approve or disapprove the created artifacts. If an artifact is deemed inappropriate or requires improvement, the teacher should provide reasons for disapproval or suggestions for improvement. This feedback from the teacher is then shared with the student, who is expected to revise their work accordingly and resubmit it for approval.

During the classroom-based collaborative activity, students are encouraged to work together in selecting a scenario and labeling an area in the given scenario picture and then construct a sentence to describe it. As students submit group artifacts, the system will extract keywords and recommend related student-generated artifacts in their home-based learning activities for reference. Students can incorporate the sentences they generated previously and apply them in new scenarios. They are also encouraged to refine or create new sentences based on the recommended artifacts. Figure 2 shows an example. “This kitten is quite frightened.” is the sentence made by a group. “kitten” and “frightened”, these keywords of the sentence are segmented and extracted automatically by lexical segmentation. As the keyword “kitten” has been used in students’ home-based learning activities, the corresponding artifacts are recommended by the system. Then students can decide by themselves if they would like to expand or refine their group sentence based on the recommended sentence or not. The recommended artifacts not only provide students with sentence examples, but also enrich the context in which the target word can be used.

Figure 2. Automatic recommendations to enrich the contexts of vocabulary usage

4. Research Design

4.1 Participants

The ARCHe system was implemented with 140 students and 6 teachers in 3 primary schools in Singapore. Home-based learning activities and classroom-based learning interventions were successfully conducted in these three schools for two terms (8 to 10 weeks, the second semester of primary 2), covering the default 4 ARCHe lessons. Each face-to-face ARCHe class took approximately 60 minutes, and before each class, students had two weeks to do the home-based learning activities. During the lessons, students from 6 classes participated following the same procedures.

4.2 Instruments

Three kinds of research instruments were used in this study. The first instrument was a test for assessing primary 2 students' students' knowledge and structural awareness of Chinese characters and vocabulary. The test was developed by the research team, referencing the tests created by Hung and Fang (2006) and the test created by Chen et al. (2013). The original test has been modified by considering the students' Chinese language proficiency levels, and the test was validated by a primary school master teacher. The test comprised thirty questions with a total score of 30. Pre-and post-tests were administered, each lasting 5 minutes, before and after students used ARCHe.

The second instrument was a questionnaire developed to assess students' learning engagement from the emotional perspective and their perceptions towards the AI feature of ARCHe. Students' emotional engagement and their perceptions towards the AI features were investigated by a post-survey. Three question items were developed for identifying students' perceived enjoyment, which can reflect their emotional engagement. Four question items were designed to investigate their perceptions towards the AI features. Each item was assessed using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The Cronbach's alpha for the scale of emotional engagement was 0.784. Since the questions regarding students' perceptions towards specific AI features of ARCHe were straightforward, we employed a single question item to evaluate each AI feature.

In this study, students' learning engagement was investigated by considering emotional and cognitive aspects. Students' cognitive engagement was investigated by the quantity and quality of the artifacts they created in in home-based learning activities and classroom-based learning activities separately. The relevant indicators for both activities are: (1) the number of artifacts; (2) the length of sentence; and (3) the complexity of sentence. Thus, the third instrument of this study was the criteria used to assess the quality of student-generated sentences by measuring their length and complexity. Sentence length is considered large-grain, length features and has been the most common approaches to measuring syntactic for the quality of L2 writing. In this study, the length of sentence was measured by the number of words of a sentence and averaged them across sentences (MLU-words). The MLU-words measure, often found high correlation with MLU-morphemes, is a common measure in the literature to gauge monolingual and bilingual language development and children's morpho-syntactic change over time (Meisel, 2011). Additionally, the measure of textual lexical diversity (MTLD) was used in this study to measure the complexity of sentences. MTLD is a strong indicator of lexical diversity, as it analyses the lexical diversity of a text without being impacted by the length (Fergadiotis et al., 2015).

4.3 Data Analysis

We conducted a paired t-test based on students' pre- and post-test results to investigate the extent to which ARCHe-supported seamless learning contributed to students' Chinese character and vocabulary acquisition. Furthermore, we compared the pre- and post-test results for each class of students, considering potential variations in ARCHe usage influenced by teacher facilitation and class culture. Considering the difference of students' language proficiency among three schools, we also conducted one-way ANCOVA by considering school effects. To examine the effect of AI features on students' learning engagement, multiple regression analysis was used, with the measure of the AI features as the independent variables and learning engagement as dependent variable. Learning engagement was investigated by considering both emotional engagement and cognitive engagement.

5. Findings

As shown in Table 1, a significant improvement can be found after the intervention in terms of the pre-and post-test results (t = 3.052; p <.001). Nevertheless, significant improvement cannot be observed in all the classes (Table 2). Even within the same school, such as School B, Class 1 shows significant improvement, while Class 2 does not. We also did an analysis of covariance (ANCOVA) to examine the significance of the mean differences among the 3 schools. The post-test score was used as the dependent variable and the pre-test score was used as the covariant. The homogeneity of the regression coefficients was examined and the result (F = 2.018; p = 0.137) did not reach the level of significance. Then, ANCOVA was performed, and the results indicate no significant difference in learning outcomes among the schools, F (2, 133) = 1.912, p = 0.152 (as shown in Table 3). The findings suggest that, to some extent, the different ways teachers employ in implementing the ARCHe-based activities may exert a more significant influence on the variation in system effectiveness, as compared to the school's effect.

Table 1: Comparison between pre-and post-tests for all the participating students

Test	**No. of students**	**Estimated Marginal Means**	**SD**	***t***	***P***
Pre-test	133	14.323	7.309	3.052	<.001**
Post-test	133	15.977	7.674		

Table 2: Comparison between pre-and post-tests for each class

School	**Class**	**Test**	**No. of students**	**Estimated Marginal Means**	**SD**	***t***	***P***
School B	Class 1	Pre-test	18	9.000	3.926	4.533	<.001**
		Post-test		14.722	7.427		
	Class 2	Pre-test	21	11.905	8.414	-1.107	.141
		Post-test		10.667	7.806		
School X	Class 3	Pre-test	20	11.850	3.453	3.857	<.001**
		Post-test		16.150	6.089		
	Class 4	Pre-test	17	12.824	4.231	3.182	.003**
		Post-test		16.118	5.862		
School T	Class 5	Pre-test	29	19.207	8.046	.615	.272
		Post-test		20.103	7.350		
	Class 6	Pre-test	28	17.179	7.029	-.870	.196
		Post-test		16.286	8.009		

Table 3. Descriptive statistics of students' pre- and post-test scores and ANCOVA on 3 schools

School	No. of students	Pre-test		Post-test		ANCOVA			
		Mean	SD	Mean	SD	Mean adjusted	SD	*F*	*P*
B	39	10.564	6.805	12.539	7.806	15.171	.973	1.912	.152
X	37	12.297	3.807	16.977	5.903	17.554	.966		
T	57	18.211	7.566	18.223	7.851	15.606	.826		

The AI features on students' perceived usefulness of ARCHe was examined by regression analysis, with the measure of students' perceptions towards AI features as the independent variable and their perceptions towards emotional engagement ARCHe as the dependent variable. The Cronbach's alpha reliability analysis shows that students perceptions towards emotional engagement in ARCHe-based activities is 0.784. As shown in Table 4, the post-survey data revealed positive perceived enjoyment of ARCHe-based learning among students (M = 4.071, SD = .986). Additionally, students exhibited a positive attitude towards the usefulness of the embedded AI features, with the highest recognition of the usefulness of automatic feedback towards pronunciation (M = 4.023, SD = .964) and followed by the usefulness of automatic recommendations (M = 3.877, SD = 1.049).

As shown in Table 5, students' perceptions towards AI features were significant predictors of their emotional engagement in ARCHe activities (F [4, 118] = 15.361, p < .001, R2 = 0.342). The analysis also met the assumptions of multicollinearity given that the tolerance value ranges from 0.714 to 0.798 while the value inflation factor (VIF) ranges from 1.00 to 2.01, indicating that multicollinearity is not a problem in this analysis. The findings suggested that students' perception toward the function of recommendation had a positive effect on students' emotional engagement (β

=0.313, $p < 0.001$). Students' perception toward the function of automatic feedback towards pronunciation also had a positive effect on students' emotional engagement ($\beta = 0.21$, $p < 0.05$). However, the results did not find a positive influence of students' perception toward handwriting ($\beta = .12$, p =1.56) and automatic marking ($\beta = .164$, p =0.57).

Table 4. Descriptive statistics about the scales of post-survey

Scales	N	Mean	SD
Perceived enjoyment	127	4.071	0.986
Usefulness of automatic feedback towards pronunciation	129	4.023	0.964
Usefulness of automatic feedback towards handwriting	129	3.876	1.090
Usefulness of automatic scoring for artifacts	131	3.847	1.026
Usefulness of automatic recommendations	130	3.877	1.049

Table 5: Results of multiple regression of students' perceptions towards AI functions on their emotional engagement

Model	*SS*	*Df*	*MS*	*F*	*p*
Regression	39.151	4	9.788	15.361	<.001**
Residual	75.186	118	.635		
Total	114.338	122			

IV = Students' perceptions towards AI functions and DV = Students' emotional engagement

The multiple regression was used to investigate the effect of the perceived AI features on cognitive engagement in the home-based learning activities and classroom-based learning activities. In this study, students' cognitive engagement was investigated by the quantity and quality of the artifacts they created in home-based learning activities and classroom-based learning activities separately. As shown in Table 6, the findings revealed that students' perceived usefulness of AI features is a significant predictor of the length of sentences they made in the classroom-based learning activities (F [4, 112] = 4.145, $p < .01$, R2 = 0.133). By further analysing which parts of AI feature predicted students' cognitive engagement, the results showed that students' perceptions toward recommendation significantly predicated their cognitive engagement in the dimension of the length of sentences ($\beta = -.368$, $p < 0.001$). As shown in Table 7, the results indicated that students' perceived usefulness of AI features was a significant predictor of the complexity of sentences they made in the classroom-based learning activities (F [4, 112] = 3.127, $p < .05$, R2 = 0.104). Additionally, the findings suggested that that students' perceptions toward automatic feedback on handwriting significantly predicated their cognitive engagement in the dimension of the complexity of sentences ($\beta = 2.000$, $p < 0.05$).

Table 6: Results of multiple regression of students' perceptions towards AI functions on the length of sentences

Model	*SS*	*Df*	*MS*	*F*	*p*
Regression	1461668.030	4	365417	4.145	.004**
Residual	9521978.057	108	88166		
Total	10983646.087	112			

IV = Students' perceptions towards AI functions and DV = the length of sentences

Table 7: Results of multiple regression of students' perceptions towards AI functions on the complexity of sentences

Model	*SS*	*Df*	*MS*	*F*	*p*
Regression	112.343	4	28.086	3.127	.018*
Residual	969.938	108	8.981		
Total	1082.281	112			

IV = Students' perceptions towards AI functions and DV = the complexity of sentences

These results underscore the value of automatic recommendations in enhancing students' learning enjoyment. Yet, the findings suggest that students find the recommendation feature more useful, the linguistic complexity of their sentences become simpler. This may indicate that while students find the feature useful, they have no sufficient awareness to consistently improve the recommendation works. As observed, students using this function might be inclined to directly adopt or refine sentences from others, without necessarily enriching the content of group sentences within the ARCHe context. To address this issue, multimodal feedback may be an effective means. Alternative non-textualized automatic feedback methods, including illustrations, pictures, videos, and animations, have evolved recently. Studies have explored visualized feedback forms as AI algorithms have progressed, such as the application of image-to-text generative AI to enhance vocabulary acquisition (Shadiev et al., 2020; Hsu et al., 2023). These studies illustrate that students engage with multiple forms of feedback for extended periods compared to traditional feedback methods. Future studies may pay attention to how AI-powered multimodal feedback/recommendations can be used in learning systems to promote more effective interaction, regulation, and reflection among young children at group level.

Another noteworthy finding is that the degree to which students find the automatic feedback on handwriting function useful is positively correlated with the complexity of their language use in group activities. This indicates that automatic handwriting feedback has a positive impact on students' vocabulary mastery. However, this correlation is not evident in home-based individual activities. Compared to classroom-based activities, students' performance in home-based activities is influenced by too many factors. Therefore, a correlation like this is not found among students' emotional engagement, students' Chinese language proficiency, and the quality and quantity of students' home-based work. Future studies can devote more attention to exploring the background variables that might impact students' learning engagement in seamless learning for young learners.

6. Conclusion

This study demonstrated promising outcomes in the realm of Chinese character and vocabulary through the usage of ARCHe. It also evidenced positive attitudes among students towards the ARCHe-based learning experience and its 4 AI features. Furthermore, the findings revealed that students' perception toward the AI function -- automatic recommendation and automatic feedback towards pronunciation -- positively influenced their emotional engagement. Students' perceptions of automatic recommendation significantly predicated their cognitive engagement in the dimension of the length of sentences, and their perceptions of automatic feedback on handwriting significantly predicated cognitive engagement in the dimension of the complexity of sentences. The study's findings underscored the necessity of improving forms of automatic recommendation to encourage students to continuously enhance the substance of their output. It suggested that AI-enabled multimodal feedback may help to enhance students' engagement in the classroom-based collaborative learning activities.

This study has a few limitations that should be addressed in future research. Firstly, there was no control class when investigating the impact of ARCHe on students' language learning. The next stage of ARCHe's research will involve within-school controls groups to assess the system. Secondly, the assessment of students' cognitive engagement relied on the quantity and quality of student-generated artefacts. Additional indicators such as students' interactions in completing tasks, could be taken into consideration when investigating their learning engagement. Thirdly, students' background factors, such as their home-spoken language and parental support while using ARCHe, may affect their usage of the system. The following stage of study should take these factors into account and further explore how they affect students' learning engagement and performance. The findings of future studies will provide insights into implementing the system like ARCHe more effectively in different school contexts.

Acknowledgements

This study is funded by Ministry of Education, Singapore, with project reference numbers: DEV 05/21 WY and ERFP 05/23 WY. The views expressed in this paper are the author's and do not necessarily represent the views of the host institution.

References

Booton, S. A., Hodgkiss, A., & Murphy, V. A. (2023). The impact of mobile application features on children's language and literacy learning: a systematic review. *Computer Assisted Language Learning*, *36*(3), 400-429.

Chen, H. C., Hsu, C. C., Chang, L. C., Lin, Y. C., Chang, K. E., & Sung, Y. (2013). Using a radical-derived character e-learning platform to increase learner knowledge of Chinese characters. *Language Learning & Technology, 17*(1), 89–106.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109.

Fu, S., Gu, H., & Yang, B. (2020). The affordances of AI-enabled automatic scoring applications on learners' continuous learning intention: An empirical study in China. *British Journal of Educational Technology, 51*(5), 1674–1692.

Godwin-Jones, R. (2018). Contextualized vocabulary learning. *Language Learning & Technology, 22(3)*, 1–19.

Hsu, H.-T., & Lin, C.-C. (2022). Factors Influencing University Students' Intention to Engage in Mobile assisted Language Learning through the Lens of Action Control Theory. *Educational Technology & Society, 25*(4), 29–42.

Hsu, T. C., Chang, C. H., & Jen, T. (2023). Artificial Intelligence image recognition using self-regulation learning strategies: effects on vocabulary acquisition, learning anxiety, and learning behaviours of English language learners. *Interactive Learning Environments*, 1–19. https://doi.org/10.1080/10494820.2023.2165508

Hung, L. Y. & Fang, J. Y. (2006a). *Test on Semantic Radicals*. Taipei, TW: Special Education Unit, Ministry of Education.

Lee, D., Kim, H., & Sung, S. (2023). Development research on an AI English learning support system to facilitate learner-generated-context-based learning. *Educational Technology Research and Development*, *71*, 629–666

Li, P., & Lan, Y. (2022). Digital Language Learning (DLL): Insights from Behavior, Cognition, and the Brain. *Bilingualism: Language and Cognition, 25*(3), 361-378.

Meisel, J. M. (2011). Bilingual language acquisition and theories of diachronic change: Bilingualism as cause and effect of grammatical change. *Bilingualism: Language and cognition*, *14*(2), 121-145.

Shadiev, R., Wu, T., & Huang, Y. M. (2020). Using image-to-text recognition technology to facilitate vocabulary acquisition in authentic contexts. *ReCALL*, *32*(2), 195–212.

Wang, X., Liu, Q., Pang, H., Tan, S. C., Lei, J., Wallace, M. P., & Li, L. (2023). What matters in AI-supported learning: A study of human-AI interactions in language learning using cluster analysis and epistemic network analysis. *Computers & Education, 194*, 104703.

Enhancing Language Learning: A Comparative Study of 360-Degree Video Technology and Traditional Video Technology in EFL Speaking Evaluation and Feedback

Rustam Shadiev[1*], Jiawen Liu[2], Nurassyl Kerimbayev[3], Narzikul Shadiev[4], Mirzaali Fayziev[4], Sang Min Lee[5], Zhanargul Beisembayeva[6], Roza Zhussupova[6], Natalya Turkenova[7] and Asror Muhamedov[8]
College of Education, Zhejiang University, China
[2]School of Education Science, Nanjing Normal University, China
[3]Faculty of Information Technology, Al-Farabi Kazakh National University, Kazakhstan
[4]Uzbekistan-Finland Pedagogical Institute, Uzbekistan
[5]College of Education, Korea University, Korea
[6] Faculty of Philology, L.N. Gumilyov Eurasian National University, Kazakhstan
[7]Zhetysu University, Kazakhstan
[8]Faculty of Social Sciences, Alfraganus University, Uzbekistan
[*] rustamsh@gmail.com

Abstract: *The study investigates the impact of 360-degree video technology (360VT) in computer-assisted language learning, particularly in assessing learners and providing feedback. Comparing 360VT with traditional video technology (TVT), the research involved university students who created videos in English as a Foreign Language (EFL) course. During the study, the videos were evaluated by peer students, and feedback was provided for revisions. While initial knowledge levels were similar, post-study assessments showed the 360VT group outperformed the TVT group and they received more detailed feedback. The findings highlight 360VT's potential to enhance language learning through content creation, evaluation, and feedback, recommending its integration into educational practices. Future research directions are also discussed.*

Keywords: 360-degree video technology, traditional video technology, computer-assisted language learning, evaluation, feedback.

1. Introduction

Achieving proficiency in speaking is a fundamental aspect of language acquisition, requiring active engagement from learners to effectively communicate and comprehend in real-time interactions (Hwang et al., 2022; Kahng, 2019). According to cognitive theories, effective feedback is crucial for this, as it should be detailed instructively aiding learners in correcting and enhancing their understanding (Fan & Yan, 2020; Rodríguez-González, 2018). The research underscores the importance of nuanced feedback in elevating the learning experience (Barrot, 20210; Jiang et al., 2020; Krause et al., 2009; Narciss and Huth, 2006; Wisniewski et al., 2020).

Situated evaluation, which evaluates performance within specific, real-world contexts, is renowned for generating impactful feedback (Bellocchi et al., 2016; Thompson & Alba-Juez, 2014). Traditional classrooms, however, often face limitations like time constraints and a lack of in-depth understanding of students' descriptive work, which can restrict the depth of feedback provided (Liu et al., 2023). Employing video technology (e.g. traditional video) in situated evaluation can effectively document and evaluate learner performance in context, enhancing the evaluator's comprehension of the learning scenario and student interactions.

Feedback, defined as critical information about one's performance or understanding aimed at improvement (Hattie & Timperley, 2007), is a significant driver in the educational process (Dressler et al., 2019; Hattie, 2009). Evaluation encompasses two primary forms: peer and teacher evaluation (Tian & Zhou, 2020). In the context of the present study, we focus on peer evaluation. Peer evaluation is an educational strategy where students actively assess and provide constructive feedback on their peers' work. This process not only involves critiquing peers' work but also receiving insights about one's strengths and areas for improvement (Shayakhmetova et al., 2020; Tian & Zhou, 2020). The essence of peer evaluation lies in engaging learners to critically assess the quality of their peers' work against set criteria (Spiller, 2012). This method is beneficial for enhancing understanding, promoting reflection on personal performance, and fostering motivation by enabling learners to compare their work with that of their peers (Adachi et al., 2018). Furthermore, peer feedback encourages a culture of self-assessment and mutual evaluation, steering learners toward greater independence in their educational journey (Tang & Rich, 2017).

In recent times, 360-degree video technology (360VT) has emerged as a transformative force in language learning, acclaimed for its capacity to create immersive, lifelike environments that enrich the learning and teaching experience (Kaplan-Rakowski et al., 2023; Shadiev et al., 2024; Shadiev et al., 2022; Shadiev et al., 2020; Shadiev et al., 2021; Shadiev & Zhou, 2023; Suvorov & Gruba, 2023; Xie et al., 2021). Celebrated for its ability to break down spatial and temporal barriers, 360VT significantly bolsters engagement and authenticity in learning contexts and evaluative settings (Smith & Townsend, 2021).

360-degree video, also known as omnidirectional or spherical video, captures a panoramic sphere with the viewer centrally placed within this immersive realm (Kaplan-Rakowski et al., 2023; Shadiev et al., 2022; Shadiev et al., 2020; Shadiev & Zhou, 2023; Taylor & Layland, 2018). This innovative approach offers viewers the autonomy to navigate and observe their environment in a complete 360-degree arc, presenting a dynamic, multidimensional viewing experience, as opposed to a fixed, singular viewpoint (Lan, 2020; Suvorov & Gruba, 2023).

Two pivotal elements define 360-degree video: immersion and presence (Shadiev et al., 2021). Immersion signifies the deeply engaging experience of being part of a rich, lifelike virtual world. This level of engagement is instrumental in sparking curiosity and enriching the educational journey (Nurym et al., 2020). Alternatively, presence is the psychological state of feeling within a specific locale or environment, transcending physical location. Within virtual settings, presence denotes the predominance of computer-generated reality over one's actual physical environment (Kerimbayev et al., 2022). Research indicates that immersion not only elevates language learning outcomes but also intensifies affective engagement, interaction with visual and auditory content, and motivational levels. Therefore, this study postulates that evaluators, deeply immersed in such environments, will engage more thoroughly in the evaluative process, culminating in a more detailed, profound and insightful evaluation experience.

Several merits of 360-degree video have been identified by researchers (Shadiev et al., 2022; Shadiev & Zhou, 2023). Firstly, it provides viewers the liberty to explore and focus on distinct elements within the video by simply altering their viewpoint, offering a full-circle perspective (Walshe & Driver, 2019). Secondly, when experienced through head-mounted displays (HMDs), immersive videos present a level of vividness superior to traditional videos (Alemdag & Yildirim, 2022; Breves & Heber, 2019; Shadiev & Yu, 2022; Xie et al., 2021). Thirdly, the three-dimensional, ultra-realistic nature of the 360-degree video (Barić et al., 2020; Frisby et al., 2020) enhances the viewer's sense of immersion and presence, focusing their attention on the depicted objects, scenes, and situations. Lastly, 360-degree video captivates viewers, fostering positive attitudes and perceptions, and is often described as engaging, immersive, and stimulating (Song, 2019).

Despite the acknowledged enhancement 360VT brings to the educational domain with its dynamic, immersive depiction, its capability to augment evaluation and feedback mechanisms remains untapped. This research seeks to bridge this gap by contrasting the implications of 360VT with those of traditional video technology (TVT) in an English as a Foreign Language (EFL) setting. The study meticulously examines how each technology influences learners' speaking proficiency, delves into the quality and impact of feedback provided, and evaluates the evaluators' interaction with 360VT, considering its applicability, advantages, and potential drawbacks. The crux of this investigation centers on determining if the choice of technology—360VT versus TVT—markedly impacts the outcomes of EFL speaking assessments.

360VT, in comparison to TVT, is postulated to replicate the nuances of the learning context more accurately. As evaluators engage with 360-degree videos, they are expected to experience a heightened level of immersion, engagement, and authenticity, coupled with a comprehensive view of the recorded scenarios (Huang et al., 2019; Peterson, 2018). This study hypothesizes that such engagement with 360-degree videos may enrich evaluators' experiences, leading to more detailed and constructive feedback. This, in turn, could prove advantageous for learners, guiding them to pinpoint and amend inaccuracies in their recorded submissions. Nevertheless, it is noteworthy that research specifically focusing on the efficacy of 360VT in evaluation and feedback contexts is scant. It remains unclear whether 360VT outperforms other technologies, such as TVT, in these domains. This study aims to fill this research gap.

For this purpose, an EFL learning activity was organized, utilizing either 360VT or TVT. Language learners crafted and recorded videos, which were subsequently evaluated by peers, with feedback being provided. Learners then leveraged this feedback to refine their content. The research delves into the impact of the evaluation and feedback offered in both 360VT and TVT settings on learning outcomes, investigating disparities in the details of feedback between the two conditions. Moreover, given the novel application of 360VT in evaluation and feedback, the study explores evaluators' subjective experiences with this technology.

The pivotal research question posed is: Do learners receiving evaluation and feedback in 360VT and TVT settings perform differently in EFL speaking tests?

2. Method

This study established two conditions: (1) the 360-degree video technology (360VT) intervention condition for evaluating and providing feedback on student work, and (2) the control condition using traditional video technology (TVT) for similar purposes. Employing a quasi-experimental, mixed-method approach, the research aimed to assess the impact of these distinct feedback environments on English as a Foreign Language (EFL) speaking scores, exploring the variance in feedback and evaluation. Additionally, it investigated participants' perceptions of their feedback and evaluation experiences within the 360VT framework.

Fifty-two female postgraduate students from a public normal university participated in the study. All were non-English majors with confirmed English proficiency and a solid foundation in English oral skills, ensuring a competent participant pool. The study was part of an elective English course focusing on enhancing EFL speaking proficiency, particularly in describing diverse elements and elevating speaking abilities across various dimensions.

Participants were divided into experimental (360VT) and control (TVT) groups, each comprising twenty-six students. The experimental process involved random group allocation, pre-testing, task assignments based on an online learning platform, direct peer evaluation training, peer evaluation, feedback implementation, and post-testing to measure EFL speaking skills.

The participants engaged in a structured learning activity that encompassed several key steps. Initially, students independently studied content related to the study's topics, provided by instructors through an online platform. Researchers also guided student learning, clarifying learning objectives and tasks, explaining the EFL speaking rubric (Huang & Gui, 2015), and offering necessary support. The second step involved students recording a video, either in 360-degree format or traditional style, where they verbally described a specific topic. This exercise aimed to apply classroom-acquired knowledge in real-world settings like their campus or local community, places with which the students were familiar. This familiarity with the environment, coupled with the knowledge gained in class, ensured the tasks were both relevant and manageable. The length of the videos ranged from 3 to 10 minutes. In the third phase, students reviewed and evaluated their peers' videos using the speaking evaluation rubrics (Huang & Gui, 2015), providing detailed written feedback on areas for improvement. The instructor, who was an experienced EFL teacher with over a decade of experience in evaluation and feedback, reviewed all feedback on the videos to ensure it was correct and acceptable. As the students were relatively inexperienced in this process, they received comprehensive instruction and training on the evaluation rubrics and feedback provision. This training included textual instructions, guidance from study instructor, observation of teacher modeling for effective feedback, and practical experience in evaluating peer content and providing relevant feedback. The instructor closely monitored these hands-on sessions, offering comments and suggestions to refine the students' evaluation and feedback skills. Throughout the activity, the instructor supported the students and addressed their queries via instant messaging services. The final step required students to review the feedback from peers, use it to improve their spoken content, and then re-record their videos. This process aimed to enhance their speaking abilities through iterative learning and refinement based on evaluative feedback.

The pre-test and post-test, designed by experienced EFL teachers, assessed basic and specific EFL speaking skills, closely related to the study's main topics and the content of students' video recordings. Students' test responses were audio-recorded and evaluated by instructors using an EFL speaking rubric (Huang & Gui, 2015), with a total score of 150 points across various question types. Instructor scoring was conducted by a comparison and consensus discussion process with one experienced researcher, ensuring inter-rater reliability, as evidenced by a Cohen's Kappa value exceeding 0.90, indicating a prominent level of reliability in the evaluation process.

The experimental group used the Insta360 ONE X 5.7K camera for recording, and head-mounted displays for viewing, while the control group used mobile phone cameras for recording and standard devices (e.g. personal computers, laptops or tablets) for viewing.

Feedback encompassed various methods including questioning, encouragement, self-expression, and offering suggestions. Questioning involved interactive feedback, where evaluators posed questions to prompt learners for further clarification or elaboration, particularly on unclear aspects of their submissions. Encouragement, categorized as affective feedback, involves commending the learners, thereby providing positive reinforcement. Self-expression refers to comparison feedback, where evaluators share their interpretations or proposed structuring of the spoken content, offering learners a comparative perspective on how others might perceive or approach the same material. Lastly, offering suggestions constituted elaborate feedback, providing detailed advice on refining, and enhancing the learners' speech or spoken content, guiding them towards improvement (Gielen & De Wever, 2015).

3. Results and discussion

Table 1 includes the pre-and post-test evaluations alongside a t-test analysis. The pre-test scores reveal no significant differences between the experimental (Mean=81.92, Standard Deviation=12.77) and control (Mean=80.08, Standard Deviation=15.52) groups (t=0.47, p>0.05), indicating comparable initial EFL speaking levels. Contrastingly, post-test scores demonstrate a notable distinction, with the experimental group (Mean=107.46, Standard Deviation=12.30) significantly surpassing the control group (Mean=94.42, Standard Deviation=14.10) (t=3.55, p<0.05), suggesting enhanced speaking performance due to evaluation and feedback carried out in the 360VT environments.

This marked improvement aligns with existing literature emphasizing the potency of specific, detailed feedback in fostering learning (Krause et al., 2009; Narciss & Huth, 2006). It's posited that comprehensive feedback, especially deep-level insights pinpointing precise strengths, weaknesses, and actionable suggestions, substantially elevates learning outcomes (Dressler et al., 2019). The 360VT group, receiving such feedback, gained a thorough understanding of their English-speaking abilities and areas for enhancement (Wiliam, 2012). This approach not only addresses the immediate learning needs but also fosters a constructive attitude towards continuous learning and reflection among students (Ferrara and Butcher, 2012). Moreover, evaluators in 360VT settings provided more extensive feedback compared to their TVT counterparts. The immersive 360-degree perspective offered evaluators a comprehensive view, enabling them to observe and comment on finer details, thereby enriching the feedback. The realism and immersion of the 360VT environment augmented evaluators' engagement, focus, and cognitive connection with the content, facilitating a deeper understanding and more nuanced feedback. The evaluators' high acceptance of the ease and utility of 360VT further contributed to thorough content review and detailed feedback provision.

Table 1. EFL test scores and the results of the independent samples t-test
Note: EG and CG – experimental group (360VT) and control group (TVT).

Test	Group	Mean	SD	t	Sig.(two-tailed)
Pre-test	EG	81.92	12.77	0.47	.64
	CG	80.08	15.52		
Post-test	EG	107.46	12.30	3.55	.001
	CG	94.42	14.10		

In terms of perceptions, overall, evaluators expressed positive feedback about their experience with 360VT during the evaluation process, noting high levels of engagement and enjoyment. The panoramic view offered by 360VT allowed evaluators to observe finer details within the video, leading to more comprehensive feedback. Evaluators remarked on the immersive quality of 360-degree video, which made them feel as though they were present in the same environment as the speaker. Most evaluators found 360VT beneficial for evaluating video content and easy to use. They praised various aspects such as its user-friendliness, vividness or presence. Evaluators were able to discern detailed elements in the 360-degree videos, and the technology's realistic portrayal made them feel as though they were in the same setting as the student. This sense of reality enhanced their ability to connect the spoken descriptions with the visual context. Additionally, the authenticity, immersion, and presence experienced during the evaluation process were highlighted as particularly enjoyable aspects, making the evaluators find the process engaging and interesting. However, a few disadvantages were noted, such as discomfort from wearing head-mounted displays for extended periods, potentially leading to vertigo.

These findings resonate with previous research underscoring the value of authentic, immersive learning materials in enhancing motivation, effectiveness, and engagement (Howe & Wig, 2017; Peterson, 2018). The VR environment, particularly 360VT, fosters a deeper content comprehension, enabling evaluators to deliver superior feedback compared to traditional video technology settings (Huang et al., 2019).

While our study aligns with prior research regarding academic performance enhancement through immersive technologies, its novelty lies in examining the specific application of 360VT in evaluation and feedback within VR-enhanced learning environments. This study not only confirms the efficacy of 360VT in enhancing evaluation and feedback processes but also paves the way for its broader application in computer-assisted language learning. It advocates for the integration of 360VT in the language learning process, particularly in evaluative and feedback mechanisms, owing to its ability to create authentic, immersive, and vivid learning environments. This immersive technology enriches the evaluative process by providing detailed insights into content and learner performance, thereby stimulating more engaged, informed, and constructive feedback from evaluators.

However, as with any technological innovation, the intervention of the present study is not without its challenges. The potential issues of utilizing 360-degree video in the learning process, such as cybersickness, spatial constraints, and the need for cautious application, remind us of the careful balance required in harnessing the power of this tool.

4. Conclusion and future research direction

We conclude that 360-degree video technology is a vast landscape and has a wide range of applications in education. The immersive potential of 360-degree video tools in language learning has unfolded, promising transformative experiences for students. As we delved into its applications, the promise of such type of video to enhance language education became evident, offering engaging and context-rich environments for learners to sharpen their English language skills. While 360-degree video technology holds immense promise in revolutionizing language education, educators and learners alike must tread thoughtfully, leveraging its strengths while addressing potential pitfalls. The integration of virtual reality into language instruction marks, not just a technological leap but a pedagogical evolution, inviting us to shape the future of language education with creativity, adaptability, and a keen understanding of the dynamic interplay between technology and learning.

The present research has set an initial stage for our upcoming investigations, where we will leverage cutting-edge technologies including 360-degree video and Virtual Reality (VR) to create immersive learning experiences, simulating real-world scenarios that facilitate authentic learning environments. This approach will be further augmented by Artificial Intelligence (AI), with the deployment of tools such as a large language model, computer-aided translation and automated corrective feedback aiding in language and cross-cultural learning. Specifically, ChatGPT will be utilized to brainstorm ideas, providing specific guidance, and helping in content creation for cross-border sharing. Tools such as IFlytek for computer-aided translation and Grammarly for automated corrective feedback will play a crucial role in overcoming language barriers, thereby improving the quality of interactions and mutual understanding among participants. Our focus will also extend to essential 21st-century skills, such as cross-cultural competence, sensitivity, innovation, and entrepreneurial skills, vital for navigating and communicating effectively across diverse cultures. By involving students from countries part of the Belt and Road Initiative in collaborative learning activities, we aim to provide a platform for the practical application of theoretical knowledge while enhancing students' cross-cultural competence, sensitivity, innovation, and entrepreneurial skills.

Acknowledgement

This work was carried out as part of project No. AP19676457 "Modeling and feedback management in educational telematics" due to grant funding from the Ministry of Education and Science of the Republic of Kazakhstan.
The present research is also supported by the Fundamental Research Funds for the Central Universities (China) and funded by the research project of innovation and entrepreneurship education of Zhejiang University (China).

References

Adachi, C., Tai, J., & Dawson, P. (2018). A framework for designing, implementing, communicating, and researching peer assessment. *Higher Education Research & Development, 37*(3), 453-467.

Alemdag, E., & Yildirim, Z. (2022). Effectiveness of online regulation scaffolds on peer feedback provision and uptake: A mixed methods study. *Computers & Education*, 104574.

Barić, D., Havârneanu, G. M., & Măirean, C. (2020). Attitudes of learner drivers toward safety at level crossings: Do they change after a 360° video-based educational intervention? *Transportation Research Part F: Traffic Psychology and Behaviour, 69*, 335–348. doi: 10.1016/j.trf.2020.01.018

Barrot, J. S. (2021). Using automated written corrective feedback in the writing classrooms: effects on L2 writing accuracy. *Computer Assisted Language Learning*, 1-24. https://doi.org/10.1080/09588221.2021.1936071

Bellocchi, A., King, D. T., & Ritchie, S. M. (2016). Context-based assessment: Creating opportunities for resonance between classroom fields and societal fields. *International Journal of Science Education, 38*(8), 1304-1342.

Breves, P., & Heber, V. (2019). Into the Wild: The Effects of 360° Immersive Nature Videos on Feelings of Commitment to the Environment. *Environmental Communication, 14*(3), 332–346. doi: 10.1080/17524032.2019.1665566

Dressler, R., Chu, M-W., Crossman, K. & Hilman, B. (2019). Quantity and quality of uptake: Examining surface and meaning level feedback provided by peers and an instructor in a graduate research course. *Assessing Writing, 39*, 14-24.

Fan, J., & Yan, X. (2020). Assessing speaking proficiency: a narrative review of speaking assessment research within the argument-based validation framework. *Frontiers in Psychology, 11*, 330.

Gielen, M., & De Wever, B. (2015). Structuring peer assessment: Comparing the impact of the degree of structure on peer feedback content. *Computers in Human Behavior, 52*, 315–325. https://doi.org/10.1016/j.chb.20

Howe, L., & Wig, A. V. (2017). Metacognition via creative writing: Dynamic theories of learning support habits of the mind in 21st-century classrooms. *Journal of Poetry Therapy, 30*(3), 139–152

Huang, H. L., Hwang, G. J., & Chang, C. Y. (2019). Learning to be a writer: A spherical video-based virtual reality approach to supporting descriptive article writing in high school Chinese courses. *British Journal of Educational Technology.* doi: 10.1111/bjet.12893

Huang, Y., & Gui, M. (2015). Articulating Teachers; Expectations afore: Impact of Rubrics on Chinese EFL Learners & Self-Assessment and Speaking Ability. *Journal of Education and Training Studies, 3*(3), 126-132.

Jiang, L., Yu, S., & Wang, C. (2020). Second language writing instructors' feedback practice in response to automated writing evaluation: A sociocultural perspective. *System, 93*, 102302. https://doi.org/10.1016/j.system.2020.102302

Kahng, J. (2019). Teaching and researching speaking skills. In Polat, N., Gregersen, T., & MacIntyre, P. D. (Eds.), *Driven Pedagogy: Implications of L2A Theory and Research for the Teaching of Language Skills.* Routledge.

Kaplan-Rakowski, R., Papin, K., & Hartwick, P. (2023). Language Teachers' Perceptions and Use of Extended Reality. *CALICO Journal*, *40*(1), 1–23. https://doi.org/10.1558/cj.22759

Kerimbayev, N., Jotsov, V., Akramova, A., & Nurym, N. (2022). Modeling and feedback control for development of mobile technologies in virtual education environments. In: Shi, P., Stefanovski, J., Kacprzyk, J. (Eds.) *Complex systems: Spanning control and computational cybernetics: applications. studies in systems, decision and control* (vol. 415). Springer.

Krause, U.-M., Stark, R., & Mandl, H. (2009). The effects of cooperative learning and feedback on e-learning in statistics. *Learning and Instruction, 19*, 158–170. doi: 10.1016/j. learninstruc.2008.03.003

Lan, Y. J. (2020). Immersion, interaction and experience-oriented learning: Bringing virtual reality into FL learning. *Language Learning & Technology, 24*(1), 1–15. http://hdl.handle.net/10125/44704

Liu, Y. F., Hwang, W. Y., & Su, C. H. (2023). Investigating the impact of context-awareness smart learning mechanism on EFL conversation learning. *Interactive Learning Environments*, 1-16. https://doi.org/10.1080/10494820.2023.2194931

Narciss, S., & Huth, K. (2006). Fostering achievement and motivation with bug-related tutoring feedback in computer-based training for written subtraction. *Learning and Instruction*, *16*, 310–322. doi: 10.1016/j.learninstruc.2006.07.003

Peterson, M. (2018). Experiential learning in the age of Web 2.0: The rap video project. *Marketing Education Review, 28*(2), 109–114.

Rodríguez-González, E., & Castañeda, M. E. (2018). The effects and perceptions of trained peer feedback in L2 speaking: Impact on revision and speaking quality. *Innovation in Language Learning and Teaching, 12*(2), 120-136.

Shadiev, R., Wang, X., Chen, X., Gayevskaya, E. & Borisov, N. (2024). Research on the impact of the learning activity supported by 360-degree video and translation technologies on cross-cultural knowledge and attitudes development. Education and Information Technologies.

Shadiev, R., Wang, X.Y., & Huang, Y.M. (2020). Promoting intercultural competence in a learning activity supported by virtual reality technology. *The International Review of Research in Open and Distributed Learning, 21*(3), 157-174.

Shadiev, R., Wang, X.Y., & Huang, Y.M. (2021). Cross-cultural learning in virtual reality environment: facilitating cross-cultural understanding, trait emotional intelligence, and sense of presence. *Educational Technology Research and Development, 69*, 2917–2936.

Shadiev, R., Yang, L., & Huang, Y.M. (2022). A review of research on 360-degree video and its applications to education. *Journal of Research on Technology in Education, 54*(5), 784–799.

Shadiev, R., & Zhou, J. (2023). A review of research on the use of 360-degree video technology in language learning. *Educational Technology & Society, 26*(4), 14-37.

Shayakhmetova, L., Mukharlyamova, L., Zhussupova, R., & Beisembayeva, Z. (2020). Developing Collaborative Academic Writing Skills in English in CALL Classroom. *International Journal of Higher Education*, *9*(8), 13-18.

Smith, H., & Townsend, S. D. (2021). Investigating the efficacy of utilizing 360° camera technology as a language teaching and learning tool in a science content-based EFL classroom. *Innovation in Language Learning and Teaching, 15*(2), 143-155. https://doi.org/10.1080/17501229.2019.1710515

Song, J. (2019). Enhancing Intercultural Competence with 360-Degree Virtual Reality Videos. *The Korean Language in America*, *23*(1), 85-98. doi:10.5325/korelangamer.23.1.0085

Spiller, D. (2012). Assessment matters: Self-assessment and peer assessment. *The University of Waikato, 13*, 2-18.

Suvorov, R., & Gruba, P. (2023). Integrating semiotic resources in CALL activity designs. *Language Learning & Technology, 27*(2), 97–117. https://hdl.handle.net/10125/73505

Tang, J. & Rich, C.S. (2017). Automated Writing Evaluation in an EFL Setting: Lessons from China. *JALT CALL Journal*, *13*(2), 117-146.

Taylor, N., & Layland, A. (2018). Comparison study of the use of 360-degree video and non-360-degree video simulation and cybersickness symptoms in undergraduate healthcare curricula. *BMJ Simulation and Technology Enhanced Learning, 5*(3), 170-173. http://doi:10.1136/bmjstel-2018-000356

Thompson, G., & Alba-Juez, L. (Eds.). (2014). *Evaluation in context* (Vol. 242). John Benjamins Publishing Company.

Tian, L., & Zhou, Y. (2020). Learner engagement with automated feedback, peer feedback, and teacher feedback in an online EFL writing context. *System*, *91*, 102247. https://doi.org/10.1016/j.system.2020.102247

Walshe, N., & Driver, P. (2019). Developing reflective trainee teacher practice with 360-degree video. *Teaching and Teacher Education, 78*, 97-105.

Wiliam, D. (2012). Feedback: Part of a system. *Educational Leadership, 70*, 30–34. Retrieved from http:// www.ascd.org/publications/educational-leadership.aspx

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in psychology, 10*, 3087.

Xie, Y., Chen, Y., & Ryder, L. H. (2021). Effects of using mobile-based virtual reality on Chinese L2 students' oral proficiency. *Computer Assisted Language Learning, 34*(3), 225-245. https://doi.org/10.1080/09588221.2019.1604551

The Effect of Gamified Learning Method on Students' Collaborative Problem Solving: Based on Learning Behaviour Data

Ying-Qi Fan[1], Yao Yao[1], Jing Chen[1], Jian-Wen Fang[1*]
[1]College of Education, Wenzhou University
* beginnerfjw@163.com

Abstract: *Collaborative problem solving (CPS) is a crucial 21st-century skill that significantly impacts students' academic success in STEM. Recent research has concentrated on CPS assessment. However, CPS necessitates that students engage in complex cognitive tasks and social interactions, which can be cognitively demanding and hinder CPS development. Gamification is an effective intervention that targets both the cognitive and social aspects of CPS. To address this issue, this study designed a gamified learning tool that provides a gaming experience, motivation, and collaboration support. The tool aims to stimulate students' interest in learning, promote the development of CPS. To assess the method's effectiveness, the study recruited 81 primary school students with a mean age of 11 from a regular primary school in eastern mainland China. The experimental group consisted of 40 students (male=19，female=21) in each class who used a gamified learning method, while the control group consisted of 41 students (male=20，female=21) in each class who used a traditional teaching method. The study results indicate that students who used a gamified learning method outperformed those who used a traditional method in terms of CPS. These findings suggest that gamified learning methods can significantly contribute to students' CPS. Therefore, this paper provides insights for future research and recommendations for researchers and educators interested in adopting gamified STEM learning in educational settings.*
Keywords: STEAM education, Gamified learning, Collaborative problem solving, Learning behaviour

1. Introduction

In the 21st century, STEM education has become an important way to cultivate interdisciplinary composite talents to meet the demand for interdisciplinary composite talents in the development of society. Therefore, how to cultivate students' CPS in STEM teaching is an important issue. The Organization for Economic Co-operation and Development (OECD, 2017) defines collaborative problem-solving as a cognitive and social process. Recent studies have assessed CPS, including the OECD's PISA 2015 measurement program. Evaluation methods include multimodal analysis (Tang et al., 2022), gamified performance assessment (Stoeffler et al., 2020), and cognitive network analysis (Swiecki et al., 2020; Zhang et al., 2022). Furthermore, researchers and scholars have shown great interest in developing students' CPS (Rojas et al., 2021). The CPS process can create a cognitive load for students, making the development of CPS difficult due to its complex cognitive and social engagement. Therefore, gamification is considered an effective means of intervening in the cognitive and social aspects of the CPS process (Hsiao et al., 2023; Kam & Umar, 2023).

Based on the above analysis, this study developed a gamified learning tool with game experience, motivational incentives, and collaborative support features to support students' STEM learning by motivating students and providing the necessary collaborative support to facilitate students' CPS development. To validate the effectiveness of this gamified STEM learning method, the research questions proposed by this study are as follows:

(1) Does the gamified STEM learning method foster CPS more than the conventional STEM learning method?

2. Literature review

2.1. Collaborative problem solving

The CPS focuses on teamwork and problem-solving (Graesser et al., 2017). Many researchers and organizations have presented their views on CPS; for example, Rummel and Spada (2005) viewed CPS as a learning process in which learners need to experience communication, reach and maintain agreement, and collaborate to accomplish common task goals. The PISA 2015 program defines CPS as " individual's skills to engage effectively in problem-solving in which two or more individuals share and pool their knowledge and skills through joint efforts to contribute to a common task goal". Based on the analysis of the above definitions, this study defines CPS as "an individual's skills to contribute to effective problem solving through cognitive engagement and social participation in a collaborative learning process."

However, research has shown that students often struggle to collaborate spontaneously and effectively. Therefore, it is necessary to provide students with collaborative support. such as collaborative scripts (Kollar et al., 2006). Rojas (2022) used games that promote group regulation skills and emotional awareness as collaborative scripts to help students collaborate and develop CPS in elementary students.

Therefore, this study employs a gamified learning method to improve students' CPS.

2.2. Gamification of learning

Most researchers agree that gamification follows the principle of introducing game elements in non-game environments to motivate people to solve problems (Deterding et al., 2011; Zhang & Hasim, 2023). Well-designed gamification strategies are effective in improving students' learning performance in STEM activities (Chen et al., 2023).

However, the literature on the effectiveness of game-based learning strategies on the development of CPS is limited. Motivation has been the shared goal of many investigators in designing gamified learning (Buckley & Doyle, 2016; Jones et al., 20-22). According to Groening and Binnewies (2019), gamified learning is effective in improving students' motivation and performance after satisfying these aspects of motivation. Poole et al. (2019) found that adding game elements, such as story situations and role-playing, to a learning situation is an effective way to increase immersion.

Therefore, this study designed a gamified learning tool with game experience, motivational incentives, and collaborative support to support students' STEM learning and promote students' CPS.

3. Experiment design

3.1. Participants

The study's subjects were sixth-grade students from an ordinary primary school in eastern mainland China, with an average age of 11 years. The experimental group of 40 students (male=19, female=21) was taught using gamified learning methods, while the control group of 41 students (male=20, female=21) was taught using traditional teaching methods. We distributed 81 surveys and received 72 valid surveys, 37 in the experimental and 35 in the control groups.Students in the two classes were randomly assigned to groups of between two and four. To exclude confounding variables, STEM instructional activities in both classes were taught by an experienced teacher. Students in both classes learned the same content.

3.2. Experimental procedure

The study lasted for two months and consisted of eight class lessons, with two sixth-grade classes participating in this instructional experiment. Figure 1 illustrates the exact product of the experiment. In the first lesson, students completed a pre-test of the CPS. In the second and third sessions, both classes completed the first round of the STEM project 'Cars' under the same learning conditions and guidance of the teacher. In the 4th and 5th lessons, the STEM project 'The Cabin in the Woods' was completed. Finally, during the 6th and 7th sessions, the STEM project 'Rocketeer' was completed, and in session 8, the teacher guided the students to complete a post-test of the CPS.

3.3. Instruments

3.3.1 CPS questionnaire

The CPS Questionnaire was adopted from the PISA 2015, with a Cronbach's alpha of 0.89. The scale consists of 24 questions categorized into four dimensions based on the process of solving a problem, namely "exploration and understanding," "representation and formation," "planning and execution," and "monitoring and reflection." The responses were given on a five-point scale point Likert scale, ranging from 1 for “strongly disagree” to 5 for “strongly agree.”

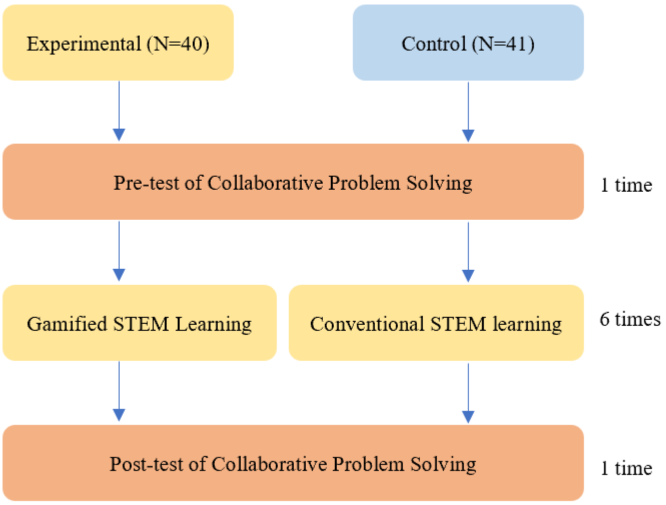


Fig. 1. Experimental produce

4. Experimental results

4.1. Collaborative problem solving

Firstly, a homogeneity of variances test (Levene's test) was carried out, which resulted in $F(1,70) = 3.43$, $p = .07 > .05$, $p > .05$, so the null hypothesis should be accepted, that is, the number of variances in the two groups is homogeneous. Secondly, the Homogeneity test of regression coefficients within groups was carried out, which resulted in $F(1, 68) = 1.52$, $p = .70 > .05$, $p > .05$, so the null hypothesis should be accepted, that is, the regression coefficients within the two groups are homogeneous. Therefore, ANCOVA analysis can be conducted.

Table 2 shows the results of ANCOVA analysis of CPS for STEM learning. The analysis indicated that there was a significant difference between the two groups in terms of CPS, $F(1, 69) = 7.74$, $p < 0.01$. Post-hoc analysis indicated that students who used gamified learning methods scored significantly higher than those who used conventional methods in terms of CPS. In other words, gamified STEM learning improved students' CPS significantly compared to conventional STEM learning.

Table 1. The ANCOVA Results for CPS

Variables	Groups	N	Mean	SD	Adjusted mean	Adjusted SD	*F*	η^2
CPS	Experimental	37	4.03	0.39	4.00	0.08	7.74^{**}	0.10
	Control	35	3.65	0.53	3.68	0.08		

$^{**}p < 0.05$

5. Discussion and conclusions

In terms of CPS, the experimental group significantly performed better than the control group.Tang(2023) et al. showed that students' intrinsic motivation positively promotes their cognitive engagement in CPS, which in turn improves students' collaborative problem-solving. Rojas (2022) et al. noted that providing collaborative scripts helped students actively interact with their group members, facilitated social engagement, and promoted the development of their CPS, Suggesting that the use of gamified learning tools that incorporate motivational incentive features and collaborative scripts to simultaneously promote students' cognitive engagement and social engagement to develop their CPS is an effective strategy for developing CPS in elementary school STEM instruction. Compared to conventional STEM learning, gamified STEM learning is more effective in developing students' CPS.

This study confirms the positive impact of utilizing gamified learning strategies in STEM instruction to develop students' CPS, but there are still some limitations. Firstly, in terms of class schedule, due to the school timetable, the period for students to complete a project is one week, which will cause some unavoidable interference with the results of the practice. Finally, in terms of the experimental subjects, this study chose a limited sample of 81 primary school students in the sixth grade of an ordinary primary school in the eastern part of mainland China.

In conclusion, this study found that the use of gamified learning strategies effectively promoted students' CPS. However, further research is needed, and this study suggests the following recommendations for future research: Future research could enhance the selection of experimental subjects and further investigate the impact of gamified learning strategies on students' CPS and STEM learning performance by increasing the sample's representativeness.

Acknowledgments

We thank all the people who wrote previous versions of this document.

References

Buckley, P., & Doyle, E. (2016). Gamification and student motivation. *Interactive learning environments*, 24(6), 1162-1175.

Chen, Y. C., Hou, H. T., & Wu, C. H. (2023). Design and development of a scaffolding-based mindtool for gamified learning classrooms. *Journal of Educational Computing Research, 61*(1), 3-29. https://doi.org/10.1177/07356331221101

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining" gamification". In Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments (pp. 9-15). https://doi.org/10.1145/2181037.2181040

Graesser, A. C., Forsyth, C. M., & Foltz, P. (2017). Assessing conversation quality, reasoning, and problem-solving with computer agents. https://doi.org/10.1787/9789264273955-17-en

Groening, C., & Binnewies, C. (2019). “Achievement unlocked!”-The impact of digital achievements as a gamification element on motivation and performance. *Computers in Human Behaviour, 97*, 151-166. https://doi.org/10.1016/j.chb.2019.02.026

Hsiao, H. S., Chen, J. C., Chen, J. H., Chien, Y. H., Chang, C. P., & Chung, G. H. (2023). A study on the effects of using gamification with the 6E model on high school students' computer programming self-efficacy, IoT knowledge, hands-on skills, and behavioural patterns. *Educational technology research and development*, 1-29. https://doi.org/10.1007/s11423-023-10216-1

Jones, M., Blanton, J. E., & Williams, R. E. (2023). Science to practice: Does gamification enhance intrinsic motivation? *Active Learning in Higher Education*, 24(3), 273-289.

Kam, A. H., & Umar, I. N. (2023). Fostering autonomous motivation: a deeper evaluation of gamified learning. *Journal of Computing in Higher Education*, 1-21. https://doi.org/10.1007/s12528-023-09358-1

Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration scripts–a conceptual analysis. *Educational Psychology Review*, *18*, 159-185. https://doi.org/10.1007/s10648-006-9007-2

OECD. (2017). PISA 2015 collaborative problem-solving framework. PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving. https://www.oecd-ilibrary.org/docserver/cdae6d2e-en.pdf?expires=1705716546&id=id&accname=guest&checksum=4AD822579634775557349F5B75B42C4E

Poole, F., Clarke-Midura, J., Sun, C., & Lam, K. (2019). Exploring the pedagogical affordances of a collaborative board game in a dual language immersion classroom. *Foreign Language Annals*, *52*(4), 753-775. https://doi.org/10.1111/flan.12425

Rojas, M., Nussbaum, M., Guerrero, O., Chiuminatto, P., Greiff, S., Del Rio, R., & Alvares, D. (2022). Integrating a collaboration script and group awareness to support group regulation and emotions toward collaborative problem-solving. *International Journal of Computer-Supported Collaborative Learning*, *17*(1), 135-168. https://doi.org/10.1007/s11412-022-09362-0

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem-solving in computer-mediated settings. *The Journal of the Learning Sciences*, *14*(2), 201-241. https://doi.org/10.1207/s15327809jls1402_2

Stoeffler, K., Rosen, Y., Bolsinova, M., & von Davier, A. A. (2020). Gamified performance assessment of collaborative problem-solving skills. *Computers in Human behaviour*, *104*, 106036. https://doi.org/10.1016/j.chb.2019.05.033

Swiecki, Z., Ruis, A. R., Farrell, C., & Shaffer, D. W. (2020). Assessing individual contributions to collaborative problem solving: a network analysis approach. *Computers in Human behaviour*, *104*, 105876. https://doi.org/10.1016/j.chb.2019.01.009

Tang, H., Dai, M., Du, X., Hung, J. L., & Li, H. (2023). Understanding college students' cognitive engagement in online collaborative problem-solving: A multimodal data analysis. *Distance Education*, *44*(2), 306-323. https://doi.org/10.1080/01587919.2023.2209025

Tang, H., Dai, M., Yang, S., Du, X., Hung, J. L., & Li, H. (2022). Using multimodal analytics to systemically investigate online collaborative problem-solving. *Distance Education*, *43*(2), 290-317. https://doi.org/10.1080/01587919.2022.2064824

Zhang, S., & Hasim, Z. (2023). Gamification in EFL/ESL instruction: A systematic review of empirical research. *Frontiers in Psychology*, *13*, 1030790. https://doi.org/10.3389/fpsyg.2022.1030790

Zhang, S., Gao, Q., Sun, M., Cai, Z., Li, H., Tang, Y., & Liu, Q. (2022). Understanding student teachers' collaborative problem solving: Insights from an epistemic network analysis (ENA). *Computers & Education*, *183*, 104485. https://doi.org/10.1016/j.compedu.2022.104485

Using Learning Analytics to Facilitate Pedagogical Decision-Making in Higher Education: A Multiple Case Study

Siu-Cheung KONG[1,2*], William Man-Yin CHEUNG[3], Sophia Sin-Manw LAM[4], Meng-Yao JIN[4], Winnie Wai-Man LAM[1], Cheuk-Nam YUEN[2], Yin YANG[1]
[1] Department of Mathematics and Information Technology, The Education University of Hong Kong
[2]Artificial Intelligence and Digital Competency Education Centre, The Education University of Hong Kong
[3]Talent and Education Development Office, City University of Hong Kong
[4]Department of Chinese Language Studies, The Education University of Hong Kong, Hong Kong
[*]sckong@eduhk.hk

Abstract: *This study explored how university teachers used Learning Analytics (LA) tools in enhancing teaching practices. By providing detailed data on student performance and behavior, LA tools offer educators various types of data that demonstrate students' learning performance and behaviors and enable teachers to gain insights into their students' learning status and identify areas where further support is needed. A multiple case study was adopted to examine four university teachers' experiences with LA tools. Data included four in-depth interviews. The interview results revealed teachers' positive attitudes toward the design and adaptation of course activities using LA tools. In addition, the study identified several challenges. The findings of this study have significant potential for informing both LA tool designers and higher education institutions, promoting more effective and widespread adoption of LA technology in academic contexts.*

Keywords: case study, higher education, learning analytics, pedagogical decision-making, teaching practice

1. Introduction

As hybrid learning has become increasingly significant in the higher education sector, there is a need to equip teachers with the knowledge and skills to use learning analytics (LA) in learning management systems (LMS) (Karaoglan Yilmaz, 2022). However, implementation of LA in higher education faces several challenges. First, teachers often lack sufficient analytical skills to interpret and make use of the data (Tsai & Gašević, 2017). Second, previous research has shown a correlation between institutional support and educators' motivation in adopting LA. The absence of robust institutional backing can lead to a diminished incentive for teachers to integrate LA into their pedagogical practices (Tsai et al., 2020; Gašević et al., 2016). In addition, concerns around student data privacy and security remain paramount (Li et al., 2022). Despite the fact that the existing studies have investigated how educators make pedagogical choices informed by LA data (van Leeuwen, 2019; Herodotou et al., 2019; van Leeuwen et al., 2017), this study narrows its focus to the application of LA tools in Moodle by analysing four cases through teacher interviews to assess the effectiveness of their use. This paper aims to answer two research questions: (1) How do teachers use LA to facilitate their teaching? and (2) What are the challenges of LA adoption in higher education contexts?

2. Literature Review

Learning analytics is defined by the Society for Learning Analytics Research (SoLAR) and refers to 'measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs' (Siemens, 2012). The role of LA is to capture students' digital footprints and present the data in a visual format. Clow (2012) introduced the learning analytics cycle, which describes how the data collected and interpreted through LA can become the driving force for pedagogical intervention. First, university students engage in online course-related activities in LMS, after which data are generated and turned into metrics or reports, depending on the design and purpose of LA. Nistor and Hernández-García (2018) noted that LA can provide four types of data: primary data directly measured in LA, data resulting from artifact measurements during the process, repurposed data initially collected for other goals and reanalysed, and transformed data. Based on these data, teachers can reflect on the class's learning progress or performance and decide whether and how to intervene or provide additional assistance.

As teachers have an active role in facilitating student learning (Naujokaitienė et al., 2020), their goals in using LA are not just to diagnose students' online activities and predict their learning outcomes but also to address the specific needs of their students (Brooks, 2020).

However, as LA design is often not based on profound pedagogical theories or practices, it lacks adequate theoretical guidance to promote the adoption of effective instructional and intervention practices (Gašević et al., 2015). Teachers require adequate sense-making skills and strategies to comprehend the information provided by LA and base proactive action on it (van Leeuwen, 2019). Although prior research has examined the utilization of LA in higher education (Guzmán-Valenzuela et al., 2021), there is a lack of studies investigating the application of LA by teachers with explicit pedagogical objectives within their courses.

This study addresses the gap by examining the implementation of LA at the course level in a specific university, using a multi-case approach to gain insight into how teachers with clear educational objectives integrate LA to enhance their teaching and identify the challenges.

3. Research Design

3.1. The LA tools adopted in this study

This section introduces three LA tools embedded in the Moodle: (1) Behaviour Analytics, (2) BookRoll, and (3) Discussion Forum Participation. Behaviour Analytics is a plug-in that extracts students' sequential access patterns based on their activity logs on learning materials in Moodle over time. It can cluster students into groups based on their activity patterns, identify common behaviours and allow teachers to visualise student usage of materials on Moodle. The e-book reading platform BookRoll enables students to highlight phrases and make notes with memos and drawings (Ogata et al., 2015). It also captures their reading activities, such as reading frequency and speed and the locations and number of highlights in the materials. Figure 1 shows an example of a dashboard provided by BookRoll that displays students' reading activities. Figure 2 shows the dashboard of the discussion forum activities by group and class. It quantifies the contribution of each student, group and the entire class in Moodle's Discussion Forum over time in the form of graphs and figures for both teachers (Figure 2.1) and learners (Figure 2.2).

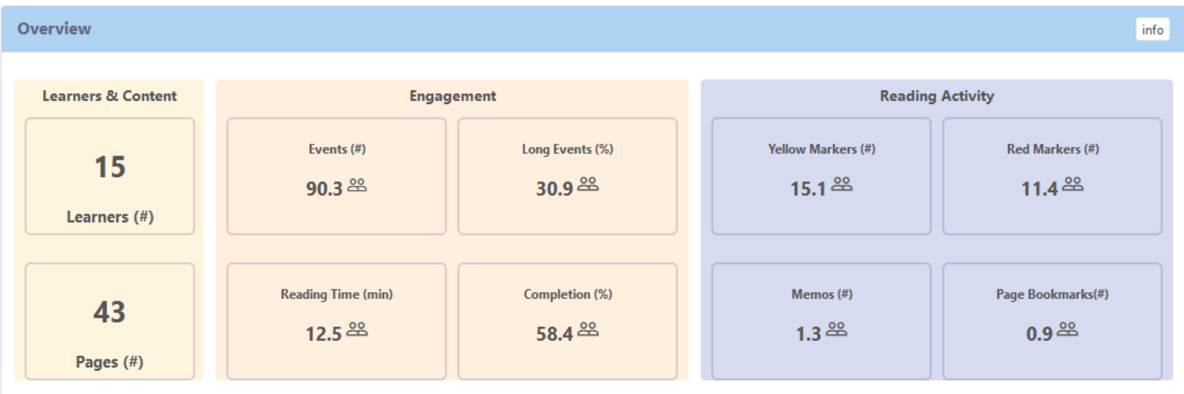


Figure 1. Overview of the dashboard in BookRoll.

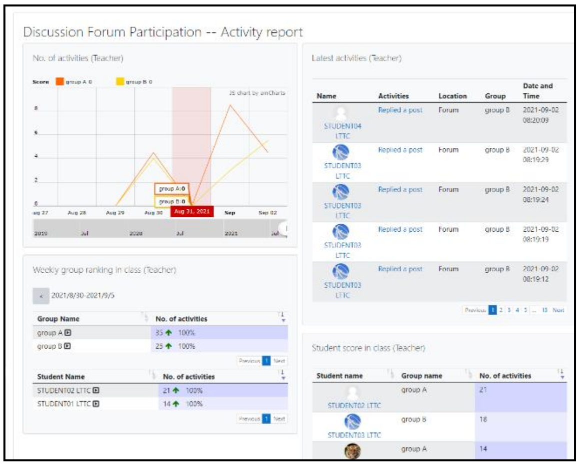


Figure 2.1. Teacher's dashboard

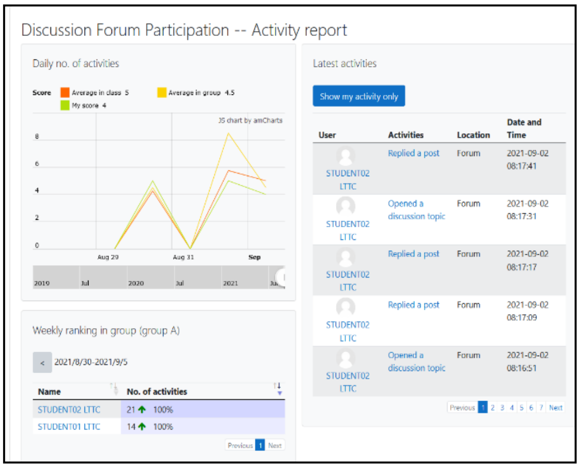


Figure 2.2. Student's dashboard

3.2. Methodology

A convenience sampling was used in this study. Four university teachers were chosen for their intentional and strategic use of LA in their courses. To examine the complexity and specificity of LA usage in diverse courses, a multiple case study design was employed. This approach enables researchers to have a detailed examination of the individual and collective pedagogical applications of LA tools across different academic disciplines (Yin & David, 2007). The study last for one semester.

3.3. Participants

This study invited four university teachers. They are all females. Teacher A taught "Theory and Practice of Classroom Language" from the Education discipline. Teacher B taught "Coding and Computational Thinking" in the field of information technology. Teacher C taught "Selected Reading in Classical Chinese" within Chinese language studies. Teacher D taught "Contemporary Issues in the Digital Society" in General Education. Table 1 shows the background information on teaching and learning among the four teachers.

Table 1. Background information on teaching and learning in the four cases.

	Teacher A	Teacher B	Teacher C	Teacher D
Course Title	Theory and Practice of Classroom Language	Selected Reading in Classical Chinese	Coding and Computational Thinking	Contemporary Issues in the Digital Society
Discipline	Education	Chinese Language Studies	Mathematics and Information Technology	General Education
Learning Analytics Tools	Behaviour Analytics	BookRoll	BookRoll	Discussion Forum Participation
Students' Course Activity	To access the online materials on Moodle	To read the assigned readings and materials	To comment on the presenters' presentation slides	To complete the class exercise and peer review
Usage Purpose	To understand how students access the course resources in Moodle	To monitor the students' reading progress	To understand the students' performance on specific topics and encourage peer feedback	To encourage and monitor the students' engagement in the online forum

3.4. Data collection and analysis

At the end of the semester, the four semi-structured interviews were conducted. Each interview was conducted in English and last for one hour. These interviews employed a retrospective approach (Côté et al., 2005) to guide the interviewees to reflect on their utilization of LA to achieve their pedagogical goals and support learning activities. Teachers were guided to reflect on their experiences with LA in facilitating their teaching throughout the course, including the challenges they faced and their expectations regarding the adoption of LA in higher education. Content analysis was employed to systematically analyze the transcripts from the four interviews.

4. Results

Teacher B and Teacher C adopted BookRoll, Teacher A used Behavior Analytics, and Teacher D employed Discussion Forum Participation. It is found out that the teacher independently applied their chosen LA tool without combining them with others. The following presents how each teacher used LA to facilitate teaching.

Teacher A integrated Behavior Analytics to scrutinize student engagement and progression within her "Theory and Practice of Classroom Language" course. The adoption of Behavior Analytics assisted Teacher A in optimizing the organization of course materials and making informed pedagogical adjustments to enhance learning outcomes. 'I became more aware of the quality and relevance of the learning resources by understanding how the students accessed the course materials through Behavior Analytics,' she said. Teacher A shared a story that at the beginning of this semester, she discovered that the supplementary readings she provided on Moodle were not accessed by most students. After evaluating the unaccessed materials, she recognised their importance for student learning and therefore went through them with the students during class to alert them to the value of these materials. After the reminder, the students accessed the materials more frequently. By getting an overview of the students' learning footprints through the Moodle resources, she was able to better arrange the learning materials and make relevant pedagogical changes.

Teacher B and Teacher C utilised BookRoll to monitor her students' reading behaviors and track their learning progress in the course. There are slight differences in the purpose of using Bookroll in the two courses. Teacher B used the BookRoll to distribute reading materials and monitor the students' reading progress. BookRoll prohibited the students from downloading the reading materials, allowing Teacher B to upload copyrighted references that could not be passed on to the students. Prior to using BookRoll, the students could only access sample works during the first class of the course. However, with BookRoll, the students could freely access the materials according to their needs and convenience. This not only allowed Teacher B to design high-impact learning activities but also promoted self-regulated learning among the students. However, Teacher B observed that some students with low activity in BookRoll performed well in the course because they studied the readings through other platforms. Therefore, the data analysis in BookRoll should be interpreted with caution. Moreover, she noticed that some students felt restricted when they learned they were being monitored, which led to a decrease in their engagement with BookRoll. Furthermore, student interest in using BookRoll was reduced due to non-user-friendly features such as slow system responses when using the highlighting and commenting functions.

Teacher C used BookRoll to understand the students' performance on specific topics and encourage peer feedback. During the presentation section, the students were tasked with annotating the presenter's uploaded slides using different colours to highlight key points and areas requiring clarification. They were also encouraged to provide feedback on their peers' work using the memo function. By reviewing the feedback from their peers or the teacher in BookRoll, the presenters were able to gain a better understanding of the strengths and weaknesses of their presentations. This interactive learning approach also enabled the presenters to respond immediately to the feedback they received on Moodle.

Teacher D utilised Discussion Forum Participation to increase student engagement and monitor their discussion performance during her course. After reading an article in class, the students were required to post their comments in the discussion forum to earn marks for class participation. The dashboard provided by the tool allowed Teacher D to monitor the class's performance in the discussion forum. Teacher D used the tool to automatically generate marks based on the students' activity. 'I now know what is happening in my class,' said Teacher D. 'As the students know they are being watched, class participation is promoted.' By actively engaging students in using the tool, Teacher D was able to encourage active participation in her course.

5. Discussion

5.1. How do teachers use LA to facilitate their teaching?

The results from four cased showed that teachers have positive views of the use of LA in monitoring students' learning progress and improving the quality of teaching and learning. They can use LA tool to align with the teaching objectives. Before the integration of LA with Moodle, the teachers reported that they were unable to systematically track student engagement within Moodle. Access to students' behavioural enables teachers' greater control over their teaching by monitoring their students' performance and then tailoring their teaching or assessment methods to suit the students' needs. For instance, Behaviour Analytics allowed Teacher A to detect low student interaction with key materials on Moodle, and to highlight their significance during lectures to stimulate interest and usage. Teacher B developed quizzes based on students' weaknesses in reading identified in BookRoll. Thus, LA serves as a valuable teaching resource by providing teachers with relevant information and facilitating their decision-making (van Leeuwen et al., 2017). By directing teacher attention to the most important data, LA enables them to take direct action to improve student learning outcomes.

Moreover, the real-time feedback of LA offer opportunities for immediate pedagogical interventions to bolster class engagement. Teacher C, for example, used BookRoll for in-class peer feedback sessions. Teacher D leveraged Discussion Forum Participation to facilitate deeper in-class discussion by encouraging students to contribute to the discussion questions in the forum. The role of teachers is to create opportunities for students to take responsibility for their own learning (Naujokaitienė et al., 2020). The instant generation of data through LA allows teachers to design more interactive in-class activities for students to reflect on their learning together. This, in turn, enhances their learning experience and overall academic performance.

Moreover, the teachers effectively utilised the capabilities of LA to enhance the learning experiences of their students. Beyond simply using the data generated by AI to make informed decisions about pedagogy, the teachers also employed LA to facilitate various learning activities. For example, Teacher A and Teacher B promoted self-regulated learning, which is considered a key attribute of student success (Dumford & Miller, 2018). Specifically, Teacher A intervened in a timely manner to encourage students to engage with the course materials, while Teacher B reminded students with low reading activity to catch up with their peers. These interventions raised the students' awareness of the importance of the materials and motivated them to spend more time reading. In doing so, the teachers effectively promoted self-regulated learning, as the students were both encouraged and empowered to take ownership of their learning. Interactive learning was also fostered by Teacher C and Teacher D using LA tools. The students were able to engage in real-time interactions with their peers and teachers using these tools, leading to interactive and reflective learning experiences under the guidance and supervision of their teachers. This approach facilitated deeper engagement with the material and promoted collaborative learning, as the students were able to share ideas and insights with their peers and receive timely feedback from their instructors.

5.2. What are the challenges of LA adoption in higher education contexts?

Several challenges were identified in LA adoption in higher education contexts. First, in the context of this study, a notable observation was that none of the teachers extensively used LA in their courses. Moreover, the teachers in our cases lacked specific examples and guidance on how to maximise the potential of LA in their classes. While trying LA in their own lessons and modifying their approach based on the class response, they had limited references on how best to implement the tools at the course level. Having to rely solely on their own observations and knowledge made it difficult for them to use LA effectively in their courses. To address this challenge, teachers would benefit from examples of how their peers have successfully implemented LA in their own classes. In-depth discussion with teachers who have encountered similar problems can also help teachers to find more relevant and precise solutions for the teaching problems they may encounter. Arthars et al. (2019) suggested that communities of interested teachers and users can promote the sharing of information and the spread of innovation, which can shift the culture of institutions to be more welcoming of LA.

Second, LA tools may not fully accommodate diverse learning preferences, such as those students who prefer physical textbooks or external resources. The teachers noticed that some students used other platforms to access the materials. This aligns with previous findings (Schumacher & Ifenthaler, 2018) that more than half of students prefer reading printed texts and that some expect more sophisticated and capable systems. It is important to acknowledge that students have their own learning styles and preferences that may not be fully supported by LA. This can affect the accuracy of the data collected. The data must also be interpreted cautiously because LA cannot capture information beyond the dashboard, such as the personal issues of students (Hlosta et al., 2020).

Third, a few students may resist adopting new technologies due to a lack of familiarity, fear of being monitored, or concerns about the data privacy (Gursoy et al., 2016). Adopting LA often requires a cultural shift within an institution to value data-driven decision-making, which can be a slow and challenging process (Kaspi & Venkatraman, 2023).

6. Conclusion

The case presented in this study suggest that LA can be effective in improving teaching and learning. However, certain challenges still need to be addressed to realise the full potential of LA in education. One challenge is the differing preferences and learning styles of students, which can impact their willingness to use LA tools. To increase LA acceptance and use, it is important to consider students' needs and preferences when implementing LA tools. Another challenge is the limited support and guidance that teachers receive in implementing LA effectively. Future research should focus on developing resources and fostering teachers' communities to support teachers in using LA tools and maximising their benefits.

The study has several limitations that should be taken into consideration. First, the participant demographic is not fully representative as all the teachers involved are female. To address this limitation and potentially uncover different perspectives, future research should aim to include male teachers to adopt LA in their courses. Second, the study primarily focuses on the teachers' perspectives and does not incorporate the students' views on LA. Future study will collect and analyse feedback from students on user experience, engagement, and the perceived value of LA in their learning process. By considering students' opinions, teachers and institutions can tailor LA tools and strategies to better meet learners' needs and address any concerns that students may have.

Acknowledgements

The authors would like to acknowledge the "Focusing on Facilitating Learning in Virtual Teaching and Learning" project with the funding support from the Research Grants Council, University Grants Committee of the Hong Kong Special Administrative Region, China (Project No. EdUHK 5195).

References

Arthars, N., Dollinger, M., Vigentini, L., Liu, D. Y. T., Kondo, E., & King, D. M. (2019). Empowering teachers to personalize learning support: Case studies of teachers' experiences adopting a student-and teacher-centered learning analytics platform at three Australian universities. In R. Huang, J. C. Yang, & M. C. Chang (Eds.), *Utilizing Learning Analytics to Support Study Success* (pp. 223-248). Springer. https://doi.org/10.1007/978-981-13-8343-0_12

Brooks, N. J. (2020). *Data changes everything: An investigation into the acceptance of learning analytics to support student success* (Doctoral dissertation, The Open University).

Côté, J., Ericsson, K. A., & Law, M. P. (2005). Tracing the development of athletes using retrospective interview methods: A proposed interview and validation procedure for reported information. *Journal of applied sport psychology*, *17*(1), 1-19. https://doi.org/10.1080/10413200590907531

Clow, D. (2012). The learning analytics cycle: Closing the loop effectively. In S. B. Shum, D. Gasevic, & R. Ferguson (Eds.), *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge (LAK12)* (pp. 134-138). ACM. https://doi.org/10.1145/2330601.2330636

Dumford, A. D., & Miller, A. L. (2018). Online learning in higher education: Exploring advantages and disadvantages for engagement. *Journal of Computing in Higher Education*, *30*, 452-465. https://doi.org/10.1007/s12528-018-9179-z

Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, *59*, 64-71. https://doi.org/10.1007/s11528-014-0822-x

Gursoy, M. E., Inan, A., Nergiz, M. E., & Saygin, Y. (2016). Privacy-preserving learning analytics: challenges and techniques. *IEEE Transactions on Learning technologies*, *10*(1), 68-81. https://doi.org/10.1109/TLT.2016.2607747

Guzmán-Valenzuela, C., Gómez-González, C., Rojas-Murphy Tagle, A., & Lorca-Vyhmeister, A. (2021). Learning analytics in higher education: a preponderance of analytics but very little learning?. *International Journal of Educational Technology in Higher Education*, *18*, 1-19. https://doi.org/10.1186/s41239-021-00258-x

Herodotou, C., Rienties, B., Boroowa, A., Zdrahal, Z., & Hlosta, M. (2019). A large-scale implementation of predictive learning analytics in higher education: The teachers' role and perspective. *Educational Technology Research and Development*, *67*, 1273-1306. https://doi.org/10.1007/s11423-019-09685-0

Hlosta, M., Zdrahal, Z., Bayer, V., & Herodotou, C. (2020). Why predictions of at-risk students are not 100% accurate? Showing patterns in false positive and false negative predictions. In *Proceedings of the 10th International Conference on Learning Analytics and Knowledge (LAK20), March 23-27, 2020, Frankfurt am Main, Germany*. ACM.

Karaoglan Yilmaz, F. G. (2022). Utilizing learning analytics to support students' academic self-efficacy and problem-solving skills. *The Asia-Pacific Education Researcher*, *31*(2), 175-191. https://doi.org/10.1007/s40299-020-00548-4

Kaspi, S., & Venkatraman, S. (2023). Data-driven decision-making (DDDM) for higher education assessments: A case study. *Systems*, *11*(6), 306. https://doi.org/10.3390/systems11060306

Li, W., Sun, K., Schaub, F., & Brooks, C. (2022). Disparities in students' propensity to consent to learning analytics. *International Journal of Artificial Intelligence in Education*, *32*(3), 564-608. https://doi.org/10.1007/s40593-021-00254-2

Naujokaitienė, J., Tamoliūnė, G., Volungevičienė, A., & Duart, J. (2020). Using learning analytics to engage students: Improving teaching practices through informed interactions. *Journal of New Approaches in Educational Research (NAER Journal)*, *9*(2), 231-244. https://doi.org/10.7821/naer.2020.7.561

Nistor, N., & Hernández-García, Á. (2018). What types of data are used in learning analytics? An overview of six cases. *Computers in Human Behavior*, *89*, 335-338. https://doi.org/10.1016/j.chb.2018.07.038

Ogata, H., Yin, C., Oi, M., Okubo, F., Shimada, A., Kojima, K., & Yamada, M. (2015). E-book-based learning analytics in university education. In *Proceedings of the 23rd International Conference on Computers in Education ICCE 2015: Main proceedings*. Asia-Pacific Society for Computers in Education.

Rienties, B., Herodotou, C., Olney, T., Schencks, M., & Boroowa, A. (2018). Making sense of learning analytics dashboards: A technology acceptance perspective of 95 teachers. *International Review of Research in Open and Distributed Learning*, *19*(5). 187-201. https://doi.org/10.19173/irrodl.v19i5.3493

Schumacher, C., & Ifenthaler, D. (2018). Features students really expect from learning analytics. *Computers in Human Behavior*, *78*, 397-407. https://doi.org/10.1016/j.chb.2017.06.030

Siemens, G. (2012). Learning analytics: Envisioning a research discipline and a domain of practice. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge* (pp. 4-8). https://doi.org/10.1145/2330601.2330605

Tsai, Y., Rates, D., Moreno-Marcos, P. M., Muñoz-Merino, P. J., Jivet, I., Scheffel, M., Drachsler, H., Delgado Kloos, C., & Gašević, D. (2020). Learning analytics in European higher education—Trends and barriers. *Computers & Education*, *155*, 103933. https://doi.org/10.1016/j.compedu.2020.103933

Tsai, Y. S., & Gasevic, D. (2017). Learning analytics in higher education – Challenges and policies: A review of eight learning analytics policies. In *Proceedings of the 7th International Learning Analytics & Knowledge Conference* (pp. 233-242). ACM. https://doi.org/10.1145/3027385.3027388

van Leeuwen, A. (2019). Teachers' perceptions of the usability of learning analytics reports in a flipped university course: When and how does information become actionable knowledge?. *Educational Technology Research and Development*, *67*, 1043-1064. https://doi.org/10.1007/s11423-018-09639-y

van Leeuwen, A., van Wermeskerken, M., Erkens, G., & Rummel, N. (2017). Measuring teacher sense making strategies of learning analytics: A case study. *Learning: Research and Practice*, *3*(1), 42-58. https://doi.org/10.1080/23735082.2017.1284252

Yin, R. K., & Davis, D. (2007). Adding new dimensions to case study evaluations: The case of evaluating comprehensive reforms. *New Directions for Evaluation*, *2007*(113), 75-93. https://doi.org/10.1002/ev.216

Development and Application of Intelligent Visual Sports Assessment and Teaching System

Yumei Zhang[1], Jianwen Fang[1], Xiangfeng Huang[2*]
[1] Department of Educational Technology, College of Education, Wenzhou University
[2] Wenzhou Education Technology Center
[*] 286998799@qq.com

Abstract: *With the national trend of promoting "Internet + education" and digital transformation, the integration of physical education and information technology has attracted much attention. How to use information technology to improve the teaching efficiency and quality of teachers, cultivate the core literacy of primary and secondary school students, and promote the comprehensive development of students' overall quality has become an urgent problem for educators. This study uses artificial intelligence algorithms, combined with machine vision technology, to design and develop an intelligent visual sports assessment and teaching system. It is hoped that through the development and application of the system, it will provide practical experience for the combination of physical education and artificial intelligence technology and promote the digital transformation of school physical education.*
Keywords: Smart Sports, Artificial Intelligence, Machine Vision, Physical Education

1. Introduction

Physical education is an important means of promoting the overall development of students' comprehensive qualities, and with the in-depth development of the new curriculum reform, physical education is required to be oriented towards the cultivation of students' core qualities. In recent years, to actively develop "Internet+Education" and promote the digital transformation of education, the national "Ten-Year Development Plan for Education Informatization (2011-2020)" puts forward that information technology should be integrated into education to promote the overall development of education quality. Nowadays, AI products are widely used in various fields of education, compared with traditional education, the integration of AI and education will bring a new mode of education development (Qu, Zhao et al., 2022), AI can help teachers to complete repetitive teaching tasks, related technology can create rich teaching scenarios (Chen, Chen et al., 2020). It can also improve the traditional manual evaluation of the effectiveness of physical education teaching, avoiding the problems of tediousness and error (YanRu 2021); in learning activities, the use of artificial intelligence can provide students with personalized learning and feedback, enhance students' learning experience, and promote personalized development (Maghsudi, Lan et al., 2021). Therefore, to promote the development of physical education in primary and secondary schools in China, the in-depth integration of artificial intelligence technology and school physical education teaching has become inevitable. However, for primary and secondary schools, the current application of smart sports systems is relatively limited, mostly based on smart wearable devices, which are overpriced and suffer from signal loss and lagging of the bracelet or device; secondly, most smart sports systems are based on monitoring and assisting in training, and lack of fun, which is an important factor affecting the long-term commitment and motivation of students and participants. Therefore, this study adopts artificial intelligence algorithms and machine vision technology to design and develop a smart visual sports evaluation and teaching system, which focuses on the following three aspects: (i) In the design of the smart sports system, the teaching scene is enriched due to the consideration of the diversity of the student's movement, and the interestingness of the scene is increased at the same time. (ii) The system should adopt standardized data formats and protocols to ensure that sports information from different sources can be interoperable and shared. It helps to integrate various types of data and improve the comprehensiveness and applicability of the system. (iii) Reduce the interference of equipment and adopt IoT cameras to realize the non-sensory collection of data, so that students can do physical exercise anytime and anywhere.

2. Design of Intelligent Visual Physical Education Assessment and Teaching System

Based on the in-depth insight and analysis of the campus sports scene and the status quo of sports teaching, this study finds that for students, the sports system needs to reduce the interference of the equipment on the students' movement, and increase the interactivity and interest of the system; for teachers, the system needs to be able to realize the demand of multiple scenarios of "teaching and practicing", and improve the comprehensiveness and flexibility of teaching; for school administrators, the system should be able to provide comprehensive data information on sports teaching. For teachers, the system should be able to realize the needs of multiple scenarios of "teaching and practicing" and improve the comprehensiveness and flexibility of teaching. Based on this, the Intelligent Vision Sports Assessment and Teaching System integrates machine vision and physical education in depth, through the Internet of Things camera and self-developed artificial intelligence motion vision algorithm, based on not destroying the original playground, the implementation of intelligent transformation of the playground, as shown in Figure 1. without affecting the students' normal physical exercise at the same time, real-time collection and analysis of the students' sports performance, posture and other indicators, assessment and guidance, and to achieve the following Automatic identification of sports performance, intelligent detection of illegal movements, precise analysis of movements and guidance and other functions. It covers the application scenarios of "teaching, physical testing, after-school practice, physical education examination" and so on, as shown in Figure 2.

Figure 1. Smart Playground

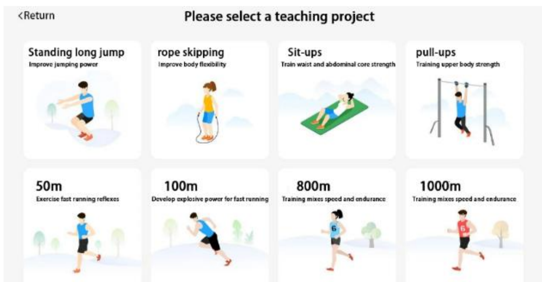


Figure 2. Teacher tablet

2.1. Core technologies

The core technology in the Intelligent Visual Sports Assessment and Teaching System mainly includes the following aspects:

(i) Intelligent Sensing Technology for IoT Cameras. The system uses IoT camera intelligent sensing technology to achieve sensorless collection of movement data and structured recording of the entire movement process. The application of this technology enables the system to accurately and real-time capture students' movement status, providing a high-quality database for subsequent analysis and evaluation.

(ii) Intelligent Motion Vision Analysis Algorithm Based on Deep Learning. With the help of deep learning artificial intelligence technology, the system adopts motion visual analysis algorithms with powerful video analysis and computation capabilities, which can accurately analyze students' movements and postures. Through deep learning, the system can continuously optimize its analysis model and gradually improve its accuracy.

(iii) More secure edge computing solutions. The system adopts an edge computing solution to collect, analyze, and process data all locally, effectively protecting students' privacy. Edge computing is more secure and avoids potential risks during data transmission, while improving the response speed of the system to ensure real-time and accuracy.

(iv) Standard visualization big data analysis and processing technology. The system utilizes standard visual big data analysis and processing technology to present the collected data in an intuitive form. This technology enables teachers and students to have a more intuitive understanding of exercise data, while the system can generate personalized exercise reports and prescriptions for students based on the analysis results. This helps to meet the diverse needs of physical education teaching and provides more targeted guidance and feedback.

The system subverts the product form based on infrared, pressure sensors, and other technologies as well as wearable devices, uses ordinary equipment and cameras for usual training to observe from afar, and allows students to complete various sports projects under the instruction of intelligent voice by providing intelligent voice and large screen interaction, automatically and accurately analyzes students' sports posture problems and gives them comments and suggestions, and real-time records and displays of relevant achievements and data to achieve the improvement of the Physical education teaching informatization level, to create a normalized, non-sensory, intelligent teaching scene.

2.2. System architecture and functionality

2.2.1. Two-tier architecture. The system is divided into two levels of architecture, school level, and district level, to generate real multi-dimensional big data and realize intelligent scientific decision-making, as shown in Figure 3.

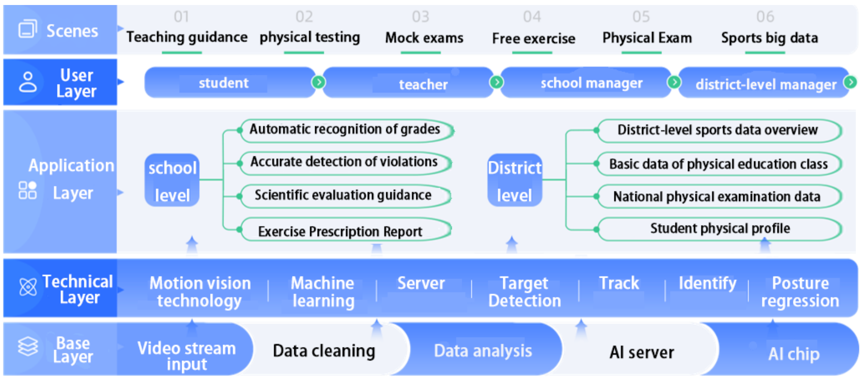


Figure 3. Intelligent Sports System

Deploying intelligent and visualized physical education teaching products at the school level provides a big data foundation for accurate measurement, multi-dimensional analysis, and unmanned intervention in the teaching process, which can effectively establish a model of students' physical fitness characteristics and scientifically promote the enhancement of students' physical fitness rate. Regional intelligent decision-making and evaluation system, from the district dimension, statistics on the rate of physical education classes, the length of classes, the number of classes, teachers, the overall situation of students' physical fitness and health, etc., and big data to support the scientific research and judgment, to realize the intelligent decision-making and evaluation at the regional level. It boosts interactive teaching and sports, elevating students' interest and skills in sports, while also focusing on enhancing their physical literacy and promoting healthy lifestyles. Addressing the imbalance between physical fitness and cultural literacy among youth, fills the gap in digital resources for physical education, thus aligning with the national sports strengthening strategy (Jia and Li 2021).

2.2.2 System functions. Intelligent Visual Sports Assessment and Teaching System can meet the whole scenario of "teaching, practicing, testing and evaluating" support for school sports, with intelligent teaching, free practice, intelligent physical testing, simulated examination, fun sports, and comprehensive evaluation functions. The details are as follows:

(i) Intelligent teaching. The system provides intelligent voice and big screen interaction, automatically sends out instructions for students to complete sports training and testing, captures students' sports posture, and gives comments and suggestions through the camera, and the teacher can analyze and explain the refined movements of the whole class through the results and data displayed on the big screen.

(ii) Free exercise. This module does not require any access guidance from the teacher, and students can go to exercise after class through face recognition self-help, and autonomy. In this mode, after students match personal information, the test data are retained, and participate in the real-time refreshment of the performance ranking, to enhance the interest of students' sports.

(iii) Intelligent physical testing. The smart playground covers all primary and secondary school testing programs. It establishes a data model based on the National Physical Fitness Standard for Students, automatically calculates the scores and grades of the physical test, and automatically enters all the scores. After the test, the student's physical test results are visualized, analyzed, and presented, providing decision-making support for physical education.

(iv) Simulated exams. In this mode, the information-based testing equipment acts as an electronic examiner, enabling students to simulate and adapt to the examination environment in advance. Intelligent recognition of illegal actions through the system makes the students' test results fairer.

(v) Fun Sports. This module provides a variety of fun game activities, including ball games, athletics, rope skipping, and physical fitness. By playing games to enhance students' interest, it allows students to participate more actively in sports activities and also promotes the interaction and communication between teachers and students.

(vi) Comprehensive evaluation of students. The system will automatically generate a personal performance report and a comprehensive quality evaluation of sports for each student. Through regularized process evaluation of students, it focuses on students' vertical improvement, assists students in using data to summarize their progress, and makes the comprehensive and complex sports data visual and intuitive.

3. Application and Feedback of the Intelligent Visual Physical Education Assessment and Teaching System

To explore the application of the Intelligent Visual Physical Education Assessment and Teaching System in experimental teaching and learning, a total of 36 students in grades 4, 5, and 6 of an elementary school were interviewed to support the development and improvement of the intelligent physical education system. The interviewed students of the school unanimously recognized that the system had helped them in sports. The reason was that students generally believed that the platform could improve the fun of physical education classes, especially jumping rope and running and students' results would be displayed on the school-wide sports ranking list, which brought them a sense of challenge and competition, prompting their classmates to be more active in sports activities and gradually fall in love with sports. Secondly, the instant feedback of the system helps them better understand their achievements and shortcomings in sports, and through the flashback of sports videos, they can continuously adjust their movements and postures, which enhances their knowledge of their performance. In addition, students also reported that the competitive sports activities provided by the system could promote interpersonal interactions. However, at the same time, they also raised the problems of "insufficient recognition accuracy" and "delayed counting of rope skipping" in the current system, and expressed the hope that some voice interactions could be added, such as motivational language after exercise.

Overall, the students were positive about the application of the system in physical education classes, but they also pointed out problems such as recognition accuracy and counting delays, which are conducive to further improvement of the system.

4. Conclusion

Integrating intelligent physical education and artificial intelligence technology, this study realizes an exploration and practice in the field of physical education. Supported by artificial intelligence technology, the intelligent visual sports evaluation and teaching system provides full-scene support for school sports "teaching, practicing, testing and evaluating". Through the introduction of machine vision and artificial intelligence algorithms, we have not only given the playground "wisdom", but also injected new vitality and possibilities into physical education. The system has also received positive feedback in teaching and learning. Although there are some problems in the initial application, students generally express their expectations for learning with the system, which provides a solid impetus and direction for future development. In the process of promoting the digital transformation of school physical education, the use of artificial intelligence technology will continue to play an important role.

References

Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. *Ieee Access*, 8, 75264-75278. https://doi.org/10.1109/access.2020.2988510

Jia, J., & Li, B. (2021). Physical health of teenagers and the biological characteristics affecting sports-related physical fitness. *Network Modeling Analysis in Health Informatics and Bioinformatics*, *10*(1). https://doi.org/10.1007/s13721-021-00291-w

Maghsudi, S., Lan, A., Xu, J., & van der Schaar, M. (2021). Personalized Education in the Artificial Intelligence Era: What to Expect Next. *IEEE Signal Processing Magazine*, *38*(3), 37-50. https://doi.org/10.1109/msp.2021.3055032

Qu, J., Zhao, Y., & Xie, Y. (2022). Artificial intelligence leads the reform of education models. *Systems Research and Behavioral Science*, *39*(3), 581-588.https://doi.org/https://doi.org/10.1002/sres.2864

YanRu, L. (2021). An artificial intelligence and machine vision based evaluation of physical education teaching. *Journal of Intelligent & Fuzzy Systems*, *40*(2), 3559-3569. https://doi.org/10.3233/JIFS-189392

Undergraduates' Perceived Difficulty, Motivating Goal-directed Affect, Epistemic Emotions and Problem-Solving in Collaborative Interdisciplinary Learning

Gaoxia Zhu, Mengyu Lim, Xiuyi Fan, Chenyu Hou, Guangji Yuan, Nanyang Technological University
gaoxia.zhu@nie.edu.sg, mengyu001@e.ntu.edu.sg, xyfan@ntu.edu.sg, chenyu004@e.ntu.edu.sg, guangji.yuan@nie.edu.sg
Atiqah Azhari, Singapore University of Social Sciences, atiqah@suss.edu.sg

***Abstract**: Empirical evidence on students' perceived difficulty of interdisciplinary learning and associated experience is limited. This study aimed to address the gap in an interdisciplinary digital literacy course. The class activities were designed based on the characteristics of interdisciplinary learning tasks, such as the problem originating from the real world, and surveys were collected over eight weeks. Our findings indicate that surprise, curiosity, confusion, anxiety, joy, and frustration are positively associated with motivating goal-oriented affect, suggesting that students were actively engaged and motivated when they experienced various positive and negative emotions. Motivating goal-directed affect positively predicts students' collaborative interdisciplinary problem-solving, while confusion and boredom play negative roles, highlighting the need to enhance students' motivation and address negative emotions to facilitate interdisciplinary learning.*
Keywords: interdisciplinary learning, emotion, motivating goal-directed affect, collaborative interdisciplinary problem solving, undergraduate

Introduction

Tackling practical issues in the real world demands not only technical abilities but also the capacity to work effectively with others and to maneuver through various domains of knowledge. One effective method to develop these abilities and capacities is to embed real-world, professional, and societal challenges into educational settings through interdisciplinary learning (Hains-Wesson & Ji, 2020). Typical interdisciplinary learning tends to share some characteristics: (1) the integration of several disciplinary elements; (2) members' collaborative contribution to shared goals; (3) designing novel solutions or new ideas using knowledge, methods, and insights across disciplinary boundaries; (4) identifying new problems, explain a phenomenon, solve a problem, or design a product (Klaassen, 2019; MacLeod & van der Veen, 2020). Growing evidence underscores the advantages of such an educational approach, highlighting its role in enhancing the organization of knowledge among learners, boosting critical thinking, metacognitive abilities, and cooperative skills, as well as aiding in the application of knowledge and skills to address real-life problems or challenges (Ivanitskaya et al., 2002).

Managing tasks across various fields and interacting with team members from different areas is complicated (Abbonizio & Ho, 2020). As a result, students might face unique difficulties in interdisciplinary learning for several reasons. First, they have difficulty engaging with multiple disciplines simultaneously and are often constrained by a single disciplinary framework of thinking (Lindvig & Ulriksen, 2019). Second, the assumption of too much prior disciplinary knowledge may confuse them because they enter the classroom with varying levels of prior knowledge (Abbonizio & Ho, 2020). Third, they may find group work "unstructured" compared to specialized, individualized learning (Boyer & Biop, 2004).

As a form of learning, interdisciplinary learning involves learners' social, psychological, emotional and academic experiences. Cognitive theories generally consider learning as a proactive, goal-driven activity (Schuell, 1986), highlighting the role of motivating goal-direct affect in the learning process. Considering the difficulties of interdisciplinary learning, motivating goal-directed affect is particularly important because it can be a source of learners' engagement in course materials (Robinson, 2013). Recent studies have acknowledged the relationships between emotions and students' motivations, social interactions, and cognitive functions (Pekrun et al., 2017). Epistemic emotions are directly related to the knowledge-generating processes during cognitive activities (Pekrun et al., 2017). Students' appraisal of cognitive incongruity between their existing knowledge and new information may trigger curiosity and surprise (Kang et al., 2009). If the incongruity can be resolved, students may experience positive emotions like joy; otherwise, they may experience confusion, frustration and boredom. When the incongruity is severe, students may experience anxiety (D'Mello et al., 2014).

Save for a recent study by Malmberg and colleagues (2022), who found correlations between physiological arousal and perceived task difficulty, most existing literature in this area has relied on qualitative interviews. A lack of empirical studies poses a challenge in quantifying if the added difficulty in interdisciplinary learning is still manageable for the students or if extra support needs to be provided. This research also explores the relationships among these elements to identify which aspects might pose greater challenges and how various factors contribute to students' collaborative problem-solving in interdisciplinary settings. We aim to answer:

1. How are students' perceived difficulty associated with epistemic emotions, motivating goal-directed affect and collaborative interdisciplinary problem-solving?
2. What contributes to undergraduates' collaborative interdisciplinary problem-solving?

Methods

Participants and Research Design

This investigation involved 44 first-year students enrolled in a digital literacy course at an Asian public university. These students were from various faculties, including Business, Education, and Computer Science, spanning ten schools. Their ages ranged between 18 and 25 years old. To promote interdisciplinary learning, the course instructor assigned students from diverse academic backgrounds into groups of four to six. The study received approval from the Institutional Review Board of the researchers' institution, and consent forms were obtained from all participants prior to their assignment into groups.

The digital literacy course was open to all undergraduate students at the university. It covered eight weekly topics, such as Computational Thinking, Quantitative Reasoning, and Blockchain. A flipped classroom learning approach was taken in course delivery. Before class, the students were asked to watch an hour-long pre-recorded video and complete a short test. In class, they participated in 90-minute group problem-solving activities and presented their work each week. The weekly group activities have the following characteristics:

1. Creating real-world scenarios, for example, "Your team is a panel of interdisciplinary advisors providing real estate consultancy services. Providing reliable consultancy requires your group to understand the latest real estate trends by studying the latest data."
2. Encouraging collaborative contributions from various disciplines: Depending on the schools you come from, you will take different roles and perspectives (e.g., business, technological, scientific investigation, societal and education perspectives).
3. Making authentic cognitive advancements, including explaining a phenomenon, resolving a problem, or creating a product. For example, as shown in Appendix A (hyperlink), the redesigned task requires groups to solve authentic and real-world issues because when buying flats, families not only consider "best economic value" but often consider whether flats meet their needs, such as the number of rooms and location.

Data Collection and Analysis

Participants completed a survey each week towards the end of the 90-minute classroom group work. The weekly survey measures four constructs: perceived task difficulty, motivating goal-directed affect, epistemic emotions, and collaborative interdisciplinary problem-solving. Perceived task difficulty was measured using a single item, "Please rate how difficult the tutorial was," on a 7-point Likert scale (1 denotes not difficult at all, 7 represents extremely difficult). Motivating goal-directed affect was measured by asking the participants the extent to which they had felt active, determined, attentive, inspired and alert during the learning process on a 5-point Likert scale. The items were adapted from the Positive and Negative Affect Scale (Watson et al., 1988). In this study, Cronbach's alpha was 0.93 for motivating goal-directed affect, suggesting good internal consistency of the five items. Epistemic emotions were measured by asking the extent to which they had felt surprised, curiosity, confused, anxiety, joy, frustration and boredom, adapted from the Epistemically Related Emotions Scale (Pekrun et al., 2017). Participants indicated the intensity of epistemic emotions on a 5-point Likert scale (0 = not at all, 5 = extremely).

Participants' collaborative interdisciplinary problem-solving was measured based on their agreement with three statements (e.g., "I investigated an issue with my team to find an acceptable solution"; "I integrated my ideas with my team to come up with a joint decision") on a 7-point Likert scale. The items were adapted from the Integration subscale of the Team Collaboration Questionnaire (Cole et al., 2018). In this study, Cronbach's alpha was 0.91 for collaborative interdisciplinary problem-solving, suggesting good internal consistency of the three items.

We conducted correlation analyses to answer the first research question on the correlations between the key constructs. To address what predicts students' collaborative interdisciplinary problem-solving, we conducted multiple linear regression using the perceived difficulty, motivating goal-directed affect, and all epistemic emotions as independent variables.

Results

Correlations between perceived difficulty and other variables

Table 1 shows the descriptive statistics of key research variables and their correlations. We found that students' perceived difficulty is positively correlated with negative emotions such as confusion, anxiety, frustration, and boredom. Perceived difficulty also negatively correlates with motivating goal-directed affect. Surprisingly, curiosity and joy are positively associated with motivating goal-directed affect and collaborative interdisciplinary problem solving. Confusion anxiety, and frustration are positively correlated with motivating goal-directed affect but negatively correlated with collaborative interdisciplinary problem solving. Motivating goal-directed affect and collaborative interdisciplinary problem-solving are positively associated.

Table 1 Descriptive statistics of key research variables

	1	2	3	4	5	6	7	8	9	10
1. DIFF										
2. SUR	0.15*									
3. CUR	-0.05	0.68***								
4. CON	0.35***	0.45***	0.30***							
5. ANX	0.34***	0.46***	0.28***	0.76***						
6. JOY	-0.03	0.67***	0.63***	0.24***	0.30***					
7. FRU	0.35***	0.42***	0.29***	0.78***	0.80***	0.32***				
8. BOR	0.23***	0.22***	0.05	0.50***	0.61***	0.14*	0.64***			
9. GOAL	-0.14*	0.60***	0.74***	0.18**	0.21**	0.74***	0.24***	0		
10. INTERD	-0.13	0.21**	0.41***	-0.17**	-0.13*	0.33***	-0.11	-0.26***	0.51***	
M	4.28**	3.01	3.34	2.57	2.27	3.23	2.20*	2.33**	3.49	5.51
SD	1.28	1.08	0.96	1.24	1.18	1.03	1.14	1.06	0.80	1.07

Note. DIFF: Difficulty; SUR: Surprise; CUR: Curiosity; CON: Confusion; ANX: Anxiety; JOY: Joy; FRU: Frustration; BOR: Boredom; GOAL: Motivating goal-directed affect; INTERD: Collaborative interdisciplinary problem solving

Prediction of students' collaborative interdisciplinary problem solving

Table 2 illustrates the factors that predict the perceived collaborative interdisciplinary problem-solving of students. The collaborative interdisciplinary problem-solving outcomes are influenced by the combined effects of students' motivating goal-oriented affect, confusion and boredom, accounting for a total of 37.9% (R^2 = .379**95% CI[.26, .44]) variance. Specifically, incrementing one unit in motivating goal-oriented affect results in a corresponding 0.62 increase in collaborative interdisciplinary problem-solving. In contrast, an increase in confusion by one unit leads to a decrease of 0.20 in collaborative interdisciplinary problem-solving, and an increase in boredom by one unit leads to a 0.16 decrease.

Table 2. Regression results with collaborative interdisciplinary problem-solving as the dependent variable

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*
(Intercept)	3.49**	[2.74, 4.24]					
Difficulty	0.05	[-0.05, 0.15]	0.06	[-0.06, 0.18]	.00	[-.01, .01]	-.13
Motivating goal-directed affect	0.62**	[0.37, 0.88]	0.47	[0.28, 0.66]	.07	[.01, .12]	.52**
Surprise	-0.06	[-0.23, 0.12]	-0.06	[-0.23, 0.12]	.00	[-.01, .01]	.22**
Curiosity	0.19	[-0.01, 0.38]	0.17	[-0.01, 0.35]	.01	[-.01, .03]	.40**
Confusion	-0.20*	[-0.37, -0.04]	-0.23	[-0.42, -0.05]	.02	[-.01, .04]	-.17**
Anxiety	-0.03	[-0.21, 0.15]	-0.03	[-0.23, 0.17]	.00	[-.00, .00]	-.14*
Joy	0.02	[-0.17, 0.20]	0.02	[-0.16, 0.19]	.00	[-.00, .00]	.35**
Frustration	0.03	[-0.17, 0.23]	0.03	[-0.19, 0.24]	.00	[-.00, .00]	-.12
Boredom	-0.16*	[-0.31, -0.02]	-0.16	[-0.31, -0.02]	.01	[-.01, .04]	-.26**

Discussion and Conclusion

This study examined the correlations between undergraduates' perceived difficulty, motivating goal-directed affect, epistemic emotions, and collaborative interdisciplinary problem-solving, and what predicts their problem-solving. We analysed 229 weekly surveys collected from 44 participants to answer these research questions. Several findings are worth further discussion.

Goal-directed affect is strongly positively associated with collaborative interdisciplinary learning, and positively activating epistemic emotions such as surprise, curiosity, and joy; it has weak positive correlations with confusion, anxiety and frustration. Negative activating emotions, confusion, anxiety and frustration could promote cognitive and metacognitive learning (D'Mello & Grasser, 2011). In the context of collaborative interdisciplinary learning, students might experience confusion when they have cognitive incongruity, frustration if they are unable to resolve the incongruity, and anxiety if they repeatedly fail (D'Mello et al., 2014). These associations might signify that students were actively engaged in and trying to resolve difficult tasks and conflicting ideas. Confusion, anxiety and frustration also significantly positively correlated with joy and curiosity, suggesting that negative emotions co-occur with joy and curiosity, which can benefit students' collaborative interdisciplinary problem-solving. We could conclude that the tasks led them to experience both positive and negative activating emotions.

We found that motivating goal-directed affect, confusion and boredom can explain a portion of the variance in collaborative interdisciplinary problem-solving. Kuo et al. (2019) found that a course designed based on the STEM Interdisciplinary Project-based Learning approach significantly improved college students’ learning motivation but did not research how motivation influenced interdisciplinary learning. Ruiz-Molina and Cuadrado-Garcia (2004) found positive relationships between students’ participation, motivation and performance in an interdisciplinary course. Previous studies also tend to suggest a negative association between boredom and academic results, as suggested by a meta-analysis of 68 empirical studies conducted by Camacho-Morles et al. (2021). The relationship between confusion and learning can be more complex as confusion signals a cognitive disequilibrium state and can lead to positive learning outcomes if resolved appropriately but to undesirable outcomes if it persists (D’Mello et al., 2014). Overall, the results suggest the importance of engaging students in interdisciplinary learning and supporting them in addressing negative emotions timely.

The results notwithstanding, some limitations of the current study should be noted. Firstly, due to sample size constraints, statistical analyses could not detect smaller effect sizes. Additionally, there were missing responses from participants across weeks. Future studies could adopt a larger sample size to account for potential participation attrition and missing data. Secondly, as the study design used repeated measures (implementing the same questionnaires every week), we collected multiple observations from a single student, resulting in a nested data structure. In the above analyses, each observation was treated as an independent data point, which does not account for the nested nature of the dataset. Finally, this preliminary investigation employed a solitary item for gauging both perceived difficulty and distinct epistemic emotions. While previous research (e.g., Fisher et al., 2016) has proposed the use of single-item measures as an alternative to multi-item ones in cases of minimizing the workload on students, forthcoming research could enhance its robustness by incorporating multiple-item assessments for these variables, thus ensuring a satisfactory level of internal consistency.

Selected References

Abbonizio, J. K., & Ho, S. S. (2020). Students' perceptions of interdisciplinary coursework: an Australian case study of the master of environment and sustainability. *Sustainability, 12*(21), 8898.

Boyer, S. J., & Bishop, P. A. (2004). Young adolescent voices: Students' perceptions of interdisciplinary teaming. *RMLE Online, 28*(1), 1-19.

Camacho-Morles, J., Slemp, G. R., Pekrun, R., Loderer, K., Hou, H., & Oades, L. G. (2021). Activity achievement emotions and academic performance: A meta-analysis. *Educational Psychology Review, 33*(3), 1051-1095.

Cole, M. L., Cox, J. D., & Stavros, J. M. (2018). SOAR as a mediator of the relationship between emotional intelligence and collaboration among professionals working in teams: Implications for entrepreneurial teams. *SAGE Open*, *8*(2), 2158244018779109.

D’Mello, S. K., Lehman, B., Pekrun, R., & Graesser, A. C. (2014). Confusion can be beneficial for learning. *Learning and Instruction*, 29, 153–170.

Fisher, G. G., Matthews, R. A., & Gibbons, A. M. (2016). Developing and investigating the use of single-item measures in organizational research. *Journal of Occupational Health Psychology*, *21*(1), 3.

Hains-Wesson, R., & Ji, K. (2020). Students' perceptions of an interdisciplinary global study tour: uncovering inexplicit employability skills. *Higher Education Research & Development*, *39*(4), 657-671.

Ivanitskaya, L., Clark, D., Montgomery, G., & Primeau, R. (2002). Interdisciplinary learning: Process and outcomes. *Innovative Higher Education*, *27*(2), 95-111.

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T. Y., & Camerer, C. F. (2009). The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science*, *20*(8), 963-973.

Klaassen, R., De Fouw, N., Rooij, R., & van der Tang, Y. (2019, December). Perceptions of Interdisciplinary Learning: A qualitative approach. In *Proceedings of the 8th Research in Engineering Education Symposium*, REES, Perth, Australia (pp. 5-8).

Kuo, H. C., Tseng, Y. C., & Yang, Y. T. C. (2019). Promoting college student’s learning motivation and creativity through a STEM interdisciplinary PBL human-computer interaction system design and development course. *Thinking Skills and Creativity*, *31*, 1-10.

Lindvig, K., & Ulriksen, L. (2019). Different, difficult, and local: A review of interdisciplinary teaching activities. *The Review of Higher Education, 43*(2), 697-725.

MacLeod, M., & van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: a case study. *European Journal of Engineering Education*, *45*(3), 363-377.

Malmberg, J., Haataja, E., & Järvelä, S. (2022). Exploring the connection between task difficulty, task perceptions, physiological arousal and learning outcomes in collaborative learning situations. *Metacognition and Learning*, 1-19.

A Blended Learning Environment Design Based on Conceptual Change and Constructivism

Yao, Wang[1], Qiyun Wang[2*]
[1] National Institute of Education, Nanyang Technological University, Singapore
[2] National Institute of Education, Nanyang Technological University, Singapore
[*] qiyun.wang@nie.edu.sg

Abstract: *This paper presents a blended learning environment designed based on conceptual change and constructivist principles. The constructivist perspective emphasizes the critical role of conceptual change in the active construction of knowledge by students. Conceptual change is a significant alteration of cognitive structure due to inconsistency with previous experience, usually caused by cognitive conflict. During the learning process, new concepts can challenge and modify established ones, contributing to the transformation and reconstruction of students' understanding. However, current science curriculum design has several issues. These include ignoring students' existing conceptual and cognitive levels, a lack of individualized instruction, and a lack of focus and coherence in curriculum design. To tackle these issues, the study proposes a blended learning environment based on constructivism, which aims to provoke cognitive conflict among students throughout the learning process. Reorganizing instructional tasks and offering technical assistance to teachers and students integrates online and offline learning to facilitate students' constructing a more profound comprehension of scientific knowledge. This design aims to offer a personalized approach to teaching and learning, promoting students' deeper understanding and reconstruction of scientific concepts. It provides valuable insights and guidance for enhancing the design of science curricula.*

Keywords: blended learning environment, conceptual change, constructivism

1. Introduction

Individuals develop their understanding and perception of the world through experience and reflection. When encountering new concepts or perspectives, they must reconcile them with their previous knowledge. It is essential to avoid biased, emotional, figurative, or ornamental language and to use clear, objective, and value-neutral language. This involves questioning, exploring, engaging in dialogue with others, and reassessing their current knowledge. Consequently, individuals play an active role in creating and constructing their knowledge (Harasim, 2018).

According to the constructivist perspective, conceptual change is critical in students' active knowledge construction. Conceptual change is a significant alteration in cognitive structure resulting from inconsistencies with previous experience, typically caused by cognitive conflict. During the learning process, new concepts challenge and modify pre-existing concepts, transforming and reconstructing students' understanding.

In daily life, individuals form pre-concepts, particularly regarding scientific concepts. These pre-concepts, shaped by direct senses and life experiences, often differ from factual concepts. Altering these pre-concepts can be challenging and affect the construction of accurate concepts. Therefore, in science education, the promotion of conceptual change and the design of classes based on cognitive conflict are topics of great concern in educational practice. However, the current science lesson design still has some issues.

Firstly, it overlooks students' pre-existing concepts and cognitive levels, resulting in a lack of personalized teaching and failure to meet students' diverse needs and comprehension levels. Secondly, the curriculum design lacks a focus on big ideas, and the lessons are not effectively linked, preventing students from establishing a coherent knowledge network. Thirdly, the teacher has not effectively guided students toward a deep understanding of the concepts, resulting in a superficial understanding of science. Any cognitive conflict generated should be addressed. This may cause students to revert to their previous misconceptions. Finally, students lack sufficient time and opportunities to explore beyond the classroom. Fixed classroom hours and poorly organized activities can result in teachers having to overlook or simplify certain aspects of the content.

This study proposes a constructivist blended learning environment based on conceptual changes to address this issue. The emphasis is on stimulating students' cognitive conflict during the learning process. By rearranging instruction distribution and providing technical support to teachers and students, we can combine online and offline learning to help students construct a deep understanding of scientific knowledge.

2. Theories Framework

2.1. Constructivism

Constructivism is a learning theory that emphasizes the active construction of new knowledge by individuals, in which students can actively construct new knowledge based on their prior experiences and knowledge. While behaviorism focuses on external stimuli, cognitivism neglects the social context's role on the individual. Constructivism compensates for the limitations of behaviorism and cognitivism by acknowledging the importance of the learning environment and social context in the individual's learning process. Schcolnik et al. (2006) claim that the teacher's role is not simply to impart knowledge onto a blank slate but to facilitate the construction of new knowledge. This approach rejects the notion of the mind as an empty vessel to be filled with knowledge. Similarly, Brown et al. (1989) believe that learners' knowledge is developed through participation in activities, their surroundings, and their cultural context.

The application of constructivism in education is primarily based on cognitive and social constructivism. Cognitive constructivism is founded on Piaget's theory of cognitive development, which explains that learners must construct their knowledge through experience. An imbalance can occur when we encounter experiences or situations that challenge our way of thinking. To restore balance, we must change our thinking by absorbing new information (Fosnot, 1989).

Therefore, teachers can facilitate this process by developing tasks and dilemma problems, and students can go through the cognitive stages of direct experience, errors, and searching for solutions to achieve assimilation and accommodation. Knowledge acquisition arises from the actions that learners take to solve tasks. Common practices involve learning through the discovery and manipulation of objects. Additionally, contemporary technologies, such as databases, simulators, and microfilms, provide a broader range of possibilities (Maruntelu, 2020).

Vygotsky views learning as a social process. Learners interact with their environment and discover the roots of personal knowledge before internalizing it (Roth, 1999). Children acquire scientific concepts in the narrow space between life experience and adult concepts. It also suggests that if concepts from the adult world are presented directly to the child, the child can only memorize everything from the adult's perspective on that concept. Constructivist perspectives share a fundamental belief: learners actively construct their knowledge instead of receiving it passively.

To achieve this goal, it is necessary to make significant changes to curriculum emphases, classroom interactions, and classroom dynamics. School learning should occur in meaningful contexts that cannot be separated from students' real-world acquisition of knowledge and experience. Students construct individual experiences and collaborations through asynchronous online communication with learning content and electronic and printed texts and ultimately gain knowledge (Maruntelu, 2020). Constructivism-based blended learning is highly suitable for online learning today as it enhances the meaningfulness of the learning experience (Syarifuddin et al., 2021).

Gharacheh et al. (2016) conducted qualitative research to investigate the capabilities and characteristics of blended learning and social constructivism theory. It provides access to content and educational resources, flexibility, the possibility of receiving timely feedback, support richness of the learning environment, and the possibility of lifelong study. The results showed that this learning model emphasizes active learning and various interactions and communication. The findings align with Al-Huneidi and Schreurs (2012) study, which examined integrating constructivism and conversation theories within blended learning environments. The case study results illustrated that the Constructivism-based blended learning model actively engages students as knowledge constructors, incorporating diverse learning activities and fostering heightened communication and interaction among students, improving learning quality, experience, and outcomes.

Capone’s (2022) study combined just-in-time teaching with a blended online and social platform named Edmodo. They chose Edmodo because it has a user-friendly interface and can be easily accessed through mobile phones. The student report indicated that students were enthusiastic about using technological tools, and their performance improved. To enhance the blended learning material, Lee (2020) utilized a student-centered approach based on constructivist learning to design an online module focusing on GI pharmacology. This study especially demonstrates a creative approach by incorporating students' feedback to guide the implementation of a constructivist framework. Most students were satisfied with the module, indicating it has improved learning effectiveness, learning efficiency, and self-efficacy.

2.2. Conceptual Change

Conceptual change should not be reduced to a simple exchange of concepts. Instead, old concepts are replaced with new ones. The theory of assimilation and accommodation proposed by Piaget traces back to the origins of conceptual change. Posner et al. (1982) developed the Conceptual Change Model (CCM), which posits that learning is a rational activity and that new concepts are accepted because they are understandable and sensible. Students must make judgments based on available evidence. The learning process involves conceptual change rather than acquiring a fixed set of correct answers, words, or behaviors. The model emphasizes how students' preconceptions change under the influence of new ideas and evidence, with particular emphasis on the impact of cognitive conflict on conceptual change (White & Gunstone, 2014).

Cognitive conflict is the catalyst for conceptual change when students are counteracted by information inconsistent with their beliefs. It involves presenting students with a counterintuitive and puzzling situation that creates discrepancies between their expectations and observations (Baddock & Bucat, 2008). Students who experience conflict tend to become psychologically uncomfortable and are motivated to try to reduce this conflict (Hirashima & Horiguchi, 2016).

Potvin et al. (2015) hold that misunderstandings must be thoroughly examined and either discarded, modified, replaced, reorganized, eliminated, or rejected. However, it is essential to note that not all pre-concepts are replaced during the conceptual change process. Eliminating pre-concepts can be challenging, and researchers have proposed two theories to explain this phenomenon: conceptual inhibition theory and coexistence theory (Dawson, 2014). Pre-concepts can be either forward or backward. If a pre-concept does not appear to solve new problems, it will likely be rejected. On the other hand, a competing pre-concept is accepted when it seems capable of solving these problems and leading to fruitful directions in the future.

Fosnot (1989) emphasizes in the definition of constructivism that new ideas arise as individuals adapt and change their old ideas. Meaningful learning occurs through rethinking old ideas and arriving at new conclusions about new ideas that conflict with our old ideas.

In the case of scientific concepts, conceptual change involves revising the original intuitions about scientific phenomena triggered by cognitive conflict. Therefore, pre-existing concepts that align with scientific concepts can facilitate students' learning of new scientific concepts. In contrast, pre-existing concepts that conflict with scientific concepts can hinder students' understanding of scientific concepts. However, this hindering effect is not absolute or entirely negative. The class design should prioritize emphasizing and enlarging students' cognitive conflict, and teachers should take advantage of this hindering effect, consider the logic behind students' cognitive conflict, and utilize it.

One of the most common conceptual change instructional strategies implemented in the classroom is to induce cognitive conflict by presenting anomalous data or contradictory information (Limón, 2001). However, there is limited evidence on the effectiveness of teaching informed by the practice of learning conceptual change in regular classrooms (Widodo et al., 2017). Haqqo et al. (2023) conducted a study to investigate conceptual changes in students' understanding of material momentum and impulses. They compared the results with those of students who did not use video learning, finding variations in the levels of understanding ranging from specific misconceptions to a solid grasp of the concepts. They suggested that teachers enhance students' conceptual understanding of physics by incorporating phenomenon-based learning into blended learning approaches. Therefore, embedding conceptual change strategies in a supportive learning environment with additional features may be effective (Dewi et al., 2022).

3. Design of the Blended Learning Environment

To tackle the issues of science classroom design mentioned earlier, we combine learning environment design with constructivism and conceptual change.

The instructional design of the science class emphasizes that students construct scientific knowledge through experimentation, observation, and inquiry rather than simply receiving abstract knowledge from textbooks. Through practical experience and predictive interpretation, students can gradually comprehend the nature and principles of scientific concepts and develop their scientific knowledge system.

Therefore, from a constructivist perspective, an effective learning environment should be centered around the student, encouraging active participation and collaborative learning. It is vital to create meaningful contexts that are closely related to the real world. The importance of conceptual change as a principle of the constructivist process should be emphasized. It is not sufficient for students to simply acquire a new concept, the process of concept formation, which can become blurred and forgotten over time, must also be emphasized. Therefore, in combination with the characteristics of scientific concepts, the design of this environment highlights the revelation of pre-existing concepts, cognitive conflict, questioning, and inquiry. Finally, the concept is further reinforced through practical application.

The proposed design of the learning environment is shown in Figure 1.

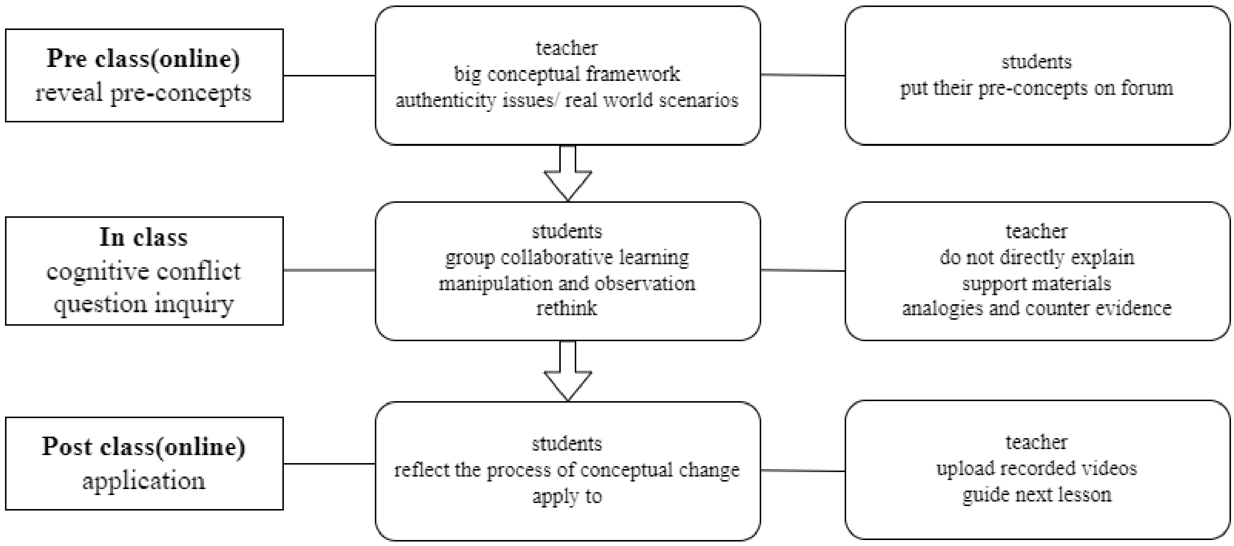


Figure 1. Blended learning environment.

3.1. Pre Class

Fragmented concepts are not woven into a coherent system, and isolated pieces of knowledge are difficult to change because the pieces are not connected (diSessa, 2013).

Therefore, building an extensive conceptual framework is necessary to integrate and structure these concepts. For example, in the science curriculum, weather and plants may appear to be separate topics, but a larger theme can link them. These two topics can be taught through the environment we live in. From what conditions do plants need to grow? So why does weather affect plant growth? This requires teachers to take a holistic view of the curriculum and help students develop a complete conceptual system.

Before class, students have their understanding of scientific phenomena from life experiences and direct observation. Therefore, introducing topics emphasizes authenticity by linking them to real-life scenarios and providing guiding questions or tasks to be solved. This approach helps students to connect their learning to real-life situations and creates teaching scenarios that activate their pre-existing knowledge. Teachers can post questions or scenarios on online forums and provide constructive scaffolding. The scaffolding sentences that teachers can use are shown in Table 1.

It is not that students sometimes do not understand new concepts but that they understand them differently from the teacher. This session maximizes the exposure of students' pre-concepts. The teacher understands the students' cognitive level and analyses the reasons for the students' pre-concepts. It can better provide the fulcrum for eliciting students' conceptual change and implementing personalization instruction during the lesson.

Table 1. Scaffolding structure

Period	Scaffolding
Pre-class	I have seen this phenomenon in …
	My opinion is …
	I used … to prove my point
In class	I have observed …. phenomenon, which is different from what I thought before; the difference is ….
	I think the reason for this change is ….
	I didn't know …. /overlooked …. before
	I still need to understand ….
Post-class	Teachers can provide scaffolding for construction.
	My opinion about …. has changed and I have the same idea about ….
	There are similar phenomena in life ….
	I think this concept can be applied to ….
	I still have problems with ….
	I have also thought about ….

3.2. In Class

In the pre-lesson, the students' preconceptions are collected. During the face-to-face lesson, the focus is on eliciting cognitive conflict and achieving conceptual change through questioning and inquiry. Scientific concepts are verifiable and interpretable through experimental observation. Teachers can conduct collaborative learning in groups based on students' preconception levels. Students are more likely to accept explanations and help from their peers. During pre-class, students make predictions. In class, the group collaborates on experimental manipulations and observations. If the experimental results do not match the predictions, the teacher does not immediately explain the phenomena or results but instead guides the students to rethink their misconceptions. The teacher guides and facilitates this process, providing support materials such as videos and models when necessary. Teachers can use appropriate analogies or counterevidence to guide students in questioning and investigating for concepts that cannot be observed experimentally. For instance, a student suggested that all plants can photosynthesize, but what about plants in the deep sea?

3.3. Post Class

Students are responsible for organizing their conceptual change process in class and documenting it on the platform, which can be shared publicly. Teachers upload recorded videos of classroom explorations, which students can watch repeatedly to deepen their understanding. It is important to note that knowledge construction and conceptual change are ongoing processes. The teacher guides the implementation of the next lesson. Even with incomplete information, students search for meaning by attempting to identify patterns and order.

The learning environment records students' thinking and conceptual change in detail, enabling teachers to observe the interactions between students' preconceptions and new concepts. This helps students reflect on the inertia of their thinking and improve their metacognitive skills. The learning platform is open for an extended period, allowing teachers and students to gradually review and add resources and ideas, building a vast knowledge database.

Preconceptions are incomplete, individual, persistent, contextual, universal, and historically similar. Teachers should assist students in comprehending conceptual inconsistencies and reflecting on why such perceptions arise. Only after clarifying the causes of preconceptions can they better support students in making constructive conceptual changes.

4. Conclusion

Based on the theoretical frameworks of conceptual change and constructivism, this study proposes a blended learning environment to address problems in science classroom design and promote a deeper understanding of scientific knowledge among students. By stimulating students' cognitive conflict, reconfiguring instructional arrangements, and providing technical support, we successfully blended online and offline learning to facilitate active knowledge construction.

This design is based on the constructivist theory, which indicates that learners construct their knowledge structures by engaging with activities, environments, and cultural contexts. Conceptual change refers to significant changes in cognitive structure resulting from inconsistencies with previous experiences, which is highly valued as a crucial process in students' active knowledge construction. Cognitive conflict is triggered by introducing new concepts that conflict with students' old concepts, stimulating students' thinking and reassessment behaviors, which drive their deeper understanding of scientific knowledge.

However, although this design has the potential to address issues in science classroom design, there are still areas to consider. Firstly, personalized instruction requires further improvement. Despite emphasizing students' prior conceptual and cognitive levels, achieving truly personalized instruction remains challenging. Other individual characteristics, such as motivation, learning preference, epistemological beliefs, and attitudes need to be considered (Limón, 2001). Secondly, curriculum design needs to focus more on big ideas and the construction of knowledge networks and to help students build a more coherent knowledge framework.

In addition, psychosocial factors including emotional attachment to a misconception, inability to recognize flaws, lack of motivation, cultural pressures, and skepticism about the credibility of new information sources can hinder conceptual change, which requires teachers to create a friendly and emotional support learning environment to facilitate students change their minds bravely (Sinatra & Seyranian, 2015).

Finally, while we encourage students to explore outside the classroom, it is important to acknowledge that they may not have sufficient time or opportunities to do so because of fixed classroom schedules and poorly organized activities.

Future research could conduct an empirical study to validate the implementation of this blended learning environment. By implementing instructional interventions with a comparison experimental group and a control experimental group and collecting data on student's academic performance, motivation, and knowledge perceptions, the impact of the design on students' learning outcomes can be assessed. Additionally, qualitative research methods can gain insight into students' perceptions and experiences of the blended learning environment, resulting in more comprehensive assessment results.

References

Al-Huneidi, A. M., & Schreurs, J. (2012). Constructivism Based Blended Learning in Higher Education. *International Journal of Emerging Technologies in Learning*, *7*(1). https://doi.org/10.3991/ijet.v7i1.1792

Baddock, M., & Bucat, R. (2008). Effectiveness of a Classroom Chemistry Demonstration using the Cognitive Conflict Strategy. *International Journal of Science Education*, *30*(8), 1115–1128. https://doi.org/10.1080/09500690701528824

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. https://doi.org/10.3102/0013189X018001032

Capone, R. (2022). Blended Learning and Student-centered Active Learning Environment: a Case Study with STEM Undergraduate Students. *Canadian Journal of Science, Mathematics and Technology Education*, *22*(1). https://doi.org/10.1007/s42330-022-00195-5

Dawson, C. (2014). Towards a Conceptual Profile: Rethinking Conceptual Mediation in the Light of Recent Cognitive and Neuroscientific Findings. *Research in Science Education*, *44*(3), 389–414. https://doi.org/10.1007/s11165-013-9388-4

Dewi, P. S., Widodo, A., Rochintaniawati, D., & Prima, E. C. (2022). Development of Indicators from Mapping the Blended Learning Environment in Science Education. *AIP Conference Proceedings*, *2468*. https://doi.org/10.1063/5.0102493

diSessa, A. A. (2013). A bird's-eye view of the "pieces" vs. "coherence" controversy (from the "pieces" side of the fence). In *International Handbook of Research on Conceptual Change*. https://doi.org/10.4324/9780203154472

Fosnot, C. T. (1989). *Enquiring Teachers, Enquiring Learners: A Constructivist Approach for Teaching*. https://api.semanticscholar.org/CorpusID:118298270

Gharacheh, A., Esmaeili, Z., Farajollahi, M., & Jamaizadeh, M. (2016). Presentation of blended learning conceptual pattern based on individual and social constructivism theory. *Int., J. of Humanities and Cultural Stud*, *1*.

Haqqo, A., Yuliati, L., & Latifah, E. (2023). *Exploration of students' conceptual changes through phenomenon based distance learning with multimedia videos momentum and impulse*. 050018. https://doi.org/10.1063/5.0112630

Harasim, L. (2018). Constructivist Learning Theory. In *Learning Theory and Online Technologies*. https://doi.org/10.4324/9781315716831-5

Hirashima, T., & Horiguchi, T. (2016). Creation of Cognitive Conflict by Error-Visualization: Error-Based Simulation and Its Practical Use in Science Learning. In *Learning, Design, and Technology*. https://doi.org/10.1007/978-3-319-17727-4_9-1

Lee, C. Y. (2020). How to Improve the Effectiveness of Blended Learning of Pharmacology and Pharmacotherapy? A Case Study in Pharmacy Program. *Technology, Knowledge and Learning*, *25*(4). https://doi.org/10.1007/s10758-020-09447-5

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, *11*(4–5). https://doi.org/10.1016/S0959-4752(00)00037-2

Maruntelu, C.-L. (2020). Constructivism - a Pedagogical Approach for the 21st Century. *Ovidius University Annals, Economic Sciences Series*, *XX*(2).

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2). https://doi.org/10.1002/sce.3730660207

Potvin, P., Sauriol, É., & Riopel, M. (2015). Experimental evidence of the superiority of the prevalence model of conceptual change over the classical models and repetition. *Journal of Research in Science Teaching*, *52*(8). https://doi.org/10.1002/tea.21235

Roth, W.-M. (1999). Authentic school science: Intellectual traditions. *Learning and Knowledge*, 6–20.

Schcolnik, M., Kol, S., & Abarbanel, J. (2016). *Constructivism in Theory and in Practice*. https://api.semanticscholar.org/CorpusID:63627914

Sinatra, G. M., & Seyranian, V. (2015). Warm change about hot topics: The role of motivation and emotion in attitude and conceptual change about controversial science topics. In *Handbook of Educational Psychology: Third Edition*.

Syarifuddin, Mardiana, & Sulistyani Eka Lestari. (2021). Constructivism Based Blended Learning for Online Learning Madrasah Ibtidaiyah Students. *Proceeding*, 1–6.

White, R., & Gunstone, R. (2014). Probing Understanding. In *Probing Understanding*. https://doi.org/10.4324/9780203761342

Widodo, A., Maria, R. A., & Fitriani, A. (2017). Constructivist Learning Environment During Virtual and Real Laboratory Activities. *Biosaintifika: Journal of Biology & Biology Education*, *9*(1), 11. https://doi.org/10.15294/biosaintifika.v9i1.7959

Future-Ready Educators: An Interdisciplinary and Multidimensional CLIL Framework for STEAM Education

Yi-Hung LIAO[1]*, Sheng-Yi WU[2], Kuay-Keng YANG[3]

[1] Mount Dawu College, National Pingtung University, Taiwan

[2] International Master Program in STEM Education, National Pingtung University, Taiwan

3 Department of Science Communication, National Pingtung University, Taiwan

* Corresponding author: yliaog@mail.nptu.edu.tw

Abstract: *In the evolving landscape of global education, the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) with bilingual education, particularly through the Content and Language Integrated Learning (CLIL) approach, represents a pioneering pedagogical strategy in this globalized world. This paper proposes a comprehensive competency framework that not only meets the pedagogical demands of delivering STEAM subjects through a foreign language but also leverages the Technological Pedagogical Content Knowledge (TPaCK) model to enhance instruction. By outlining key competencies, implementation strategies, and objectives, this framework aims to equip educators with the necessary skills and knowledge to effectively teach STEAM subjects in a bilingual context, thereby preparing students for an interdisciplinarily inspired, technologically advanced,*
globalized future.

Keywords: STEAM Education, CLIL Approaches, Interdisciplinary Teaching and Learning, Teacher Competencies

1. Introduction

Redefining Global STEAM Education in the Local Context

The global rise of STEAM education has highlighted a critical need for engaging and effective teaching materials (All Education Schools, 2019; Inomjonovna, 2023; Kanadli,2019; Leavy, et. al., 2023; Ortiz-Revilla, et. al., 2023). Addressing this deficiency, a research team comprising members from various disciplines (science education, teacher education, and English education) has collaboratively designed and developed national curriculum-aligned instructional materials for a CLIL (Content and Language Integrated Learning) for STEAM (Science, Technology, Engineering, Arts, and Mathematics) project/course that is applicable to elementary schools in Taiwan. This innovative approach targets cultivating students' inquiry competencies and problem-solving skills in real-life and authentic learning scenarios. Titled "STEAM Lights the Way: No More Traffic Jams," this 4th-grade semester-long (20-week) curriculum and teaching materials are designed to guide students through integrated subject learning in bilingual settings (Table 1). The curriculum encourages students to leverage their prior knowledge and develop strong problem-solving skills in an English-friendly and authentic language output environment.

Taiwan's Bilingual 2030 Policy presents a significant reform for all stakeholders in the education system, including teachers, curriculum developers, and schools. This need is further underscored by our year-long on-site teaching practice, which utilizes a CLIL-for-STEAM approach. This experience revealed the critical role of teacher competency in ensuring the success of such programs. Recognizing this crucial element, our research team developed a comprehensive competency framework. This framework addresses the demands of a globalized educational landscape by integrating STEAM education with bilingual methodologies like CLIL. It empowers educators with the necessary skills and knowledge to effectively deliver STEAM subjects in a foreign/second language while also strategically utilizing technological pedagogy to enhance learning and engagement.

Table 1. 4th Grade STEAM Curriculum Design and Instruction Framework

STEAM Lights the Way: No More Traffic Jams					
Disciplines	**Science**	**Engineering**	**Mathematics**	**Arts**	**Technology**
Intended Learning Outcomes	• Understand the scientific principles of ***series and parallel circuits*** and their applications.	• Differentiate the shape types and areas • Describe the characteristics of 3-D objects and 2-D shapes • Apply the ***engineering design process*** (ask, imagine, plan, experiment, and improve) practical problems.	• Demonstrate an understanding of arithmetic (addition, subtraction, multiplication and division) • Apply the mathematical principles to ***analyze real-world data*** and problems	• Understand the ***meaning of colors and design*** in practical applications.	• Use ***Micro:bit to program*** and automate traffic lights.
Lesson Topics (aligning with 4th-grader curriculum)	Series Circuit and Parallel Circuit Energy & Circuit • 電路好好玩 • 能源與電路	Cardboards in the Building of Traffic Light Stand • 角與形狀 • 圓與面積 • 周長與面積	The Signal Timing of Traffic Light • 乘法與除法 • 整數四則運算 • 時間的計算	Light and Colors • 色彩大發現 • 彩色的世界	Programming Automated Traffic Lights with Micro:bit • 運算思維 • 數位創作能力
Learning Objectives (4th-grader curriculum)	Explore basic electrical circuits; understand the differences and applications of each type.	Apply principles of design and modeling to create a functional traffic light stand.	Use mathematical calculations to determine the timing of traffic lights for efficient flow.	Investigate the impact of color and artistic design in the context of traffic light systems.	Learn to program and automate traffic light sequences using the Micro:bit platform.

2. The Imperative for a CLIL-for-STEAM Competency Framework

Cultivating a Global Mindset Beyond Boundaries: Competency for Interdisciplinary Learning and Linguistic Diversity

In today's interconnected world, educators face the challenge of providing students with disciplinary knowledge while also preparing them to navigate the multilingual, global landscape. The rationale for developing a CLIL for STEAM teacher competency framework, grounded in the **ATTITUDE, SKILLS,** and **KNOWLEDGE** (ASK) paradigm and the TPaCK (Technological Pedagogical and Content Knowledge) model, is rooted in the recognition of today's educational trends and imperatives. This proposed teacher competency framework addresses the need for educators to cultivate an **ATTITUDE** that values interdisciplinary learning and linguistic diversity, fostering an environment where students are encouraged to be critical thinkers and real-life problem solvers. In other words, incorporating CLIL into STEAM education ensures that language acquisition is not separate from content learning, but rather is meaningfully embodied into STEAM disciplinary subjects, becoming an integral part of comprehending, applying, and sharing STEAM concepts, allowing students to develop dual proficiency that is both academically empowered and linguistically enriched.

SKILLS in using technology to improve student learning experiences are critical in this information-technology age, and the **TPaCK model** serves as a foundation for this competency. Educators can create dynamic learning environments that meet the needs of all learners by combining technological tools, pedagogical strategies, and content knowledge.

KNOWLEDGE within this CLIL for STEAM teacher competency framework spans across understanding STEAM concepts to implementing CLIL methodologies effectively, ensuring that teachers are well-equipped to navigate the challenges of a steam-integrated bilingual classroom. The CLIL for STEAM teacher competency framework represents a strategic response to the evolving educational landscape and paves the way for a future generation of education innovators who can confidently bridge disciples, languages, and cultures to thrive in this globalized world.

3. Framework Objectives and Overview

Enabling a Synchronized Teaching Approach for STEAM and Language Education

This proposed CLIL-for-STEAM teacher competency framework (Table 2) aims to empower educators with a comprehensive toolkit. This toolkit not only promotes the integration of STEAM education principles and CLIL methodologies, but it also extends beyond isolated content mastery or language development. Instead, it builds on the ASK model and the TPaCK framework to create a strong structure that prepares educators to face the dual challenges of teaching complex STEAM subjects while also improving students' language skills. By taking a holistic approach, the framework enables educators to cultivate well-rounded learners who are not only proficient in STEAM disciplinary learning but also confident communicators in a globalized world.

Table 2. Synergistic Approaches to Bridging STEAM and CLIL for Enhancing Teacher Competencies in Curriculum Design

		STEAM		CLIL		Integrated Synergy for CLIL-STEAM
Dimension		STEAM Competency	STEAM Description	CLIL Approach	CLIL Description	
Attitude & Value	1.1	Core Values	Commitment to interdisciplinary problem-solving and STEAM values.	Cultural and Linguistic Awareness	Fostering intercultural understanding and language diversity.	Development of global citizens with strong STEAM foundations, equipped with linguistic and cultural competence for global challenges.
	1.2	Reflective Awareness	Continuous reflective practice in STEAM teaching.	Reflective Language Practice	Ongoing development of bilingual language teaching strategies and reflection.	Integration of reflective practices that continuously enhance both STEAM and language instruction, driving educational innovation.
	1.3	Professional Growth	Pursuit of professional growth within STEAM education.	Professional Language Development	Engagement in lifelong language learning and pedagogical refinement.	Lifelong professional development that synergizes STEAM expertise with advanced language teaching methodologies for enriched educator capacity.
Skill	2.1	Interdisciplinary Curriculum Skills	Deep understanding of STEAM education value and interdisciplinary design.	Bilingual Curriculum Integration	Ability to integrate language and content learning objectives.	Seamless fusion of STEAM content with language learning, promoting transdisciplinary thinking and communication.
	2.2	Teaching Methods and Design	Dynamic instructional capabilities informed by TPaCK.	Methodological Flexibility	Use of varied CLIL strategies (multimodality & Multiliteracy) to deliver content effectively in a second language.	Innovative instructional designs that cater to diverse linguistic and cognitive needs, fostering a holistic educational experience.
	2.3	Learning Assessment	Multifaceted assessments for STEAM competencies.	Language and Content Assessment	Balanced evaluation of language proficiency and content understanding.	Comprehensive assessment strategies that validate both subject mastery and linguistic development, ensuring academic equity.
	2.4	STEAM Practical Teaching Competency	Design of engaging and collaborative STEAM experiences.	Authentic Communication	Facilitation of authentic and meaningful language use through subject content.	Project-based learning experiences that naturally integrate content mastery with language use, enhancing real-world applicability.
	2.5	Learning Environment Creation	Development of a STEAM inquiry environment.	Linguistically Supportive Environment	Creation of a space that supports language acquisition through content.	Cultivation of an immersive learning atmosphere that stimulates curiosity, creativity, and linguistic fluency through STEAM inquiry.
Knowledge	3.1	Subject Knowledge	Mastery of multiple STEAM subject areas and interconnections.	Content Mastery	Proficiency in subject content delivered in the target language.	Enhanced content understanding through bilingual STEAM contexts, enriching conceptual knowledge with language skills.
	3.2	National and Global Curriculum	Understanding of both national and global curriculum standards in STEAM education.	Curricular Contextualization	Awareness of how language learning fits within various curricular frameworks.	Strategic alignment of STEAM teaching with language objectives, informed by national and global educational standards.

At its core, the framework advocates for a shift in educators' attitudes, encouraging them to embrace and capitalize on STEAM's inherent interdisciplinarity and CLIL's linguistic diversity. This attitude not only recognizes the importance of multidisciplinary knowledge and multilingualism but actively seeks to incorporate these elements into the pedagogical process. Educators are encouraged to take a global perspective to foster inclusivity and cultural sensitivity, which is critical in a world where technological advancements and societal challenges transcend borders.

The skills dimension of the framework focuses on the effective use of technology to enhance STEAM learning experiences. Using the TPaCK model, educators are trained to carefully select and use digital resources and tools that aid not only in the comprehension of STEAM concepts but also in the acquisition of language skills. This strategic use of technology encourages students to interact both the language of instruction and their mother tongue, thereby promoting bilingual or multilingual education.

Furthermore, the knowledge component goes beyond traditional subject boundaries to include an understanding of CLIL methodologies in STEAM education. Teachers are expected to be familiar with curricula in both national and global contexts, allowing them to design lessons that are relevant, challenging, and accessible to students with a variety of learning needs and languages. This curriculum knowledge, coupled with pedagogical expertise, enables educators to design and implement interdisciplinary lessons that are both linguistically rich and academically rigorous.

From the standpoint of students, the synergy of CLIL and STEAM within this framework promotes an authentic and dynamic learning ecosystem. Students are encouraged to investigate scientific concepts, solve engineering problems, engage in mathematical reasoning, express artistic creativity, and take advantage of technological advances—all while developing their language skills. This integrated approach not only prepares students to learn more profoundly and broadly through interpersonal engagement and meaning-making but also equips them with the critical thinking, problem-solving, and communication skills necessary for success in a globalized world.

4. Conclusion

Embracing a Global Vision for Transdisciplinary Learning and Plurilingual Education

Established within the educational landscape of Taiwan, this proposed CLIL for STEAM teacher competency framework stands as a symbol of pedagogical innovation on a glocal scale and encourages cross-border educational models to modify and incorporate its principles. The framework's potential is not limited by geography; it is intended to be flexible and applicable in a variety of educational settings. By encouraging international collaboration and adaptation, the framework can grow in richness, informed by a tapestry of global educational practices and theories to empower future educators and learners.

As we look ahead, the success of this framework is dependent on promoting self-autonomy and cultivating a growth mindset, not only among educators but also among students. Students must gain the confidence and independence to direct their own learning journey across disciplines, thereby becoming active participants in their interdisciplinary and intellectual development. Educators, who serve as both guides and role models, must also embrace the values of continuous learning and adaptability. Together, students and teachers embark on a path of lifelong learning, characterized by curiosity, resilience, and the pursuit of excellence.

Acknowledgements

This research is supported by the "The Development, Promotion and Research of Bilingual STEAM Teaching Materials and Digital Platforms" of Ta-You Wu Memorial Award Research Project, sponsored the Ministry of Science and Technology, Taiwan, R.O.C. under Grant no. MOST 111-2423-H-153 -001 -MY3.

We sincerely acknowledge the participation of teachers and students in this project.

References

Bertrand, M. G. and Namukasa, I. K. (2023). A pedagogical model for STEAM education. *Journal of Research in Innovative Teaching & Learning, 16(2),* 169-191. https://doi.org/10.1108/JRIT-12-2021-0081

Inomjonovna, R. I. (2023). Steam Education is one of the main trends in the world. *Journal of New Century Innovations*, *21*(2), 27-32.

Kanadli, S. (2019). A Meta-Summary of Qualitative Findings about STEM Education. *International Journal of Instruction*, *12*(1), 959-976. https://doi.org/10.29333/iji.2019.12162a

Leavy, A., Dick, L., Meletiou-Mavrotheris, M., Paparistodemou, E., & Stylianou, E. (2023). The prevalence and use of emerging technologies in STEAM education: A systematic review of the literature. *Journal of Computer Assisted Learning*, *39*(4), 1061-1082. https://doi.org/10.1111/jcal.12806

Ortiz-Revilla, J., Ruiz-Martín, Á., & Greca, I. M. (2023). Conceptions and Attitudes of Pre-School and Primary School teachers towards STEAM Education in Spain. *Education Sciences*, *13*(4), 377-400. https://doi.org/10.3390/educsci13040377

Rahman, S. M. M., Krishnan, V. J., & Kapila, V. (2017). Exploring the dynamic nature of TPaCK framework in teaching STEM using robotics in middle school classrooms. *ASEE Annual Conference and Exposition*, *Conference Proceedings*, *2017-June.*

Recognizing Learners Based on Time Management Images in the Process of Self-Regulated Learning

Taihe Cao[1], Fati Wu[1]*, Jiangbo Shu[2], Weijia Chen[1]
[1]School of Educational Technology, Beijing Normal University, Beijing, 100875, China
[2]Faculty of Artificial Intelligence in Education, Central China Normal University, Wuhan, 430079, China
* Corresponding author: wft@bnu.edu.cn

Abstract: *Owing to its flexibility and autonomy, online learning has become a widely popular learning mode in higher education in which students need to actively carry out self-regulated learning (SRL) to ensure the quality of learning. Deep learning (DL), especially the advantages of the convolutional neural network (CNN) model in image recognition, provides an opportunity for learner recognition in the learning process. This study aimed to utilize CNN model to recognize learners based on time management images transformed from clickstream data in the process of self-regulated learning. The analysis results suggested that using the CNN model based on the time management images can recognize learners with different academic performance categories to a certain extent. This study confirms an effective way to find meaningful information and knowledge from the data collected in the real educational environment by integrating learning analytics and deep learning technologies for learner recognition.*

Keywords: learner recognition, time management images, convolutional neural network (CNN), self-regulated learning (SRL), online learning

1. Introduction

In the highly flexible and autonomous online learning environment of higher education, students need to actively carry out self-regulated learning (SRL) to ensure the quality of learning (Cao, Zhang, Chen, & Shu, 2022; Shih, Liang, & Tsai, 2019). Self-regulated learning (SRL) refers to the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning processes (Zimmerman, 1989). Nowadays, learner recognition is still a hot research direction in the field of learning analytics. Previous studies have attempted to carry out learner recognition in the learning process using traditional machine learning methods which typically use a very limited number of input variables in the built prediction models (Ji, 2016; Macfadyen & Dawson, 2010). Deep learning (DL) provides an opportunity to effectively recognize learners early in the learning process, especially the advantages of convolutional neural network (CNN) model in image recognition (Alzubaidi et al., 2021). Therefore, this study attempts to utilize the CNN model to recognize learners with different academic performance categories based on time management images transformed from clickstream data in the process of self-regulated learning.

2. Methods

The specific research context of this study was carried out in a Normal University in China, which has developed a learning management system - starC to support the effective implementation of self-regulated learning in the online learning environment of higher education. At the end of the semester, the Academic Affairs Office organized several formal examinations to test the learning effect of each learner in Chinese universities. This study collected the academic performance score data of each learner. Based on the grade points and credits, we calculate the average grade point (GPA) of each learner in the pre-processing stage. At the same time, the K-means algorithm was utilized to divide 8019 students' academic performance (GPA) into two categories – Groups low and high. This study also collected clickstream data which records whether or not learners participate in online learning every day, how many periods in a day, and how long they participate in online learning every day. This research converted clickstream data into three channels time management images. This study customized two datasets, namely, three channels time management image datasets for all learners, and for learners from science department. After the preparation of the time management image datasets, this study built the convolutional neural network CNN model as shown in Figures 1 with reference to the architecture of LeNet-5 for digit recognition, which is used to recognize learners based on three channels time management images.

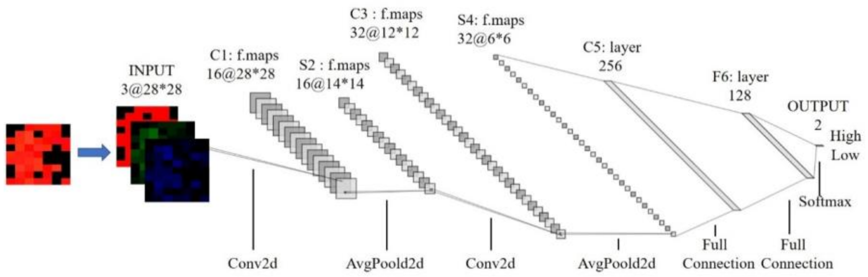


Figure 1. Architecture of CNN for learner recognition based on three channels time management images.

3. Conclusions

Table 1. Learner recognition results based on time management images using the trained CNN model.

Evaluation indicators	Three channels (all learners)	Three channels (science learners)
Accuracy rate	0.6176	0.6369
Recall rate	0.7649	0.8808

Table 1 shows the learner recognition results (accuracy rate and recall rate) based on time management images using the trained CNN model. This study found that the accuracy rate of recognizing learners based on three channels (science learners) time management images was slightly improved than that on three channels (all learners) time management images. The recall rate of recognizing learners based on three channels (science learners) time management is significantly higher than that on three channels (all learners) time management images. This study explored integrating learning analytics and deep learning technology for learner recognition research, which can reveal meaningful information and knowledge from the data collected in the authentic educational environment. This research only recognized learners with different academic performance categories based on time management images converted from clickstream data without considering specific learning design and personal characteristics. In the future research, we should examine intelligent recognition, understanding and support of learners' self-regulated learning process based on multimodal data considering not only specific learning situations, but also the individual characteristics of each learner.

This work was supported by the Project funded by China Postdoctoral Science Foundation under Grant number 2023M730291; Postdoctoral Fellowship Program of CPSF under Grant number GZC20230262; and National Natural Science Foundation of China under Grant number 62177008.

References

Alzubaidi, L., Zhang, J., Humaidi, A. J., Al-Dujaili, A., Duan, Y., Al-Shamma, O., Farhan, L. (2021). Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions. *Journal of big Data, 8*, 1-74.

Cao, T., Zhang, Z., Chen, W., & Shu, J. (2022). Utilizing clickstream data to reveal the time management of self-regulated learning in a higher education online learning environment. *Interactive Learning Environments*, 1-18.

Ji, W. Y. (2016). Identifying significant indicators using LMS data to predict course achievement in online learning. *The Internet and Higher Education, 29*, 23-30.

Macfadyen, L. P., & Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers & Education, 54*(2), 588-599.

Shih, M., Liang, J.-C., & Tsai, C.-C. (2019). Exploring the role of university students' online self-regulated learning in the flipped classroom: a structural equation model. *Interactive Learning Environments, 27*(8), 1192-1206.

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81*(3), 329-339.

Research on the Application of Artificial Intelligence Enlightenment Education in Preschool Interest Classes

Han Chen[1*], Xinxian Liang[1],
Yingshan Chen[1]
[1] South China Normal University
* chenha_n@163.com

Abstract: *With the rapid development of computer science and technology, the popularisation of AI education has become one of the important elements of China's education development strategy. Introductory AI education is usually a popular science course with robot model construction as the main content, and the current introductory AI classroom suffers from the problems of large age differences among students, different levels of a priori knowledge, and difficulties in achieving an inclusive and open classroom. In order to solve these problems, this study adopts the method of action research, and firstly proposes a targeted teaching implementation method based on the characteristics of the concept of inclusive education and the current situation of AI learning for preschool children, and then takes "Smart Straw" as an example to design a teaching programme and carry out teaching practice, so as to provide theoretical references and practical guidance for introductory AI courses for preschool children. Provide theoretical reference and practical guidance for the introductory course of artificial intelligence for preschool children. It provides theoretical references and practical guidance for preschool children's AI introductory programmes.*

Keywords: keyword 1, keyword 2, keyword 3, keyword 4, keyword 5

1. Introduction

The development of artificial intelligence has become one of the key driving forces in modern society, and the AI enlightenment course is becoming more and more important. In order to make the artificial intelligence technology flourish in China, we must pay attention to the methods and tools that can be used to train and educate the users of the intelligent system, and pay attention to the cultivation of children's artificial intelligence hobbies. Therefore, the youngest generation of exposure to AI from childhood has become a crucial issue in the education community (Liu,F.Kromer, P.2020).

The concept of inclusive education is an educational concept with all children as the center, respecting differences and paying attention to educational fairness. Inclusive education theory generally holds that all students should be educated in the same educational environment, with an emphasis on presence, participation, and success (Argemi-Baldichetal., 2022). Although the concept originates from special education, with the development of society, its connotation has been further expanded, and the concept is gradually applied to more educational contexts. Many scholars have put forward the model of preschool education. For example, Love,H.R. and Horn, E. (2021) discuss recent advances in the conceptualization and promotion of inclusive education about three ongoing challenges in the study of inclusive education for young children: implementing inclusive education independent of physical placement, ensuring full consideration of context, and appropriate measurement of quality. Also provides recommendations for future research aimed at continuing the contribution of the field of early childhood education to quality inclusive education. There are also studies on the combination of inclusive education and specific disciplines. Xueetal. (2023) discusses the application of inclusive education model in physical education, and collects data of primary and secondary school physical education teachers through national Internet convenience sampling, indicating that the inclusive education atmosphere plays a significant role in the improvement of physical education teachers' inclusive education ability. To sum up, the concept of inclusive education has been deeply studied in some fields and some disciplines, and people's understanding of inclusive education has been further deepened.

However, in the AI enlightenment class, there are large differences in age, per-knowledge, language expression and practical ability that affect the classroom effect. It is urgent to explore the teaching strategy of the AI enlightenment course based on the concept of inclusive education to solve the above problems. Therefore, this paper aims to explore the research on the teaching strategies of AI enlightenment courses based on the concept of inclusive education, so as to improve the teaching effect and promote the development of AI education for young children.

2. The concept and current situation of artificial intelligence enlightened courses

The AI enlightenment class based on the concept of inclusive education is committed to making students of different ages, genders and backgrounds gain and grow. The ai enlightenment classroom based on the concept of inclusive education has the characteristics of inclusiveness, participation, openness and respect。

First, the level of students is uneven. The artificial intelligence enlightenment course targets students aged 4-6 years old. The age of children at this age has a significant impact on various abilities, and there is a significant difference in language expression, logical thinking, hands-on making and communication. By designing the learning theme that each student can understand and setting the tasks to be completed in each class, students are driven to complete the tasks. Due to different levels, there may be different task completion time, and the class adopts inter-group mutual assistance, migration and expansion to make up for this difference. Be supported by teachers or competent students.

Secondary, advanced students develop good habits in the process of helping others and improve other abilities in the migration and expansion; secondly, AI enlightenment courses require rich creative courses: AI education and computational thinking, programming, robotics, Steam, maker (Chai Yangli & Du Hua. 2022). However, in the AI enlightenment course, because children themselves have little exposure to other knowledge, the classroom is basically popular science, mainly based on robot model building, and supplemented by certain programming, Steam and other knowledge according to their age. Fire safety, green life, natural disaster prevention and other contents can be integrated into the course to increase students' vision, which is also a kind of knowledge preparation for preschool children about to enter the compulsory education stage, based on the curriculum framework.The frame structure is shown in Fig. 1.

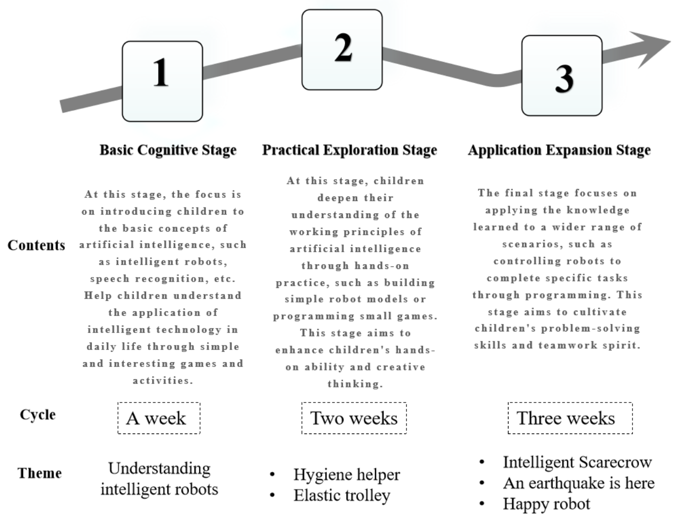


Figure 1. The Framework Structure of Artificial Intelligence Enlightenment Course

Finally, the AI initiation class is more attractive to male students of the same age, hence the class imbalance; due to family background and age gap, the class performance motivation and task completion speed are different; students from different nationalities and countries have different classroom experiences and ideas. The classroom based on the concept of inclusive education will accept all students, not because they are the minority group in the class, and accept students' different ideas and respect of students. In the artificial intelligence enlightenment course, it is embodied that teachers will communicate with students, listen to students 'own ideas and understanding of the works, guide each student's demands for targeted guidance, and guide them to carry out creative transformation of the classroom works.

……

4. The strategy of developing artificial intelligence enlightenment course based on the concept of inclusive education

After practical exploration, the artificial intelligence enlightenment curriculum strategy based on the concept of inclusive education can be summarized into three points(see Fig. 2).

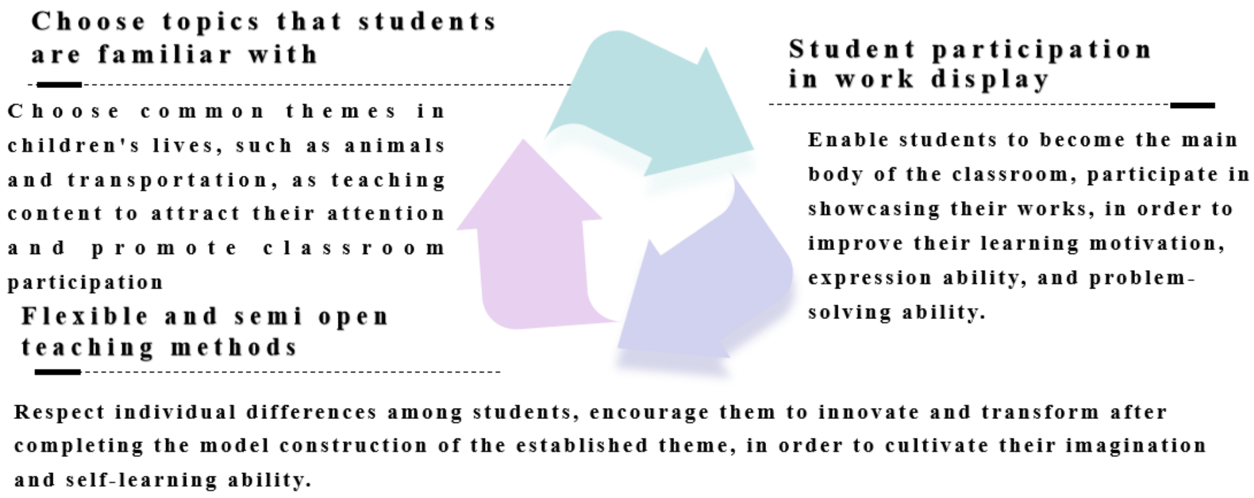


Figure 2. The strategy of developing artificial intelligence enlightenment course based on the concept of inclusive education

……

5. Conclusion

In 2005 UNESCO Education Guide: Access to Education for All, inclusive education is a process of responding to the diverse needs of all learners, and responding to them, by increasing learning, culture, and community participation. At present, a lot of artificial intelligence education, robot education is always confined in the school community classes, related competition, only positive or excellent students can get the chance, many students are excluded, artificial intelligence education needs certain change, inclusive education concept advocate with inclusive education idea, can guide the implementation of the transformation of artificial intelligence education and execution, from the artificial intelligence enlightenment course change education thinking can be let more children enjoy the first step of high quality artificial intelligence education.

References

Argemí-Baldich, R., Padilla-Petry, P., & Massot-Lafón, M. I. (2022). What Is Inclusive Education? Voices and Views From a Carpentry Classroom Workshop. Social Inclusion, 10(2), 75-84.

Love, H. R., & Horn, E. (2021). Definition, context, quality: Current issues in research examining high-quality inclusive education. Topics in Early Childhood Special Education, 40(4), 204-216.

Xue, R., Chai, H., Yao, L., & Fu, W. (2023). The influence of school inclusive education climate on physical education teachers' inclusive education competency: The mediating role of teachers' agency. Frontiers in Psychology, 14.

Liu, F., & Kromer, P. (2020). Early age education on artificial intelligence: Methods and tools. In Proceedings of the Fourth International Scientific Conference "Intelligent Information Technologies for Industry"(IITI'19) 4 (pp. 696-706). Springer International Publishing.

Yang Li & Du Hua. (2022). Framework and implementation approach of ai enlightenment education for young children. Research on Audio-visual Education (09), 89-97. doi:10.13811/j.cnki.eer. 2022.09.011.

Huang Zhicheng. (2001). Inclusive Education: a new topic of global education research in the 21st century. The Global Education Outlook (01), 51-54.

A Study on the Development and Evaluation of VR Learning Materials in Traffic Safety Education

Jun-Wei You[1], Ah-Fur Lai [2]
Department of Computer Science, University of Taipei[1]
G11116007@go.utaipei.edu.tw
Department of Computer Science, University of Taipei[2]
laiahfur@gmail.com

Abstract: *This research adopted the ADDIE instructional design model to plan the learning content and used Cospaces to create virtual reality learning materials for traffic safety education. These materials will be provided for third to sixth graders through reward mechanism and game-based approaches. Finally, this study invited experts to test and evaluate the suitability of this VR material, and their feedbacks were used for revising the VR content. The quantitative evaluation results showed that this educational material is appealing to elementary school students and can enhance their learning motivation. It is suitable for integration into traffic safety education.*

Keywords: ADDIE, Traffic safety education, Virtual Reality, Game-based learning

1. Introduction

This study adopted Virtual Reality (VR) technology to develop traffic safety learning materials, utilizing a game-based learning approach to deepen students' awareness of traffic safety. The incorporation of gaming elements in VR aims to engage students in the learning content actively. Through the use of VR, the educational material showcases scenarios depicting traffic-related issues, encouraging students to proactively propose solutions (Nguyen & Dang, 2017). The digital learning materials developed in this study through VR aim to assist students in establishing awareness of traffic safety within a virtual and immersive 3D environment, and comprehending the severity of traffic violations.

This study employed the ADDIE instructional design model for VR material planning and analysis. The subjects are elementary school students. After completing the VR-based learning materials, expert evaluations were conducted to ensure their suitability.

3. Development and evaluation

3.1. Development of Traffic Safety VR Material Using the ADDIE Instructional Design Model

In the analysis phase, this study analyzed the learning objectives of traffic education in elementary school through teacher interview, including the familiarity with traffic rules. Children are more susceptible to external interference and incentives when crossing the road, which can lead them to unsafe behaviors, so children's traffic safety education is very important (Leung et al., 2021).

In the design phase, this study designed instructional frameworks for elementary school's students based on the literature review and interview. This VR material in the study included "Hazard perception ability", "Road ethics and responsibility", "Walking and vehicle use", "Traffic performance and technology use" and "Traffic incident response". Through teacher guidance, students will understand the current traffic safety conditions and develop key learning scenarios.

In the development phase, We Utilized CoSpaces for developing interactive and immersive learning materials in a VR virtual 3D environment to help students establish awareness of traffic safety and comprehend the severity of traffic violations. Based on the structures of developed content, three challenging game levels were designed, as shown in Figure 1 to Figure 3. The third level simulates "car accidents". Players are asked to deal with and help others deal with car accidents, shown in Figure 3 .

Figure 1. Level 1: "Crossing the Road – Stop, Look, Listen!"

Figure 2. Level 2: "Traffic Signal Detective"

Figure 3. Level 3: "The Road, a Tiger's Mouth"

The implementation and evaluation stages will be conducted in the future. In addition, this study invited expert to test and evaluate this VR material through suitablility-evaluation questionaire.

3.2. Evaluation results

This study developed an evaluation questionnaire, and invited experts to evaluate our VR materials. One-sample t test was adopted for analyzing the collected data, and Cronbach's Alpha was used for showing its reliability instrument.

Table 1. Reliability coefficients and one-sample t test results (test value=3)

Facet	Number of questions	Cronbach's Alpha	M	SD	$t_{(19)}$
Learning Value	5	.765	4.77	.338	23.358***
Course Inspiration	4	.795	4.73	.375	20.673***
Interface Operation	7	.927	4.48	.551	12.056***
Pre-assessment	3	.763	4.56	.519	13.479***
Post-assessment	8	.870	4.74	.383	20.328***

****p<.001*

The Cronbach's Alpha values for each dimension are all greater than 0.7. The overall Cronbach's Alpha value is .955, showing excellent reliability for the scale, making it suitable for expert evaluation. The one-sample t-test (with a critical value of 3) yields a p-value of < 0.001, reaching a significant level, in Table 1, indicating that the experts showed significant and high appraisal towards our VR materials for each facet.

4. Conclusions

Through the adopting of the ADDIE instructional design model, this study has compeleted a comprehensive curriculum plan and analysis for developing a VR-based traffic safety learning module targeted at elementary school's students. According to the expert evaluation results, the developed VR material is found to be appealing to elementary school students, enhancing their motivation to learn, and is deemed suitable for integration into traffic safety education. The immersive experience provided by the VR module allows students to correct misconceptions about traffic rules and understand the consequences of their actions deeply.

References

Nguyen, V. T. & Dang, T. (2017). Setting up virtual reality and augmented reality learning environment in Unity. *IEEE International Symposium on Mixed and Augmented Reality Adjunct Proceedings*, 315-320.

Leung, K. Y. K., Loo, B. P. Y., Tsui, K. L., So, F. L., & Fok, E. (2021). To cross or not to cross: A closer look at children's decision-making on the road. *Transportation Research Part A: Policy and Practice, 149*, 1-11.

Establishing the Baseline for Student Risk Prediction Task on Learning Behaviors and Strategies (LBLS) Dataset

Owen H.T. Lu
International College of Innovation, National Chengchi University
owen.lu.academic@gmail.com

Abstract: *One application of learning analytics is the prediction of students' risk of experiencing learning difficulties. This approach utilizes recorded behaviors and strategies adopted by students in the classroom to assess the risk level of each student. For the implementation of this research, access to extensive open datasets is crucial. However, previous studies have seldom focused on data related to students' learning activities and strategies. Consequently, this study has introduced a dataset collected from a programming course in 2020 using BookRoll and VisCode, alongside assessments of their learning strategies through questionnaires. The aim is to establish this dataset as a foundational resource for studying risk prediction and to support future research.*

Keywords: Learning Analytics, LBLS, Machine Learning

1. Introduction

The surge in AI advancements in recent years has underscored the pivotal role of data, with big data emerging as a key driver of AI success. ImageNet (Deng et al., 2009) serves as a prime example of this phenomenon. Launched in 2009, this image dataset was meticulously annotated with 14 million images by researchers, setting a foundation for groundbreaking developments in image recognition and generation technologies. Although this was considered modest by today's standards, it was a groundbreaking achievement at the time. In 2022, we pioneered the release of a compact dataset named LBLS160 (Lu et al., 2022), encompassing the learning activities and strategies of 160 students. This underscores the considerable value of continuing to make such data available for the field of learning analytics (Lu & Bobea, 2023). In summary, the overarching goal of this research is to forge a robust model that will underpin future learning analytics endeavors. With the compilation and groundwork laid by the LBLS dataset, we are positioned to explore the following a research question as: **How effective is the model in predicting student learning performance?**

2. Methodology

This study has collected a total of nine courses with a total of 467 students' information, especially their final grades. In addition, in order to collect students' reading behavior, this study used the e-book system developed by Kyoto University: BookRoll (Ogata et al., 2015); in order to collect students' programming behavior, this study used the online program development environment developed by National Central University: VisCode (Lu et al., 2016). The screens of the two systems are as shown in the figure below.

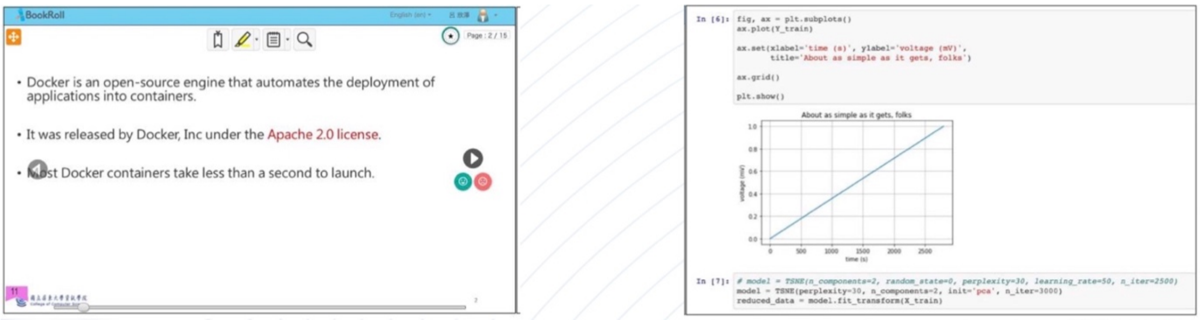


Figure 1. Example of figure.

4. Results and Conclusion

The analysis of LBLS467's risky student predictions reveals notable outcomes. Initially, the risk prediction model, which utilized all available features, achieved a classification accuracy of 63.83%. However, the accuracy level is still considered suboptimal due to several factors. Notably, the SVM (Support Vector Machine) algorithm employed in this experiment was not fine-tuned for optimal parameters. Furthermore, the choice of SVM may not have been the most effective for this application, given the potential of other models like Decision Trees and Logistic Regression.

Acknowledgements

This study is supported in part by the National Science and Technology Council of Taiwan under contract numbers NSC 112-2410-H-004 -063 -.

Reference

Deng, J., Dong, W., Socher, R., Li, L.-J., Li, K., & Fei-Fei, L. (2009). Imagenet: A large-scale hierarchical image database. 2009 IEEE conference on computer vision and pattern recognition,

Lu, O. H., & Bobea, M. (2023). Applying Learning Analytics in Programming Courses: A Feasibility Analysis on VisCode. *Journal of Humanities College of Liberal Arts National Chung Hsing University*(70), 85-107.

Lu, O. H., Huang, A. Y., Huang, J. C., Huang, C. S., & Yang, S. J. (2016). Early-Stage Engagement: Applying Big Data Analytics on Collaborative Learning Environment for Measuring Learners' Engagement Rate. 2016 International Conference on Educational Innovation through Technology (EITT),

Lu, O. H. T., Huang, A. Y. Q., Flangan, B., Ogata, H., & Yang, S. J. H. (2022). *A Quality Data Set for Data Challenge: Featuring 160 Students' Learning Behaviors and Learning Strategies in a Programming Course* the 30th International Conference on Computers in Education,

Ogata, H., Yin, C., Oi, M., Okubo, F., Shimada, A., Kojima, K., & Yamada, M. (2015). E-Book-based learning analytics in university education. International conference on computer in education (ICCE 2015),