Chen Li · Simon K. S. Cheung ·
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Lessons Learned and Ways Forward

16th International Conference on Blended Learning, ICBL 2023
Hong Kong, China, July 17–20, 2023
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Preface

Welcome to the proceedings of the 16th International Conference on Blended Learning (ICBL 2023). This year, ICBL 2023 was hosted at the Hong Kong Metropolitan University, Hong Kong SAR, China, during 17 to 20 July 2023.

Blended learning is a promising pedagogical approach that integrates traditional learning with innovative means with an aim to improve learning effectiveness and enrich learning experience. Over the past two years, owing to the Covid-19 pandemic, teachers and students have adapted to live with social distancing requirements. The pandemic-driven changes in learning styles and habits seem to be irreversible, implying that the changed styles and habits will likely continue even when the pandemic is over. While blended learning practices have been transformed into so-called new normal practices, it is time for researchers and practitioners in the field to reflect on what we have learnt and explore the ways forward on blended learning.

Under the theme *Blended Learning: Lessons Learned and Ways Forward*, ICBL 2023 aimed to provide a platform for knowledge exchange and experience sharing among researchers and practitioners in the field.

ICBL 2023 attracted a total of 57 paper submissions. After a rigorous review process, during which all papers received at least 2 single-blind reviews, 24 papers were selected for inclusion in this volume. These selected papers cover various areas in blended learning and beyond, including but not limited to smart classrooms, digital literacy, online and distant learning, learning analytics, big data in education, gamification, interactive learning environments, and content and pedagogy development for blended learning.

We would like to take this opportunity to thank the following parties who made the conference a success: (a) the conference organizing committee; (b) the international programme committee; (c) the conference organisers and co-organisers; (d) the conference sponsors, and (e) all the conference participants.

We trust you will enjoy reading the papers.

July 2023

Chen Li
Simon K. S. Cheung
Fu Lee Wang
Angel Lu
Lam For Kwok

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Ready or Not? Investigating Teachers' Readiness for Adopting Online Merge Offline (OMO) Learning in Digital Transformation

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Abstract. Online Merge Offline (OMO) learning has become one of the crucial modes within the digital transformation wave to provide students with more flexibile and personalized learning experiences, hence overcoming educational challenges, such as the post-COVID-19 educational crisis. For the successful adoption of OMO learning in educational institutions, teachers must have the necessary competencies to do so, however scant information exist in the literature about the teachers' readiness to adopt OMO learning. Therefore, this study conducts an empirical investigation to investigate the level of teachers' readiness to adopt OMO learning. The obtained results revealed that teachers reported a low level of readiness for adopting OMO learning. Particularly, the teachers were more competent in Digital Literacy and Environment management compared to pedagogy, curriculum design, and learning assessment for facilitating OMO learning. Additionally, female teachers were more competent in OMO pedagogy compared to male teachers. This study provides valuable evidence that might be used to develop a flexible, suitable, and helpful teacher's professional development program (TPD) to prepare teachers for the OMO learning modality in future education.

Keywords: Digital transformation · OMO Learning · Blended Learning · Hybrid Learning · Higher Education · Teachers readiness · Teachers competency

1 Introduction

Digital technologies have evolved from stand-alone projects to networks of tools and programmes that connect people and locations across the world, as well as help address personal and global challenges (UNESCO 2023). The digital transformation in education is considered as one of the mega trends in education domain and gained increasing interest in recent years. Particularly, the implementation of innovative technologies into education has provided new opportunities for personalized learning, collaborative learning, and continuous assessment. In addition, the use of digital tools and platforms has transformed traditional classrooms into a dynamic and interactive learning environment, enabling students to learn anytime and anywhere. This has led to a paradigm shift in the way people teach and learn.

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In the process of digital transformation in education, the Online merge Offline (OMO) Learning (Huang et al. 2021) concept has emerged and opened new doors for more immersive and flexible learning experiences by overcoming many of the educational challenges, especially the educational crisis in the post-COVID-19 era. According to Huang et al. (2021), OMO Learning combines online and face-to-face instruction using hybrid infrastructure, providing students with more flexibility and personalized learning experiences. A typical OMO learning environment consists of internet connection to connect both offline and online students, an interactive smart screen allowing the teacher to simultaneously instruct online and offline students together, cameras to capture, record, and transmit the classroom activities for the online participants, sound system to transmit the voice of instructors and students and tablets which are optional and can be used for a variety of instructional activities. These technologies allow OMO learning to provide an immersive and authentic learning opportunities to all students and aid teaching and learning process. In one hand, by adopting interactive technologies, students can share the learning process by combining two distinct but interconnected environments together, facilitating collaboration and interactive between students and teachers (Huang et al. 2022). In another hand, students have access to online course materials and learning activities while also attending in-person seminars or workshops in OMO learning (Huang et al. 2022). With (open) online resources and activities that cater to different learning styles and abilities, OMO learning can be tailored to meet the individual needs of students, making learning more personalized.

The effective integration of digital technologies in education can transform pedagogy and empower students. It is therefore crucial that teachers have the needed competencies to adopt these innovative technologies and learning modes (e.g., OMO learning) in their teaching practices. For instance, UNESCO (2018) has developed The ICT Competency Framework for Teachers (ICT CFT) to facilitate teachers' ICTs capacity building. Moreover, years of research have demonstrated that educational technology depends heavily on how prepared each teacher is for it (Cahapay 2020; Saboowala et al. 2021). In the same vein, as teachers are the primary stakeholder in the education process, they should be competent enough to adopt OMO learning to provide quality education for better learning outcomes. The successful adoption of OMO learning in educational institutions also largely depends on the competences of teachers to incorporate digital technologies into their teaching practices (Apak et al. 2021; Howard et al. 2021; Huang et al. 2021; Rashid et al. 2021; Scherer et al. 2021; Suryanti et al. 2021). According to Huang et al. (2021), the competencies for implementing OMO learning are more advanced than just online or traditional learning competencies. Teachers' readiness for OMO learning refers to the extent to which they can effectively design, deliver, and evaluate instruction in a blended learning environment that maximizes the benefits of both online and offline learning through the use of a combination of technical, pedagogical, and organizational skills.

Although, attentions have been paid on teachers' ICT capacity building (An et al. 2023), the research on teachers' competencies and readiness to facilitate OMO learning is still scant. Therefore, this study investigates teachers' level of readiness for adopting OMO learning. Additionally, numerous studies have revealed that teachers' readiness might depend on several factors, such as individual difference (Kamahinaet al. 2019). Economy (Mhlanga 2020) and social factors (Razak et al. 2023). Therefore, this present study takes one step forward and further investigates if gender or place of teaching can impact the teachers' level of readiness to adopt OMO learning. Specifically, this study answers the following research questions:

RQ1. What is the teachers' level of readiness to adopt OMO learning?
RQ2. Does gender affect teachers' level of readiness to adopt OMO learning?
RQ3. Does teaching place affect teachers' level of readiness to adopt OMO learning?

2 Method

2.1 Research Design

The purposive sampling technique was used to collect the data. The term "purposive sampling" describes a range of non-probability sampling techniques where units are chosen because they have the needed characteristics in a given sample. In this technique, the researcher carefully chooses the participants considering the study's intention, expecting every respondent to be able to furnish unique and rich data relevant to the study. In this context, 265 teachers, including 164 males and 101 females from public sector universities in Pakistan with experiences in OMO learning were selected in this study. Particularly, 134 participants were from Punjab, 41 from Islamabad, 38 from KPK, 34 from Sindh, and 17 from Baluchistan. Additionally, among the chosen sample, 213 teachers were from more developed provinces, and just 52 teachers were from less developed provinces. The more or less developed provinces were categorized based on the poverty rate (Bank 2002), literacy rate (Rehman et al. 2015), educational infrastructure, number of universities, and ranking of the universities (Dilshad et al. 2012; Parveen et al. 2011).

2.2 Instrument and Data Collection

A five-point Likert scale (range from strongly disagree to strongly agree) questionnaire was designed following a teachers' competency model for facilitating OMO learning. Some of the adopted items were used in the light of previous instruments (Archibald et al. 2021; Cahapay 2020; Graham et al. 2019) and then modified following the current objective of the study. The questionnaire comprised 68 items clustered into five main competencies, namely, digital literacy (2 sub competencies), pedagogy (17 sub competencies) curriculum design & development (14 sub competencies), learning assessment (2 sub competencies), and environment management (4 sub competencies). The reliability of the questionnaire was assessed using Cronbach's alpha and it was above 0.7, implying that it is reliable. The data was then collected from the teachers through a Google form where the questionnaire was designed.

2.3 Data Analysis

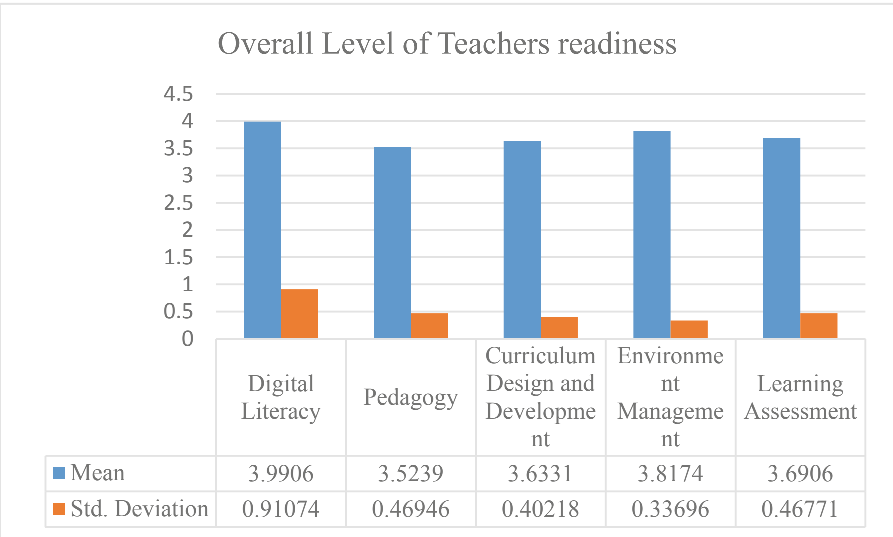
The collected data was analyzed using descriptive statistics such as frequency count and weighted mean. SPSS software was used to analyze the data. The mean scores of the dependent and independent factors and standard deviations were calculated for comparison, and multivariate analysis (ANOVA and independent T-test) was used to examine significant differences among two or more groups. Data were analyzed across gender and teaching place. The results of the average means were classified into five levels: 2.80–3.20 indicates a very low level of readiness, 3.21–3.80 indicates a Low level, 3.81–4.20 indicates a medium level, 4.21–4.80 indicates a High level and, 4.81–5.00 indicates Very High (Al-Awidi and Aldhafeeri 2017) level of readiness for facilitating OMO Learning.

3 Results and Discussions

3.1 Teachers' Level of Readiness to Adopt OMO Learning

Table 1 shows the teachers' readiness for adopting OMO learning. Overall, teachers' readiness was found to be Low (M = 3.73; SD = .51). The highest mean was recorded for Digital Literacy (M = 3.99; SD = .91) which shows that teachers have a medium level of readiness in terms of Digital Literacy. The second highest level of readiness was Environment Management (M = 3.81, SD = .33), showing that teachers have a medium level of readiness. Meanwhile, the lowest overall mean was recorded for Pedagogy (M = 3.52; SD = .46) which shows that teachers have a low level of readiness in terms of pedagogy. The analysis further revealed that all competencies had a standard deviation greater than 1, meaning that there is no large dispersion (Parrill et al. 2019). The teachers' level of readiness for adopting OMO learning was low, indicating they lack the skills and knowledge for adopting OMO learning. This is due to traditional adherence to classical methods and practices (Farooq et al. 2020), low-level classroom infrastructure, teachers-led pedagogy, and low interactive content.

Table 1. Overall Teachers' Level of Readiness for Facilitating OMO Learning



Teachers' Level of Readiness in Terms of Digital Literacy. The results indicate that teachers have a medium level of readiness in terms of digital literacy compared to other competencies. Particularly, software literacy (M = 3.99, SD = .966) and hardware literacy (M = 4.0, SD = .90) have no significant difference following digital literacy. According to the results from Appendix A, the teachers were found to be inadequately prepared to communicate, collaborate, and interact with students using digital collaboration and communication software, such as online conferences, online communication and collaboration tools, interactive boards, LMS, and collaboration online games. On the other hand, teachers reported having sufficient knowledge about how to handle instruction, the classroom, activities, learners, instructional materials, gadgets, and infrastructure, and therefore, on using classroom management software, learning management systems, and plagiarism detection software. The findings also show that teachers need to have training on organizing, understanding, and assessing information using digital technologies and participating in the rapid expansion of the online interaction channel by interpreting, managing, communication, and creating meaning (Asmyatullin 2021).

Teachers' Level of Readiness in Terms of Pedagogy for Facilitating OMO Learning. The results show that teachers' level of readiness in terms of pedagogy was found to be low (Mean = 3.52; SD = .46) as compared to other core competencies, such as digital literacy (M = 3.99; SD = .91), environment management (M = 3.81, SD = .33), curriculum design and development (M = 3.81; SD = .46) and learning assessment (M = 3.69; SD = .46). Additionally, according to the results from Appendix A, teachers reported medium level of knowledge (M = 3.7283 and SD = .59) to use search engines (e.g., Google, Bing, Or Yahoo) to research subject-related content and using citation tools like Edmodo or Endnotes to improve the reference quality. The teachers also reported a medium level of knowledge of using learning management systems for managing students learning and for group discussion. However, in contrast, teachers reported low skills (M = 3.26, SD = .89) in sharing or working collaboratively in open teaching and learning communities. Moreover, they reported the lowest level of knowledge (M = 2.85, SD = .95) and skills (M = 2.77, SD = .96) about game-based learning, simulation-based learning, or the virtual 3D world. The results show that teachers need to have proper training to increase their level of knowledge and abilities to deal with fundamental ideas and pedagogical approaches for adopting OMO learning, including open pedagogy, game-based learning, simulation base or immersive learning for facilitating students' learning in OMO settings.

Teachers' Level of Readiness in Terms of Curriculum Design and Development . The results show that teachers' level of readiness in terms of pedagogy was found to be the second lowest (Mean = 3.52; SD = .46) compared to the other competencies. According to the results from Appendix A, teachers showed low readiness (M = 3.3962, SD = .90) in terms of open educational practices. In addition, teachers have insufficient knowledge (M = 3.26, SD = .94) about the requirements and restrictions of an open license, and determine whether a resource has a license and of which type. The teachers also showed the lowest level of readiness and knowledge (M = 2.92, SD = .99) in game-based learning to make lectures more fun and interactive.

Teachers' Level of Readiness in Terms of Learning Assessment. The teachers reported a low level of readiness in terms of learning assessment. According to the results from Appendix A, the teachers showed a medium level of readiness and knowledge (M = 3.8189, SD = .46) in creating formative assessments to measure students' learning progress during the lecture and a medium level of knowledge (M = 3.84, SD = .47) to create summative assessments. However, they reported that they do not have enough skills (M = 3.52, SD = .75) to develop preliminary evaluations to track students learning progress during the lecture, and they do not have technical skills (M = 3.53, SD = .75) to create summative assessments throughout a course. The results indicate that teachers must equip with online assessment tools every time they teach their students to make data-backed personalized learning (Reffiane et al., 2021). Teachers also showed a medium level of readiness and knowledge in creating formative assessments to measure students' learning progress during the lecture and a medium level of knowledge to create summative assessments in OMO settings. In previous studies, Teachers also reported similar problems in online learning during covid-19 (Arifuddin et al., 2021). Therefore, adequate teacher trainings on formative and summative assessment in OMO settings are crucial.

Teachers' Level of Readiness in Terms of Environment Management. The teachers reported a medium level of readiness, and a significant difference was found compared to the level of other competencies in terms of environment management for facilitating OMO leaning. For instance, according to the results from Appendix A, teachers reported that they have skills (M = 3.8, SD = .46) to provide clear guidance/procedures to students for moving back and forth between online and face-to-face learning activities. These skills are not at their highest level but could be improved through training. They also reported that they know (M = 3.7811, SD = 58) how to protect students from noise and provide them with proper lighting, maintain classroom temperature and air quality, and ensure the blackboard quality, whiteboard, bench, etc. The teachers also reported having skills (M = 3.78, SD = 1.28) to protect students from noise, provide proper lighting, maintain classroom temperature and air quality, and ensure the blackboard quality, bench, etc. However, the teachers' reported the lowest level of readiness regarding the security and privacy of online data. They achieved the lowest skills (M = 3.20, SD = .37) to secure a Learning environment. The teachers also stated that they do not have enough knowledge (M = 3.22, SD = .35) to guide the students in navigating online and f2f learning activities.

3.2 Impact of Gender on Teachers' Level of Readiness to Adopt OMO Learning

The five competencies (Digital literacy, Pedagogy, Curriculum design and development, Student learning assessment, and Environment management) of teacher readiness were investigated further regarding gender differences. The mean differences between males and females were also compared. The independent T-Test was used to determine whether there is a significant difference in male and female teacher readiness. Table 2 reveals that there was a significant difference between male and female teachers in terms of digital literacy and pedagogy. Particularly, male teachers were more ready than female teachers in terms of digital literacy ($p = .000 < .01$), however, female teachers were more ready than male teachers in terms of adopting OMO pedagogy ($p = 0.018 < .05$). Results indicates that readiness of Pakistani higher education teachers for adopting OMO learning is shaped by various factors, including training, resources, and socio-cultural norms. While male teachers may exhibit higher levels of digital literacy, female teachers may be more competent in pedagogical practices in online settings. Addressing these gender-based disparities in OMO readiness could help to improve the overall quality of OMO teaching and learning in Pakistan.

Table 2. Teachers' Level of Readiness in Terms of Gender

OMO Competencies	Gender	N	Mean	Std. D	Interpretation	Sig
Digital Literacy	Male	164	4.0137	1.00239	Medium	.000
	Female	101	3.5050	.85658	Low	
Pedagogy	Male	164	3.2976	.69814	Low	.018
	Female	101	3.4782	.53463	Low	
Curriculum Design and Development	Male	164	3.4736	.62540	Low	.194
	Female	101	3.5612	.46415	Low	
Environment Management	Male	164	3.8095	.36453	Medium	.611
	Female	101	3.8301	.28790	Medium	
Learning Assessment	Male	164	3.7363	.39383	Low	.062
	Female	101	3.6163	.56188	Low	

3.3 Impact of Teaching Place on Teachers' Level of Readiness to Adopt OMO Learning

The five competencies (Digital literacy, Pedagogy, Curriculum design and development, Student learning assessment, and Environment management) of teacher readiness were investigated further in terms of the difference between less developed and more developed provinces. Further, the independent T-Test was conducted to see the difference between the two groups. Table 3 reveals that there is a significant difference between the teachers' level of readiness in more developed and less developed provinces in terms of Digital Literacy ($P = .000$), Pedagogy ($P = .000$), and Curriculum Design and Development ($P = .000$). However, no signification difference was found in terms of environment Management ($P = .098$) and Learning assessment ($P = .890$).

Table 3. Teachers' level of readiness in terms of more and less developed provinces

OMO Competencies	Provincial-Status	N	Mean	S.D	Interpretation	Sig
Digital Literacy	More Developed	213	3.9495	.95789	Medium	.000
	Less Developed	52	3.2885	.89166	Low	
Pedagogy	More Developed	213	3.4894	.53661	Low	.000
	Less Developed	52	2.8628	.79972	Very Low	
Curriculum Design and Development	More Developed	213	3.6094	.43171	Low	.000
	Less Developed	52	3.0874	.82694	Very Low	
Environment Management	More Developed	213	3.8395	.29587	Medium	.098
	Less Developed	52	3.7267	.46198	Low	
Learning Assessment	More Developed	213	3.6925	.47201	Low	.890
	Less Developed	52	3.6827	.45405	Low	

4 Conclusions, Limitations and Future Work

This study is considered as one of the initial attempts to assess teachers' readiness for adopting OMO learning for future education. Overall, teachers reported a low level of readiness. Moreover, the Digital Literacy and Environment management levels were higher than the pedagogy, curriculum design and development, and learning assessment. The results also demonstrated that university teachers in Pakistan felt more competent in Digital Literacy and Environment management compared to the pedagogy, curriculum design, & development, and learning assessment for facilitating OMO learning.

The findings further revealed a significant difference in pedagogy between male and female teachers, where female teachers were more ready than male teachers. Additionally, the teachers from the developed provinces felt more competent, and a significant difference was found compared to less developed provinces regarding pedagogy.

Teachers reported the lowest level of knowledge and skills about open educational practices, game-based learning, simulation-based learning, or the virtual 3D world. Therefore, the teachers must be trained to integrate OER, game-based learning, simulation based, or immersive learning to facilitate students' learning in OMO settings. In addition, there are differences between developed and less-developed provinces regarding pedagogy, curriculum development, and digital literacy for OMO learning.

This study provides useful evidence that might be used to develop a flexible, suitable, and helpful teacher's professional development program (TPD) to prepare teachers for the OMO learning modality in future education.

Appendix A:

The appendix is available on: https://docs.google.com/document/d/1BAk0G9AsZmgu5XmrKpKvElQKJtIjicu7kABNVuwGr_Q/edit?usp=sharing.

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Agile-Blended Learning as a Metropolitan Teaching Approach

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Abstract. This paper proposes a novel pedagogical approach, named Agile-Blended Learning (AB learning), designed for individuals residing in metropolitan areas who have a multitude of commitments, including long working hours and familial obligations, and who prefer utilizing technology for learning. Learners in metropolitan areas require flexibility, personalized learning, and possess a strong inclination towards self-management of their learning process. The AB learning approach consists of four fundamental features: flexibility, collaboration, learner autonomy, and technology mediation. AB learning offers flexibility in various areas, such as time, spatial delivery, study mode, pace, course design, learning activities, and learning materials. As a crucial component of AB learning, collaborative learning emphasizes both peer-to-peer collaboration and collaboration between learners and teachers throughout the learning process. Additionally, learners are provided with a high degree of autonomy when planning, designing, and implementing their learning, including in terms of time, space, content, and learning modes. Finally, AB learning incorporates a broad range of technologies to enhance flexibility and personalized learning. The use of educational technologies not only enriches learners' experiences but also improves their digital literacy.

Keywords: Agile-blended Learning · Metropolitan · Agile Learning · Blended Learning · Innovative Pedagogy

1 Introduction

This paper presents a novel pedagogical approach, Agile-Blended Learning (AB learning), that caters to the learning needs of individuals residing in metropolises. AB learning is an innovative approach that combines the principles and elements of 'agile learning' [1] and 'blended learning' [2]. As the name suggests, AB learning is characterized by its agility, which enables it to respond promptly to changes in the learning environment and adapt to modifications in the curriculum contents and pedagogy.

Agility, as a pedagogical concept, allows teachers to integrate into their teaching strategies, principles, processes, and values that are inherent in agile thinking, enabling them to effectively meet the ever-evolving learning needs of students [1]. In addition,

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AB learning incorporates the blended learning aspect, which has been significantly influenced by recent technological advancements [3]. These advancements have transformed the higher education landscape from traditional face-to-face learning in a physical classroom to online learning, where students can complete their coursework both synchronously and asynchronously without having to return to campus.

In the subsequent sections, the unique characteristics of learners in metropolitan areas are highlighted, and then the features of AB learning will be delineated in detail, explaining why it is a highly effective pedagogical approach for individuals pursuing education in metropolitan areas.

2 Characteristics of Learners in Metropolises

AB learning is tailored to meet the specific learning needs of individuals residing in metropolitan areas who face a host of commitments, including long working hours, familial obligations, and a strong preference for utilizing technology for learning.

The long working hours in metropolises necessitate learning that yields quick outcomes and impacts. In Asia Pacific, cities/countries such as Singapore, China, Malaysia, and Hong Kong have consistently ranked among the most overworked, with working hours per week ranging from 41 to 45 h in 2022 [4]. As a result, the efficiency of further studies is a significant concern for this population.

Research has consistently shown that learners in metropolitan areas have a positive attitude towards educational technology and prefer its use in their learning process [5–7]. Scholars such as Shen et al. [8] have highlighted the importance of incorporating technology in higher education through multi-mode digital learning, while the exponential increase in published academic papers on digital learning underscores the increasing significance of educational technology [9].

Given their various commitments, working adults in metropolitan areas require learning that is flexible in terms of time, spatial delivery, and study pathways [10, 11]. Furthermore, the transition to online teaching during the Covid-19 pandemic has made the use of technology, including synchronous and asynchronous learning, the norm.

Metropolitan learners also exhibit a strong preference for self-management of their learning, reflecting their autonomy as learners. They also express a desire for personalized learning experiences [12]. While tailoring learning activities for individual learners could mean too high a cost in the past, it has become highly feasible with computing technologies. The results of a review conducted by Xie et al. [13] indicate that research on technology-enhanced personalised learning from 2007–2017 mainly focused on the use of computers or devices. They recommended the implementation of other technologies such as artificial intelligence, virtual reality, cloud computing and wearable computing for personalised learning.

3 Features of Agile-Blended Learning

AB learning is characterized by four features: flexibility, collaboration, learner autonomy, and technology mediation. Firstly, AB learning provides learners with flexibility in various aspects, including time, spatial delivery, study mode, pace, course design, learning activities, and learning materials. This flexibility enables learners to tailor their learning experiences to their unique needs and preferences, accommodating their busy schedules and diverse learning styles. Second, AB learning emphasizes both peer-to-peer collaboration and collaboration between learners and teachers throughout the learning process. This collaborative approach fosters a positive learning environment and promotes social interaction, communication, and knowledge sharing. Third, AB learning places a high degree of emphasis on learner autonomy, providing learners with the freedom to plan, design, and carry out their learning independently. Learners have control over various aspects of their learning, including time, space, content, and learning modes, empowering them to take charge of their learning and achieve their learning goals. Finally, AB learning utilizes a wide range of educational technologies to create flexibility and personalized learning experiences for learners. The use of educational technologies enriches learners' learning experiences, advances their digital literacy, and enhances their ability to engage with course content in new and exciting ways.

3.1 Flexibility

Te first feature of AB learning, flexibility refers to the ability of learners to access learning materials and resources anytime, anywhere, and using any devices or tools deemed suitable. Both agile and blended learning approaches prioritize flexibility in student learning, with the former emphasizing the speedy and adaptable nature of the curriculum [14, 15], and the latter focusing on temporal and spatial flexibility [16]. As highlighted by Salza et al. [17], agility in learning involves flexible planning that takes into account student feedback, abilities, interests, difficulties, and experiences, with the aim of unlocking their hidden strengths and passions (p. 41).

It is worth noting that there should be multiple modes of student-instructor interaction. For example, while online learning modes are common in distance learning, students should be given the option to attend face-to-face classes. This is crucial because it addresses the diverse needs and limitations of learners due to work or family commitments. Li [18] emphasized that students who are unable to attend face-to-face classes can access recorded classes on the online learning platform. Incorporating varied modes of learning into student learning experiences is essential. For instance, one mode of learning, such as conventional face-to-face instruction, could be taken as primary, while the other, such as online learning, could serve as supplementary, or both could be used as primary. This practice is critical in enhancing the effectiveness of distance learning, as prior studies have shown positive connections between varied modes of learning, learner outcomes, and teacher commitment to teaching [19].

3.2 Collaboration

This second feature of AB learning promotes a collaborative and interactive learning environment that facilitates knowledge construction and exchange among learners. Both agile and blended learning approaches place significant emphasis on collaboration, teamwork, and communication. Previous studies have confirmed the positive effects of such an approach. For instance, Wu and Luo [20] noted that blended learning provides students with a variety of additional materials, enhancing their learning experience and promoting a collaborative learning community. It has also been argued that blended learning fosters not only collaboration and communication between students and teachers [21], but also active and collaborative learning without adding to students' overall workload [19]. Agile learning encourages not only physical co-location or close online collaboration among team members [22], but also enables learners to self-organize into teams to produce knowledge [17].

3.3 Learner Autonomy

The third feature of AB learning is learner autonomy, which refers to the ability of students to self-regulate and direct their own learning process. One of the primary aims of both agile and blended learning approaches is to promote self-regulation and independence among students [21]. A significant body of prior research on agile and blended learning has emphasized the positive impact of these approaches on learner autonomy. For example, in a study conducted by Smyth et al. [23], nearly 50 students were interviewed to gather their perceptions of a postgraduate program delivered through blended learning. The authors found that the majority of participants agreed that using a blended learning approach increased their autonomy in learning, as they could decide how they engage with the program, such as the amount of time dedicated to it. In another study of the usefulness of a project-centered collaborative approach focused on agile management, Gros [24] observed positive evaluations of the approach from participants. One of the significant comments was that the approach allowed them to be creative and work autonomously to solve real-world problems. Based on these observations, the authors argued that an agile-based collaborative approach to learning is beneficial in enhancing students' independent learning and problem-solving skills.

3.4 Technology Mediation

The fourth feature of AB learning is technology mediation, which involves utilizing diverse teaching and learning materials in digitized form, such as hypertexts, videos, audios, 2D/3D visuals, synchronous and asynchronous activities, among others. The use of digitized materials is not only beneficial in improving students' perceptions of learning, but also enhances their learning outcomes. For instance, Li [18] found a positive correlation between the use of digitized materials and students' perceived learning effectiveness. Similarly, Wu and Luo [20] reported positive perceptions of blended learning over traditional face-to-face classroom teaching. These findings underscore the significance of digitizing teaching and learning materials, as explained by Peter and Deimann [25], as digitization allows individual students to choose different modes of educational delivery that suit their learning needs.

4 Conclusion

This paper has examined the characteristics of learners residing in metropolitan areas and how their learning needs can be addressed. It has introduced the novel pedagogical approach of AB learning and explained how it meets the unique learning needs of learners residing in metropolitan areas. This learning approach effectively addresses the challenges faced by learners in metropolitan areas and provide them with a flexible, collaborative, autonomous, and technology-mediated learning experience. The implementation of this approach can enhance learners' engagement, motivation, and learning outcomes, ultimately contributing to their personal and professional growth.

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Collaborative Approaches to Research-Informed Practice in Tertiary Education

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Abstract. There is increasing pressure on instructors in tertiary settings to justify their practice with evidence; to describe and explain decisions made in the design of units, and the enactment of teaching. To do this effectively, educators need to be able to articulate the various steps and processes involved in research-informed planning and decision making. Fortunately, this requirement corresponds to a growing emergence of digital tools for data collection and analysis that are able to be connected to conceptual models of learning and teaching, and new methodological approaches, including learning analytic and AI techniques. I will demonstrate that collaborative approaches to research-informed practice can allow knowledge to be connected across disciplinary boundaries, supporting the integration of data analysis, technology development, design for learning, and pedagogical knowledge for the creation of innovative approaches to learning and teaching in higher education.

Keywords: tertiary education · research-informed practice · interdisciplinary collaboration · design for learning; educational data

1 Introduction

There is increasing pressure on instructors in tertiary settings to justify their practice with evidence; to describe and explain decisions made in the design of units, and the enactment of teaching [1]. This evidence may be data collected by the educators themselves or it may draw upon data collected by others including system level data. To do this effectively, educators need to be able to articulate the various steps and processes involved in research-informed planning and decision making. Fortunately, this requirement corresponds to a growing emergence of digital tools for data collection and analysis that are able to be connected to conceptual models of learning and teaching, and new methodological approaches, including learning analytic and AI techniques. In addition, there is substantial investment by universities in learning and teaching spaces to support the collection and analysis of such data. This paper presents a body of research to show how collaborative approaches to research-informed practice can allow knowledge to be connected across disciplinary boundaries [2], supporting the integration of data analysis, technology development, design for learning, and pedagogical knowledge for the creation of innovative approaches to learning and teaching in higher education.

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2 A Collaborative Approach to Research-Informed Practice

Understanding the processes of collaboration is the primary focus of the research reported on in this paper. Collaboration can be supported by various types of technology, in online and face-to-face settings, and particularly in interdisciplinary teams. "Collaborative learning requires the group to complete the task together, through dialogue and joint action" p. 440 [3]. Collaborative learning can take place in classrooms, networks, communities, teams, workplaces as well as in other areas of our lives.

Collaboration can occur in teams that are multidisciplinary, interdisciplinary or transdisciplinary. Interdisciplinary collaboration has been defined as "efforts that are synergistic across academic disciplinary perspectives, with each discipline drawing on concepts from others while remaining independently identifiable. Interdisciplinary efforts produce new linkages among disciplines that may yield new insights regarding interactions between processes that were previously not identified." p. 279 [4]. A transdisciplinary research approach supports the identification of complex problems, including diverse local and scientific perceptions of those problems, linking abstract and case specific knowledge, in order to develop new knowledge and practices [5].

In order to conduct successful interdisciplinary collaboration, individuals need to bring diverse knowledge, skills and orientations to solve complex problems [6, 7]. Some of the key research that informs the conceptual model of collaboration on which this work is based began development in 2010 [4]. In order to participate productively in an interdisciplinary team, individuals need specific knowledge as well as an awareness of the structure and limits of one's own understanding and an ability to assess what knowledge will be useful for a particular complex problem. Communication is also key in interdisciplinary teams, and participants need to build awareness of potential barriers to mutual understanding and have a willingness to listen. There are five indicators of productive collaboration [4]: identification of an appropriate question; development of a shared vocabulary; the co-creation of boundary negotiating objects; the use of tools for visualizing and combining data; and a new, more connected understanding of the question.

This paper is organized around steps that have been the focus of training for educators to engage in research-informed teaching over several years. Key to this approach is an assumption that successful interdisciplinary and transdisciplinary teams include members who have different types of expertise. This may include members who have expertise in the content (such as the unit coordinator); pedagogy (ways of teaching using technology, approaches, age ranges); the technology (the specific tool, or technology for learning); learning (such as a learning scientist); data (collection, analysis, visualization, communication); and design (such as an educational designer). It builds on an understanding of collaborative processes [4], design for learning [8], and data science [9].

3 Creating a Shared Model of the Problem Space

The first step in any collaborative project is to create a shared model of the problem space. Models are representations of ideas, objects, events, processes or systems [10], and are generally simplifications of reality [11, 12]. Models can be used for explanatory purposes, as representations for anything that cannot be observed naturally, such as theories [13] or to investigate phenomena that occur over different time or spatial scales [14]. If we consider our team working within tertiary education, the creation of a shared model of the problem space may result in more comprehensive long-term learning outcomes for the professional members of the staff [12, 15]. The creation of a dynamic model would allow members to combine fragmented knowledge into larger constructs by allowing them to explore that knowledge [16] and ensure the establishment of a common language to discuss the area of interest [4].

One of the important roles of a shared conceptual model in tertiary education is to help understand how multiple perspectives can connect. As more data is available to us, and statistically significant results can be found with almost any comparisons, it is crucial to connect the questions we ask to our theoretical assumptions about learning [17]. There is extensive, existing research available about learning, and specific to the higher education context from which to draw. In our teams, we must create an environment in which members can create a shared understanding of what learning and teaching means, informed by research, and which supports members of the team to discuss and challenge any ideas about learning and teaching that are not supported by evidence [18]. In research reported in [19], it was reported that the creation of a shared conceptual model was key for groups to be able to undertake the creation of an integrated research proposal with key questions identified. In this case, they were developed by individuals about their own expertise, shared with the team, and then revised and combined to ultimately define the problem space.

In our tertiary education team, this conceptual model could include some foundational aspects of how learning and teaching intersect between themes such as behavior, learning outcomes, motivation, interaction, engagement, the role of technology, the assumptions of the particular discipline area. The model can be as informal as a diagram that is created on a whiteboard to one that is more formally mapped to a design framework. Once the team has created a shared conceptual model of the problem space, this can be used to generate questions that will direct the collection of data and evidence to inform future teaching and design decisions.

4 Identifying Questions about Learning, Teaching and Design

In tertiary education contexts, questions about learning, teaching and design can be related to many different areas, including the materials created, the pedagogical approach, or the learning outcomes.

Conjecture mapping [20] provides a useful method to differentiate between design conjectures, to identify assumptions about design elements, and theoretical conjectures, to identify assumptions about the relationship between learner activity and learning outcomes. In previous work [1] this has been linked with the Activity-Centred Analysis and Design (ACAD) framework [8] to support an inquiry approach to practice. The ACAD framework is inspired by accounts of situated learning and divides the elements of design into those that relate to the epistemic (the tasks to be completed and the knowledge to be learned), the social (the rules, and roles), and the set (the tools, resources and physical/digital spaces for learning). Learner activity is assumed to be central, as it connects the design and the learning outcomes. The ACAD framework shows that while set, epistemic and social can be separated for the purposes of design, in the process of learning and teaching they merge to form a complex web of activity. The ACAD framework has been adopted in a number of studies [20, 21, 23].

In our tertiary education team, questions could be generated by subject matter experts that would be classified as research (for example, are students better able to learn about science when engaged in an inquiry approach?), by learning designers that would be classified as design (did the sequencing of lectures, workshops and reading support student engagement), by data scientists that would be classified as research (what is the best way to combine data from the learning management system with previous data about learners to visualize for educators to inform their practice?), or by technology and visualization specialists that would be classified as design (how do different types of visualizations support the practice of instructors?). Once the questions have been identified, that are of interest to all members of the team, the decisions about what data will be collected to provide answers to the questions can be made.

5 Collecting Evidence for Learning and Design

Designing for learning involves uncertainty in terms of predicting how particular designed features of learning environments will play out for different groups of learners. Design frameworks, such as the ACAD framework [8] have been created as tools that can help designers maximize the alignment between desired learning outcomes and design. Design frameworks often recommend that designers begin by clearly articulating learning objectives and designing backwards to create tasks that are intended to lead to those outcomes. Alignment between designs, learning outcomes and measures guides the design process. Collecting evidence of those outcomes can help designers gauge their success. The research on educational design teams (see for example [24]) shows that tools that allow representations of the design to be co-created and shared, are important in communication of ideas, and continue to support the ongoing collaborative design.

At this stage in the collaborative process, all members of the team can provide data scientists with information about what data would be appropriate to collect, identifying data that already exists and that which would be generated during the implementation of the learning situation. Data scientists can provide expertise regarding the collection of data, as well as cleaning processes, data exploration, and appropriate statistical and modelling processes to provide answers to the questions posed by the team. The shared model of the problem that was co-created is then used to frame these data science decisions. There are expanding opportunities to source data that can inform educational design decision making. These include the advancing click-based analytics available through commercial learning management systems, as well as the use of other technology such as sensors to provide data about movement and activity of learners and teachers [25, 26]. The inclusion of data scientists, technology and software developers and visualization experts in the team ensure that bespoke solutions to the combination of multiple models of data can be found [27]. The inclusion of multiple types of data in some statistical models and visualizations that would support explorations of connections between data types that range from evaluations, activity, learning outcomes, and observations.

6 Closing the Loop: Adjusting the Model and Asking New Questions

As the data scientists apply statistical models to the data that has been collected, the creation of visualizations for exploration (by the team) and communication (to instructors, students, and other end users) is necessary. The development of a shared language [4] is important for communication beyond the team. Opportunities exist for re-creation of the conceptual model of learning in context, as discoveries are made about the learning situation [19]. The team of educators, data scientists, and learning designers can then make decisions about the next iteration of the unit or class. This also results in the creation of a new conceptual model, to inform a new learning design, and prompts new design and research questions as well as (potentially) new sources of data. As different ways of knowing are connected to create a new conceptual model, there is the potential for the collaboration to shift from interdisciplinary to transdisciplinary knowledge creation. The process of research-informed teaching in tertiary education is a lifelong approach to learning for professionals and researchers.

7 Conclusions

To ensure that practitioners are able to do this work, they need skills that allow them to identify high quality existing research to inform the creation of a conceptual understanding of learning and teaching based on their expertise; analysis and interpretation of multiple sources and types of data; collaboration; communication through recommendations, visualizations and design decisions. This can include considering system level student data as well as complex teacher data, generated and analyzed using digital technologies. There is significant overlap between these skills as those needed to engage in innovation and research and development processes in other industries [28]. Building collaborative capacity to enable educators, students, professionals to develop, teach, and assess new units, are also similar to the capacity needed to solve global problems such as climate change, or local problems such as land use along the Brisbane River.

We need to consider tertiary education to be a research-informed and research-led profession, with a strong emphasis on collaboration and working in interdisciplinary teams. We must develop the capacity of our communities to make effective use of student data, including how to read, interpret and then employ this data to enhance the learning and teaching process.

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The Power of Rotation: Investigating the Impact of the RST Model on Students' Deep Learning

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Abstract. The multiple synchronous smart-classroom learning environments (MSSC) model uses synchronous broadcasting technology to simultaneously teach large audiences in several smaller spaces, increasing instructor efficiency and providing more students with access to quality education. However, while technology is a critical component of the MSSC, it may not be sufficient to reduce the psychological distance and increase the teaching presence that students experience, resulting in surface learning rather than deep learning. As a solution that addresses the MSSC's limitations, the rotational synchronous teaching (RST) model distributes the lead instructor's physical appearance evenly across classrooms, with teaching assistants facilitating discussions, practice, and reflection. Through this model, students benefit from optimal face-to-face instruction, which promotes deep learning and enhances their learning experiences. This paper delves into the intricacies of the development, implementation, and effectiveness of the RST model in a Chinese university, highlighting its impact on teaching presence, connected classroom climate, learning environment preference, and students' deep learning.

Keywords: The rotational synchronous teaching model · Connected classroom climate · Teaching presence · Learning environment preference Deep learning

1 Introduction

The shortage of qualified instructors is a well-recognized issue globally [1, 2], particularly in China, where the rapid expansion of higher education has led to an uncontrollable demand for instructors [3]. Compulsory or general courses, with large and demanding audiences, are the most affected by instructor shortages, resulting in class size expansion and the use of large lecture halls to accommodate students' learning needs [3]. However, this approach does not provide students with individual attention and poses challenges for even the most skilled instructors, who struggle to provide timely feedback and employ teaching methods beyond lecturing [4]. In some cases, lecture hall scheduling cannot accommodate the full capacity of required and/or general courses, forcing students to enroll in courses with underqualified or inexperienced instructors [3].

To address this issue, multiple synchronous smart classroom learning environments (MSSC) are becoming increasingly popular in higher education. MSSC is a technology-rich learning approach that enables remote students to simultaneously participate in the

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same course taught by the same instructor using rich-media concurrent technologies with local face-to-face (F2F) students. However, remote students may feel a significant sense of distance from their learning, which can lead to a lack of connected learning climate and result in surface learning instead of deep learning [5–9].

To overcome this weakness of MSSC, the rotational synchronous teaching (RST) model has emerged in teaching practice. The RST model evenly distributes the lead instructor's F2F presence between classrooms and includes teaching assistants to facilitate class processes such as discussion, practice, and reflection. Each student is not only assisted by a teaching assistant but also has the same opportunity to receive F2F instructions from the lead teacher, eliminating the physical absence of the lead instructor for remote students [3, 10, 11].

This research aims to explore the development, implementation, and effectiveness of the RST model in a Chinese university, highlighting its impact on teaching presence, connected classroom climate, learning environment preference, and students' deep learning.

2 The RST Model

The RST model has used a flipped classroom structure of blended learning. It involves several procedures that aim to enhance student learning experiences [3].

Before class, students are presented with the learning subject and relevant goals in a virtual learning space called the cloud classroom. This allows students to prepare themselves prior to attending the class, reducing concerns about addressing massive audiences at the same time. Additionally, students complete a self-evaluation in the cloud classroom to provide the instructor with insights into their pre-existing knowledge. This helps the instructor determine areas that require more attention during instructional time.

During the class, instruction is split into three segments. The first segment provides a lecture-based learning experience. The second segment involves small group tasks that require the application of the knowledge provided by the instructor in the previous segment. The third segment brings the students back to the full course group to discuss difficulties and offer feedback if necessary. The instructor manages the process of material presentation while teaching assistants handle the processes of discussion, practice, and reflection.

After class, students are given a project or test to assess their understanding of new ideas or concepts. This assessment provides insight into the essential subjects that the instructor should focus on during the next instructional session. Additionally, video recordings of instruction are available in the cloud classroom to enhance retention and provide support when students are absent.

To promote the joint teaching process, the teaching assistants will meet with the instructor to discuss the learning content, responsibilities, potential challenges that students may encounter, and effective instructional techniques before the class starts. After the class, they reflect on methods for improving future processes and discuss the specific progress of each class with the lead instructor [3].

In central China, a university requires about 300 first-year students majoring in STEM fields to take the mandatory course "Advanced Mathematics." The course has consistently implemented the RST model over time. The lead instructor is experienced in teaching mathematics and implementing flipped classroom instruction. Additionally, each class has at least one teaching assistant who was either recommended by the instructor or had to complete the MSSC course as a prerequisite. Our research team investigated the effectiveness of the RST model on student learning in this course. We conducted a series of investigations, including examining teaching presence, learning environment preference, connected classroom climate, and students' deep learning.

3 Study One: Examination of the Connected Classroom Climate

Our first study [3] focused on the connected classroom climate (CCC). CCC refers to the supportive and cooperative communication environment among students in the classroom [12]. Previous research has indicated that CCC is crucial for students' cognitive, affective, and self-regulated learning [13–15]. The RST model mostly employs synchronous computer-mediated communication, which differs from traditional face-to-face communication but centralizes student-to-student communication and interaction in the learning process. Our study aimed to investigate the effectiveness of the RST model while considering the potential negative effects of computer-mediated communication on social relationships. We used a mixed-method research design, collecting survey and interview data from 305 college students at the end of the spring semester in 2017. We used the Connected Classroom Climate Inventory to measure CCC and conducted interviews using a pre-scripted protocol. We coded for cooperation, supportiveness, and bonding.

The results of our study revealed that students' perception of CCC in the RST model was similar to previous studies. The survey responses indicated a positive and supportive student-to-student communication environment of the RST that stimulated CCC. The interview data provided valuable insights into students' perceptions of the RST model. They expressed excitement about social interaction and the use of technology, which created a sense of belonging to their peer groups. Despite the absence of face-to-face instruction, the RST model managed to foster a positive learning environment that facilitated effective communication among students.

4 Study Two: Examination of Relationships Between Teaching Presence, Connected Classroom Climate, and Deep Learning

The importance of deep learning in education cannot be overstated. Scholars have identified three dimensions of deep learning: higher-order, integrated, and reflective learning [16]. In online learning environments and/or when working with a large group of students, teaching presence has been found to be crucial for promoting deep learning [17–19]. This includes instructional design, facilitating discourse, direct instruction, and assessment [20–22]. Interestingly, students perceive that their instructors' performance can positively influence their connected classroom climate, highlighting the important leadership role of educators [23]. Our second study [10] aimed to explore how the RST model affects deep learning when teaching presence and connected classroom climate

(CCC) are considered together. We employed a range of scales to measure students' perceived teaching presence, CCC, and deep learning. Data from 264 students were collected.

We used structural equation modeling to examine the relationships between teaching presence, CCC, and deep learning. The findings revealed that teaching presence and CCC were positively related to students' deep learning, with CCC partially mediating the relationship between facilitating discourse and reflective learning, as well as assessment and higher-order learning, and fully mediating the relationship between facilitating discourse of teaching presence and higher-order learning of deep learning. Specifically, facilitating discourse of teaching presence had a direct effect on the reflective learning dimension of deep learning and CCC, while the assessment dimension had a direct effect on the higher-order learning and integrated learning dimensions of deep learning and CCC. These results of our study suggest that educators can leverage the findings to enhance teaching presence and CCC to promote students' deep learning within the RST model.

5 Study Three: Examination of the Effects of Teaching Presence and Learning Environment on Deep Learning

Students' learning environment preference plays a critical role in their academic success as it affects their motivation, engagement, and performance. A positive learning environment that fosters comfort and interest can lead to active participation in class discussions, a deeper level of learning, and better retention of information [24, 25]. Learning environment preference refers to students' attitudes and feelings toward learning activities, resources, facilities, and other elements of a particular learning environment [26]. By understanding students' preferences in specific settings, researchers and practitioners can develop more suitable and effective learning environments that facilitate the acquisition of knowledge and skills. Our third study [11] aimed to investigate the impact of teaching presence and learning environment preference on students' deep learning in the RST model.

To explore this relationship, we administered a survey using the Preference Instrument of Smart Classroom Learning Environments [27], Teaching Presence Scale [22], and Deep Learning Scale [17]. A total of 274 students participated in the survey. Our findings suggest that teaching presence and learning environment preference are positively related to deep learning. We also found that teaching presence had a positive effect on learning environment preference. Through mediation analysis, we found that learning environment preference partially mediated the relationship between teaching presence and deep learning.

6 Conclusion

The studies described in this paper reveal critical revelations about the efficacy of the RST model in fostering a conducive learning environment and encouraging profound learning among a large cohort of students. The findings accentuate the central role played by teaching presence, CCC, and learning environment preference in promoting profound learning within the RST model. These outcomes could be instrumental in crafting effective teaching models that inspire active participation and meaningful learning among a massive number of students.

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Smart Classroom and Digital Literacy

Investigating the Influence of Seating Factors on Perception of the Learning Environment in Smart Classroom

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Abstract. Human-machine and interpersonal distance are important location features in the spatial layout of rich media, reflecting the individual emotional connection. As a typical rich media learning environment, smart classrooms have gradually become one of the important contexts of education and instructional activities in universities. However, the influence of seating factors on perception in smart classroom space needs to be further explored. In our study, from the perspective of interpersonal and human-computer connection, 165 college students were selected as participants, and the quasi-experimental method was adopted to explore the effects of location preference, actual location, and location matching on perception of the learning environment. First, we found the students who prefer to be far away from the media have stronger media technology perception and overall perception of the learning environment; Second, compared with the actual distance from the lectern, students who are close to the lectern have a higher sense of social interaction; Third, compared with the students with position matching, the students with position mismatch have a higher perception of the learning environment. These conclusions contribute to improving students' perception of the learning environment.

Keywords: Seating Factors · Perception of the Learning Environment · Self-determination Theory · Smart Classroom · PST Model

1 Introduction

Smart classrooms are rich media learning environments that integrate emerging technologies such as interactive whiteboards, wireless networks, and mobile technology. Smart classrooms are an innovation in instructional models for enhanced learning experiences in digital learning environments [1]. Recently, smart classrooms have gradually become an important context in higher education [2]. Seats in the classroom have rich characteristics, for example, proximity to podium, interaction area, and media screens.

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Perception of the learning environment is a multidimensional concept that encompasses the perception toward teacher, peer, and media factors [3]. In the smart classroom space, perception of the learning environment includes not only the perception of technology and media but also the perception of social relationships such as teacher support and peer interaction, with the former pointing to the human-computer connection and the latter pointing to the interpersonal connection. It is important to explore the influence of learners' seating factors on perception of the learning environment, which is a necessary process to understand the smart education environment and to better enhance student interaction and engagement.

Seats in the classroom have mixed findings on learning-related variables. Some studies have found that seating factors have a positive effect on learning experience [4]. Other studies have found no effect of seating factors on learning experience and performance [5, 6]. The reasons for such contradictory findings are manifold. One important aspect is the research context, where most research contexts (e.g., classroom size, course content, etc.) varied considerably. Most of the existing research contexts focus on traditional classrooms and multimedia classrooms. Unlike traditional contexts, smart classrooms are a flexible and convenient media-rich environment. In this environment, the influence of seating factors on learning experience remains to be further explored. Based on this, in the present study, questionnaires and quasi-experimental design were used in smart classrooms to explore the effect of seating factors on perception of the learning environment.

2 Literature Review

2.1 Seat in Smart Classrooms

Through a systematic literature review, Saini et al. [7] found that advanced technological tools in smart classrooms can create a better physical environment, better presentation and interaction, and enhance student engagement. Although there are some differences in hardware configurations among different smart classrooms, a typical smart classroom is equipped with student-centered interactive whiteboards, projectors, student mobile terminals, touchscreen monitors, and ergonomic tables and chairs [2]. Smart classrooms are mainly designed for conducting collaborative and individualized learning, mostly in a round-table layout, and mainly include interactive devices, shared devices, display devices, and personal terminals. According to previous studies [4, 8–11], the classification seat location in smart classrooms can be divided in terms of distance from podium, screen, and social center. First, based on the distance from podium, it is classified as far and near from podium; second, based on the distance from screen, it is classified as far and near from screen; third, based on the convenience of social interaction, it is classified as high and low interaction area, or far and near from the center point of interaction.

2.2 Perception of the Learning Environment

The PST model (Pedagogy, Social Interaction, and Technology), which emphasizes that technology-supported learning environments can be designed from pedagogical, social, and technological perspectives, provides a theoretical basis for understanding the characteristics of instructional contexts [12]. According to the model of PST and the classification of existing studies [3], this study classified the perception of the learning environment in smart classrooms into three categories: teacher support, social support, and media support. The perception of teacher support refers to the extent to which students perceive that teachers are supportive and the extent to which they perceive being respected, attended to, and cared for in the smart classroom. The perception of social support refers to the perceived experience of interacting with peers in the smart classroom. The perception of media support refers to the extent to which students perceive the rich media environment to be useful for learning in the smart classroom.

2.3 The Influence of Seating Factors on Perception of the Learning Environment

Seating factors include preferred seat, actual seat, and matching seat. Preferred seat refers to the tendency of students to prefer and choose seats in a specific area of the classroom, which is a kind of trait of individuals. For example, if a student likes this seat one week, he or she tends to like it the next week as well. Actual seat has a significant impact on students' learning experiences. For example, as early as the 1970s, there was the extensive evidence that "front and middle seats" had a positive impact on student experience and performance [13]. In traditional classrooms, the front/middle row has a higher learning experience than the back row [14, 15]. Matching seat may be also an important factor that affects students' learning. According to Self-Determination Theory (SDT), autonomy is one of the important human needs. SDT argues that autonomy of individuals in learning will be enhanced when they have a certain choice about their learning time and location, learning style, and learning conten [16]. According to the conditions of autonomy and the conceptual definition of seat preference, seat match reflects the satisfaction of the autonomy needs of the individual's physical environment. Seat mismatch reflects the failure to satisfy their autonomy needs.

In smart classrooms, each student is close to the screen and can see the content on the screen and access rich learning resources from anywhere. Then, it's worth to investigate how seating factors with rich characteristics (e.g., students' actual seats, preferred seats, etc.) influence the learning experience in smart classrooms. Interpersonal connection and man-machine connection are two important forms of individual emotional connection, which also are important expressions of perception of the learning environment in smart classrooms. Interpersonal connection is a sense of belonging that reflects an individual's emotional connection to other people (teachers or peers) and is needed for social interaction. Man-machine connection refers to the emotional connection established between students and media technology as media technology becomes more pervasive in the classroom [17]. From the perspective of interpersonal connection and man-machine connection, based on the PST model, this study explores the impact of seating factors on the perception of the learning environment from distance (distance from screen, podium, and center) and seating type (preferred seat, actual seat, and matching seat). The research model is shown in Fig. 1 and focusing on the following research questions: (1) Does the perception of the learning environment differ between students with different preferred seats? (2) Does the perception of the learning environment differ between students with different actual seats? (3) Does the perception of the learning environment differ between students with different matching seats?

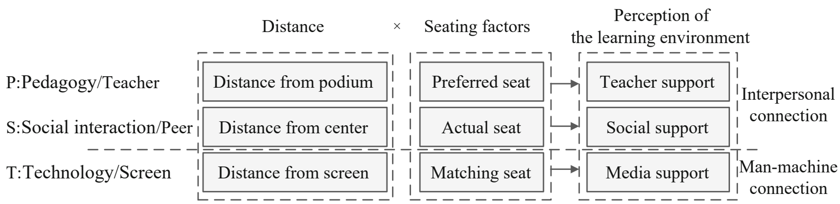

Fig. 1. Research model

3 Method

3.1 Context

The smart classroom of the university of H in China was selected as the study context (more details see [3]). Students can easily interact with teachers, peers, and media technology. Collaborative student-centered learning is used to conduct instruction in the smart classroom. The smart classroom layout is shown in Fig. 2. In this layout, seat 11 is the most popular point, as social center [18].

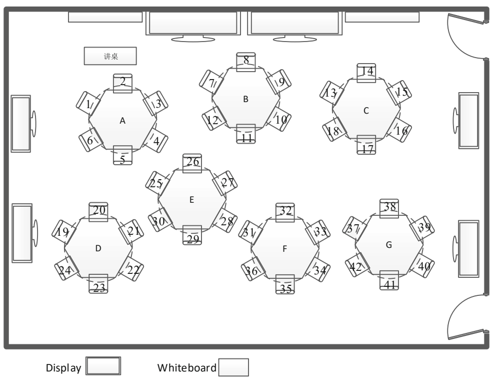

Fig. 2. Smart classroom layout

3.2 Procedure

Data were collected using a purposive sampling method, and 165 undergraduate students were recruited from 2 majors, Educational Technology and Digital Media, and 4 classes at the university of H for the study. Informed consent was obtained from the instructors and students to conduct a survey on students' preferred seats, academic motivation, etc. During the instructional process, students' actual seats were recorded by video recording and photographs.

Questionnaire and quasi-experimental design were used in combination. Since students' perception of the learning environment was influenced by self-efficacy and academic motivation, we included these variables in the covariates. Before the quasi-experiment, the questionnaire method was used to measure individual demographic variables, self-efficacy, autonomous motivation, and controlled motivation. During the quasi-experiment, the smart classroom space seats were divided into three different groups according to distance from podium, screen, and center dimensions. Before the class, the students' seats were randomly assigned. To minimize the disturbance to the subjects and not interrupt the normal instructional flow, the student's perception of the learning environment was measured immediately after the end of the class.

3.3 Measures

Pre-survey was used to measure personal information, expected performance, smart classroom seating preference, academic motivation, and self-efficacy. First, expected performance was measured by one item "what is your expected course grade?" A total of five options include excellent, good, moderate, poor, and very poor. Second, the survey of smart classroom seating preference was adapted from the study of Kaya et al. [19]. Students mark above the serial number of the seat they want to sit in most in the smart classroom layout, as shown in Fig. 2. Third, the survey of academic motivation was adapted from academic self-regulation scale [20]. Based on SDT, this scale measures academic motivation in four dimensions: intrinsic motivation, identified regulation, introjected regulation, and external regulation. The first two are autonomous motivation and the last two are controlled motivation. Fourth, the survey of self-efficacy in smart classrooms was adapted from the self-efficacy scale developed by Greene et al. [21] It has been shown to have good reliability and validity [22].

Then, in one classroom session, we recorded students' actual seating in the smart classroom and measured their perception of the learning environment, which involved the perception of media support, teacher support, and social support. The part of media support was adapted from the survey of students' perception of the use of technology [23]. The part of teacher support was adapted from the scale of teacher support [24]. The part about social support was adapted from the questionnaire of learner perceived interaction with others [25]. All scale items were measured using a six-point Likert scale (1 = strongly disagree and 6 = strongly agree). Higher self-reported scores indicate a higher level of student perception of learning in the current smart classroom.

3.4 Data Analytical Procedure

SPSS 23.0 was used to analyze the questionnaire data. First, we merged the two data together according to user IDs and coded the seating factors, involving the three dimensions of preferred seat, actual seat, and matching seat, which all contain three indicators of distance from screen, podium, and social center. Second, after coding, descriptive statistical analysis and correlation analysis were performed on the data. Finally, analysis of covariance (ANCOVA) was conducted on students' perceptions of media support, teacher support, social interaction, and the overall degree of perception of the learning environment after controlling the pretest variables, to investigate the influence of seating factors in the smart classroom on students' perceptions of the learning environment.

4 Result

4.1 Descriptive Statistics and Correlation Analysis

Three variables per dimension were coded as seating factors. The coding and frequency of seating factors are shown in Table 1. For the coding of the preferred seat, the variable of distance from podium was coded as "Pre_Podium near" if the student prefers to sit at table A B C, and "Pre_Podium far" if the student prefers to sit at other tables. Regarding the coding of the actual seat, the variable of distance from screen is coded as "Ac_screen far" if the student sits at E and F, and "Ac_screen near" if the student sits at other round tables. Regarding the coding of matching seats, if a student sits in his or her preferred area, the seat is matched, otherwise, the seat is not matched. For instance, for the variable "distance from screen" in the dimension "matching seat", we coded a new variable indicating whether the student sat in his or her preferred seat area by comparing the student's preferred seat with the actual seat. If the value is 1, it means in the preferred area, and if the value is 2, it means not in the preferred area.

Table 1. Coding and frequency of seating factors (n = 165)

Dimension	Variables	Key	Value	N	Percent (%)
Preferred seat	Distance from screen (Pre_Screen)	Pre_Screen near	1	133	80.6
		Pre_Screen far	2	32	19.4
	Distance from podium (Pre_Podium)	Pre_Podium near	1	95	57.6
		Pre_Podium far	2	70	42.4
	Distance from center(Pre_Center)	Pre_Center near	1	89	53.9
		Pre_Center far	2	76	46.1
Actual seat	Distance from screen (Ac_screen)	Ac_screen near	1	122	73.9
		Ac_screen far	2	43	26.1
	Distance from podium (Ac_Podium)	Ac_Podium near	1	64	38.8
		Ac_Podium far	2	101	61.2
	Distance from center (Ac_Center)	Ac_Center near	1	61	37.0
		Ac_Center far	2	104	63.0
Matching seat	Distance from screen(Metch_Screen)	Screen metch	1	110	66.7
		Screen mismatch	2	55	33.3
	Distance from podium(Metch_Podium)	Podium metch	1	78	47.3
		Podium mismatch	2	87	52.7
	Distance from center(Metch_Center)	Center metch	1	89	53.9
		Center mismatch	2	76	46.1

Table 2 presents the descriptive statistics and Pearson's correlations. Students' overall expected performance ranged between "moderate" and "good" with high self-efficacy

(M = 4.22, SD = .71). Autonomous motivation (M = 4.52, SD = .66) was relatively strong and controlled motivation (M = 3.28, SD = .83) was relatively weak; the mean values of the perception of the learning environment variables were between 4 and 5, indicating that overall, students had a higher perception of the smart classroom space (M = 4.06–4.70; SD = .85–.97), with the perception of teacher support being the strongest, media support the second strongest, and social support weaker.

In addition, all variables were significantly correlated with the dependent variable, except for expected performance and teacher support, controlled motivation, and social support. Thus, it is necessary to include the variables of expected performance, self-efficacy, autonomous motivation, and controlled motivation in the model as covariates for ANCOVA in the subsequent analysis. Then, we explored the effect of seating factors on the perception of the learning environment in the smart classroom through three dimensions, namely, the preferred seat, the actual seat, and the matching seat.

Table 2. Descriptive statistics and Pearson's correlations (n = 165)

Variable	M(SD)	1	2	3	4	5	6
1. Expected performance	2.13(.75)	1.00					
2. Self-efficacy	4.22(.71)	−.587**	1				
3. Autonomous motivation	4.52(.66)	−.432**	.683**	1			
4. Controlled motivation	3.28(.83)	−.067	.153	.172*	1		
5. Media support	4.37(.97)	−.174*	.226**	.214**	.189*	1	
6. Teacher support	4.70(.85)	−.105	.233**	.253**	.168*	.414**	1
7. Social support	4.06(.95)	−.267**	.428**	.386**	.104	.276**	.420**

4.2 ANCOVA of Preferred Seat Differences

To investigate the effect of preference of distance from screen on perception of the learning environment, ANCOVA was used to analyze the sample data with preference of distance from screen as the independent variable, perception of the learning environment as the dependent variable, and individual factors as covariates. First, the interaction between the covariates and the independent variables was analyzed, and the results of the homogeneity test of the regression coefficients within groups showed that the interaction between the independent variables and the covariates did not reach a significant level ($F(1, 151) = 0.225–1.207$, $p > .05$), indicating that the regression lines between the covariates and the dependent variables within each group were parallel, so the ANCOVA could be continued. In addition, Levene's test for homogeneity of variance did not reach a significant level ($F(1, 162) = .036–2.624$, $p > .05$), indicating homogeneity of variances. Then, the interaction term was removed and the variance analysis was conducted.

ANCOVA results showed that the main effects of perception of media support ($F(1, 156) = 8.24$, $p < .01$) and overall perception of the learning environment ($F(1, 156) =$

7.76, $p < .01$) reached a significant level, while the main effects of perception of teacher support and social support did not reach a significant level. We compared the covariate-corrected means and found that students who preferred far from media perceived higher media support ($M_{near} = 4.30 < M_{far} = 4.70$) and overall perception of the learning environment ($M_{near} = 4.34 < M_{far} = 4.55$). Meanwhile, there was no significant difference in the degree of teacher support, and social support between the two groups of students in preference of distance from screen. The results showed that two groups of students, who preferred podium near and far, had no significant differences in media support, teacher support, social support and overall perception of the learning environment. In addition, we found that, two groups of students, who preferred center near and far, had no significant differences in media support, teacher support, social support perception and overall perception of the learning environment.

4.3 ANCOVA of Actual Seat Differences

We found that two groups of students, who was actually near and far from the screen, had no significant differences in media support, teacher support, social support mutual perception and overall perception of the learning environment. We found that the main effects of media support, teacher support and overall perception of the learning environment did not reach a significant level.

In addition, we also found significant differences in the degree of social support ($F(1, 156) = 12.31$, $p < .001$) and overall perception of the learning environment ($F(1, 156) = 4.38$, $p < .05$) between the two groups of students who were physically close to and far from the podium. Compared to students who were physically far from the podium, students who were close to the podium had higher perceptions of social support ($M_{near} = 4.30 > M_{far} = 3.92$) and overall perception of the learning environment ($M_{near} = 4.47 > M_{far} = 4.32$). Finally, we found that there was no significant difference for two groups of students, who were near and far from the center, in media support, teacher support, social support and overall perception of the learning environment.

4.4 ANCOVA of Matching Seat Differences

We found that two groups of students, who match or mismatch in distance from the screen, had no significant differences in media support, teacher support, social support and overall perception of the learning environment. We found that two groups of students, who match or mismatch in distance from the podium, differed significantly in the degree of media support ($F(1, 156) = 3.95$, $p < .049 < .05$). Compared to students who were matched in distance from podium, students who were not matched in distance from podium had higher media support ($M_{mismatch} = 4.51 > M_{match} = 4.22$). In addition, the main effects of teacher support, social support and overall perception of the learning environment did not reach a significant level.

We found that two groups of students, who match or mismatch in distance from the center, differed significantly in teacher support ($F(1, 156) = 5.00$, $p = .027 < .05$), overall perception of the learning environment ($F(1, 156) = 4.15$, $p = .043 < .05$). Compared to distance from the center seat matching, students who were not matched, had higher teacher support ($M_{mismatch} = 4.83 > M_{match} = 4.58$), and overall perception of the learning environment ($M_{mismatch} = 4.46 > M_{match} = 4.31$). In addition, the test for the effect between groups of media support, and social support did not reach the significant level.

5 Discussion

5.1 Preferred Seat: Preferred Far Distance from Screen Better Than Near

We did not find stronger perceptions of media support for students who preferred proximity to the screen. However, contrary to our expectations, we found that students who preferred distance from the screen had stronger media support and overall perception of the learning environment. We speculated that this may be related to the study context. According to the model of PST, media technology is a key element in smart classrooms [12]. The preference for distance from the screen reflects, to some extent, the individual's emotional connection to the media. In a traditional multimedia classroom, only one multimedia screen is located at the front of the classroom, and control of the multimedia is in the hands of the teacher. In this context, an individual's seating preference is reflected in the distance from the multimedia screen, and it has been shown that this preference has an impact on the learning experience and academic achievement [11]. However, unlike traditional multimedia instruction, our scenario takes place in a smart classroom where students have access to rich media from anywhere. Therefore, the students who preferred near distance from screen, did not have a better perception of the learning environment in smart classrooms.

5.2 Actual Seat: Actual Near Distance from Podium Better Than Far

Students' actual seat has a certain randomness, which may lead to changes in students' perception of the learning environment. This study did not find that students close to the podium perceived higher levels of teacher support than students far from the podium. According to the model of PST, the teacher is a leading role in the smart classroom. In a smart classroom, the teacher does not have a fixed area. Regardless of students' distance from the podium, there was no significant change in perceived teacher support in the smart classroom. However, the actual seat in the smart classroom had a significant effect on perception of the learning environment. We found that students who were physically closer to the podium had higher social support, and the findings were similar to those of previous studies in other contexts. For example, through multilevel path analyses, Shernoff et al. [4] found that back students in the large university lecture hall had lower learning engagement and experience compared to middle and front students. The seats where students are located, especially those close to the podium, play a positive influence on the learning experience. To a certain extent, the smart classroom itself does not automatically eliminate this difference, and there is still a certain golden and shadow zone [26]. This requires teachers to optimize students' learning experience in the instructional process and try to eliminate this bias.

5.3 Matching Seat: Seat Mismatch Better Than Seat Match

The matching degree reflects whether the needs of autonomy are met. We did not find that matched students had a higher perception of the learning environment. In contrast, we found that mismatched students had a higher perception of the learning environment. For example, students who mismatched distance from podium had higher media support than students who matched distance from podium. Compared to students matched distance from center, students, who mismatched distance from center, had higher teacher support and overall perception of the learning environment. Similar findings have been found in previous studies, for example, in large classrooms where initial student seating played a role in student performance, course experience, and even when these students were switched from their initial seats, they showed higher engagement [5]. Our samples were college students with largely mature minds. SDT suggests that if students are given a high level of autonomy, it can drive their academic motivation and promote their learning outcomes. However, we found that if the students' preferred seat was not met, it may promote the perception of the learning environment to some extent. In other words, in the actual instructional process, teachers do not cater to students' preferences all the time, especially their seating arrangement. Adjusting such preferences or needs, when appropriate, may facilitate to some extent the individual's experience and perception of the learning environment. The present study gives new evidence to support this point.

6 Conclusion and Implications

From the perspective of interpersonal connection and man-machine connection, based on the model of PST, We built a model of the influence of seating factors on the perception of the learning environment. The quasi-experimental method was used to explore the influence of seating factors such as preferred seat, actual seat, and matching seat on the perception of the learning environment. We found that: (1) preferred seat has a significant impact on the perception of the learning environment. Specifically, preference of distance from screen did not promote the perception of the learning environment as expected, but instead, Students, who preferred distance from the screen, have a strong perception of media support and overall perception of the learning environment. (2) Compared with students, who are actual far distance from podium, students, who are actual near distance from podium, have better social support. (3) Compared with students who seat match, students who seat mismatch have higher media support, teacher support, and overall perception of the learning environment.

There are several important implications for practice. First, instructors should adopt appropriate seating allocation strategies, even in smart classrooms. We found that seats in smart classrooms had a significant impact on individuals' social interaction and learning experience, which is an important reference for classroom instruction. If instructors adopt a fixed seating strategy to arrange students' seats, then this strategy is unfair to students, especially those who choose to sit back in the room for a long time and will affect individuals' learning experience and perception in the teaching process, which in turn may affect students' academic achievement. Therefore, students' "independent choice" and "appropriate intervention" should be combined in smart classrooms. Instructors should adopt appropriate seating allocation strategies to guide students' seating choices and improve students' social interaction and learning experience. For students who have been sitting far away from the podium, instructors should pay attention to them to understand their learning environment and improve their perception of the learning environment, thus improving student engagement. Second, instructors should improve interpersonal connections. The distance between media, podium, and center reflects two kinds of emotional connection (i.e., man-machine and interpersonal connection). It was found that interpersonal connection had a more significant impact on student's perception of the learning environment than man-machine connection. Our findings reflect students' need for interpersonal connection. In smart classrooms, to meet students' needs of relatedness, it is necessary to create a rich media learning environment full of teacher attention, peer care/support, and parents' concern to improve individual social interaction, and promote the internalization of academic motivation, to optimize their perception and experience.

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Study on the Influencing Factors of Junior High School Students' Learning Engagement Under the Smart Classroom Environment

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Abstract. To explore the influencing factors of junior high school students' learning engagement in the smart classroom, this paper took eighth-grade students in a public junior high school in the northwest of China as the subjects, analyzed the relevant factors of junior high school students' learning engagement in the smart classroom through questionnaire survey. In addition, the structural equation model is used to verify and analyze the internal logical relationship among self-efficacy, performance expectancy, teacher support, and students' learning engagement in the smart classroom. The results indicated that the self-efficacy and performance expectancy of junior high school students in the smart classroom had a significant positive impact on students' behavioral engagement, emotional engagement, and cognitive engagement, while teacher support had a significant positive impact on students' behavioral engagement and emotional engagement.

Keywords: Smart Classroom · Junior High School Student · Learning Engagement · Self-efficacy · Performance Expectancy · Teacher Support

1 Introduction

The smart classroom is a physical classroom that integrates advanced educational technology, which provides opportunities for student learning and participation in formal educational learning experiences [1]. The smart classroom has injected new vitality into traditional classroom teaching, by integrating modern technologies such as the Internet and intelligent terminals. The smart classroom environment can effectively promote the interaction level between teachers and students, enhance students' learning interest, motivation, and engagement [2], and thus improve students' learning effect.

Learning engagement is generally regarded as a series of conscious goal-oriented behaviors and reflections that indicate meaningful and deep involvement of students in learning activities [3]. Studies have shown that there is a certain correlation between learning engagement and students' academic performance [4]. Therefore, how to improve students' learning engagement has become the focus of educators. Studies have pointed out that the traditional learning environment is relatively boring, and the

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interaction between teachers and students is relatively small, while the smart classroom can fully mobilize the enthusiasm of students and improve their engagement in learning to a certain extent [5]. Therefore, it is necessary to examine the influencing factors of students' learning engagement in the smart classroom environment, to improve students' learning engagement in the smart classroom environment, and finally provide references for improving students' learning effect in the smart classroom environment.

2 A Literature Review

2.1 Learning Engagement

Learning engagement is often used to measure the extent to which students continue to work hard to achieve learning goals. Meanwhile, learning engagement is considered to be a concept with multiple dimensions, including behavioral engagement, emotional engagement, cognitive engagement, etc. [6]. Behavioral engagement refers to the active, lasting, and effective behavioral state, which is the result of the behavioral expression of learners to exchange information with learning resources and the community with the help of seamless learning space and under the control of tools, learning styles, and learning tasks [7]. Emotional engagement is an expression of the emotional response level of learning, involving the emotional feelings generated during the participation of activities in the learning process. Emotional engagement can help learners to carry out in-depth cognitive processing of learning tasks [8]. Cognitive engagement generally includes the high engagement of cognitive strategies and psychological resources used by students in learning [6]. By integrating a series of information technology tools, the smart classroom provides a smart learning environment for students to actively participate in classroom learning [9]. Many researchers have explored students' learning engagement in the smart classroom. Some studies have shown that the creation of smart classrooms can promote students' engagement in learning [1]. Thus, it can be seen that classroom instruction under the smart classroom environment can effectively exert students' subjectivity, promote teacher-student interaction, and improve students' engagement in classroom learning.

2.2 Research on Influencing Factors of Learning Engagement

Compared with traditional classrooms, smart classrooms can mobilize students' learning interests to a certain extent and improve their learning engagement. However, many studies have shown that students have non-participating behaviors such as distraction and detachment from learning objectives in a smart classroom environment [10], which harm students' learning engagement and thus affect their learning effect. Therefore, it is necessary to explore the influencing factors of students' engagement in the smart classroom environment, to provide suggestions for effectively improving students' learning engagement in the smart classroom environment.

Some studies have analyzed the factors affecting students' learning engagement in different learning environments. For example, Tas et al. (2016) found that the better students perceive teacher support and classroom equity, the higher students' engagement in science, and individuals with high self-efficacy show higher cognitive and emotional engagement in science courses [11]. Pellas (2014) found that computer self-efficacy, metacognitive self-regulation, and self-esteem in online courses can predict students' learning engagement [12]. Generally, current studies on the influencing factors of learning engagement mainly focus on the traditional learning environment or the online learning environment, while relatively few studies have been conducted on the influencing factors of students' learning engagement in the smart classroom.

Students' motivation is highly correlated with students' learning engagement [13], and one of the important motivational structures affecting students' engagement is self-efficacy [14]. According to the self-determination theory, conditions in the learning environment can encourage or hinder individual development and performance [15], and the relationship with teachers is an important feature of students' motivation and engagement [13], it is believed that teacher support will affect students' engagement in learning. Therefore, self-efficacy and teacher support are included in this study as influencing factors of student engagement. In addition, students' use and acceptance of technologies will affect students' learning engagement in the smart classroom [16]. Therefore, performance expectancy related to students' use of technology in the smart classroom environment is selected as one of the factors influencing students' engagement. Finally, this study takes self-efficacy, teacher support, and performance expectancy as the main factors affecting junior high school students' learning engagement in the smart classroom environment [17], and further explores the influence of junior high school students' self-efficacy, teacher support, and performance expectancy on their behavioral engagement, emotional engagement and cognitive engagement in the smart classroom environment.

2.3 Research Hypothesis

Due to relatively few studies on students' engagement in the smart classroom, it is still unclear which factors can affect students' learning engagement in learning in the smart classroom environment. Therefore, an influencing factor model of students' learning engagement in the smart classroom environment was constructed in this study, as shown in Fig. 1, and the following nine hypotheses were proposed based on the above literature review.

Hypothesis 1: Self-efficacy has a positive impact on students' behavioral engagement in the smart classroom environment (H1).
Hypothesis 2: Self-efficacy has a positive effect on students' emotional engagement in the smart classroom environment (H2).
Hypothesis 3: Self-efficacy has a positive influence on students' cognitive engagement in the smart classroom environment (H3).
Hypotheses 4: Performance expectancy has a positive influence on students' behavioral engagement in the smart classroom environment (H4).
Hypothesis 5: Performance expectancy has a positive influence on students' emotional engagement in the smart classroom environment (H5).
Hypothesis 6: Performance expectancy has a positive influence on students' cognitive engagement in the smart classroom environment (H6).

Hypothesis 7: Teacher support has a positive impact on students' behavioral engagement in the smart classroom environment (H7).
Hypothesis 8: Teacher support has a positive impact on students' emotional engagement in the smart classroom environment (H8).
Hypothesis 9: Teacher support has a positive impact on students' cognitive engagement in the smart classroom environment (H9).

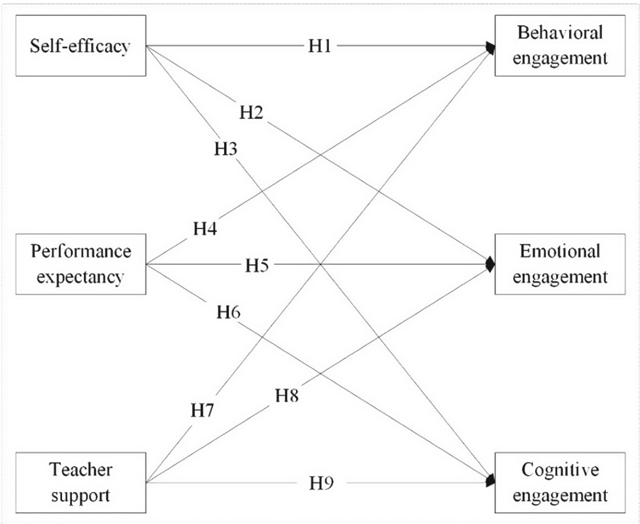

Fig. 1. Influencing factor model of students' learning engagement

3 Research Methods and Processes

3.1 Sample and the Smart Classroom Learning Environment

The study sample is eighth-grade students in a public junior high school in northwest China. This school had smart classrooms and carried out regular teaching applications in grades seven and eight. Especially, students in grade eight have had one year's experience in learning in the smart classroom environment, so students in grade 8 are selected as the research object. Students participated in an online survey. A total of 236 questionnaires were collected, and 226 valid questionnaires were obtained after removing invalid questionnaires. Among the 226 responses, 108 (47.8%) were boys, and 118 (52.2%) were girls.

The smart classroom involved in this study is a tablet-based learning environment, including an interactive touch-controlled all-in-one computer (hereinafter referred to as "all-in-one computer"), which is mainly used for presenting teaching content and can also be used for group discussion or presentation of group results in classroom teaching. Each student is equipped with a tablet computer that can interact with the all-in-one computer, including receiving resources from teachers and submitting answers to in-class tests. In addition, the smart classroom is also equipped with relevant teaching systems, such as a cloud-based learning platform, intelligent interactive recording, and a broadcasting system.

3.2 Instruments

By referring to the relevant measurement standards and scales that were used in previous studies on learning engagement [18], self-efficacy [19], performance expectancy [20], and teacher support [21], this study developed a questionnaire by integrating these scales. The questionnaire is divided into two parts, part one is the basic information about students (3 items), such as name, and gender. Part two includes six subscales (36 items in total), namely behavioral engagement (5 items), emotional engagement (6 items), cognitive engagement (8 items), self-efficacy (5 items), performance expectancy (4 items), and teacher support (8 items), and each item is designed with a 5-level Likert scale style.

3.3 Data Collection and Analysis

Data collection for this study was conducted at the end of the semester. All the students were asked to complete the questionnaire within 30 min. They were told that the survey was voluntary and anonymous, the information they provided would only be used for educational research, and the results of the survey would not affect their academic performance. After completing the questionnaire, all the answers were downloaded and then imported into SPSS and Amos for data analysis. The structural equation modeling method was used to analyze the relationship between self-efficacy, performance expectancy, teacher support, and student engagement. The Partial Least Squares (PLS) method was used to verify the research model presented in this study and it is appropriate for the sample size of this study [22]. The procedure of PLS-SEM analyses includes (1) evaluating external estimations (reliability and validity), and (2) assessing the internal structural model (validating hypotheses) [23].

4 Data Statistics and Analysis

4.1 Reliability and Validity Test

Exploratory factor analysis was used to analyze the questionnaire data. The KMO coefficient was 0.931 and the Bartlett Sphericity Test's approximate chi-square value was 6606.674 ($p < 0.001$), indicating that each part of the questionnaire was suitable for factor analysis. Then, the convergent validity and discriminant validity of the questionnaire data were analyzed by confirmatory factor analysis. It is generally believed that the factor load value of each observed variable should be greater than 0.5. The factor load values of the observed variables BE4, BE5, EE6, CE7, CE8, and TS8 are all less than 0.5, so they are deleted. After removing the above six questions, confirmatory factor analysis was conducted again, and the results were shown in Table 1.

Table 1. Validity test values of the measurement model

Variable	Item	Factor load	The modified factor load	CR	AVE
Behavioral engagement(BE)	BE1	0.751	0.749	0.847	0.650
	BE2	0.867	0.857		
	BE3	0.799	0.809		
Emotional engagement(EE)	EE1	0.735	0.735	0.897	0.636
	EE2	0.849	0.853		
	EE3	0.799	0.798		
	EE4	0.866	0.866		
	EE5	0.730	0.725		
Cognitive engagement(CE)	CE1	0.835	0.840	0.884	0.564
	CE2	0.679	0.677		
	CE3	0.855	0.868		
	CE4	0.645	0.649		
	CE5	0.634	0.629		
	CE6	0.811	0.805		
Self-efficacy(SE)	SE1	0.800	0.800	0.909	0.668
	SE2	0.903	0.903		
	SE3	0.651	0.651		
	SE4	0.862	0.862		
	SE5	0.847	0.848		
Performance expectancy(PE)	PE1	0.936	0.936	0.967	0.880
	PE2	0.953	0.953		
	PE3	0.973	0.973		
	PE4	0.889	0.889		
Teacher support(TS)	TS1	0.944	0.945	0.933	0.669
	TS2	0.780	0.780		
	TS3	0.868	0.868		
	TS4	0.859	0.859		
	TS5	0.660	0.659		
	TS6	0.758	0.757		
	TS7	0.828	0.826		

The factor load value of each variable is above 0.629, which conforms to the parameter standard. At the same time, the composite reliability (CR) of each variable ranges from 0.847 to 0.967, all greater than 0.8, and the average variation extraction (AVE) ranges from 0.564 to 0.880, all greater than 0.5, indicating that the measurement model has good convergent validity.

It can be seen from Table 2, the square root of AVE of each variable is greater than the correlation coefficient between this variable and other variables, indicating that the interpreted variance of each variable is greater than the common variance of this variable and other variables, meeting the requirement of discriminant validity.

Table 2. Correlation coefficient analysis table

	BE	EE	CE	SE	PE	TS
BE	(0.806)					
EE	0.746	(0.798)				
CE	0.768	0.739	(0.751)			
SE	0.693	0.720	0.721	(0.817)		
PE	0.690	0.770	0.660	0.604	(0.938)	
TS	0.647	0.657	0.539	0.519	0.568	(0.818)

Cronbach's α was used in this study to test the internal consistency of each factor. Generally speaking, Cronbach's α coefficient value is greater than 0.6, indicating high reliability of the factor [24]. After the deletion of items with factor loading less than 0.5, Cronbach's α of behavioral engagement, emotional engagement, cognitive engagement, self-efficacy, performance expectancy, and teacher support ranged from 0.848 to 0.967, and the Cronbach's α of the six variables was 0.963, all greater than 0.8. It shows that each factor has good internal consistency and the reliability of the questionnaire is good. The mean value, standard deviation (SD), and Cronbach's α coefficient of the six variables are shown in Table 3.

Table 3. Reliability test values of the measurement model

Variable	Mean	SD	α	Variable	Mean	SD	α
BE	4.31	0.629	0.848	SE	3.95	0.719	0.904
EE	4.06	0.701	0.893	PE	4.16	0.674	0.967
CE	4.02	0.648	0.877	TS	4.27	0.600	0.929

The results showed that students' behavioral engagement (M = 4.31), emotional engagement (M = 4.06), cognitive engagement (M = 4.02), self-efficacy (M = 3.95), performance expectancy (M = 4.16) and teacher support (M = 4.27) were all above average. In other words, students' learning engagement, self-efficacy, performance expectancy, and teacher support are all at a high level when they are learning in smart classrooms.

4.2 Structural Equation Model Test

Amos 24.0 was used to explore the relationship between the factors influencing students' learning engagement in the smart classroom environment. Through software analysis, the index values reflecting the fit degree of the model can be obtained, among which the Chi-square value of freedom ratio is 2.337, IFI is 0.914, TLI is 0.904, CFI is 0.914, all close to the ideal value, while RMSEA, NFI, RFI are 0.077, 0.859 and 0.843 respectively, which are all within the acceptable range. Therefore, through comprehensive consideration of the above indicators, the overall model fit is good. The test results of the structural equation model are shown in Table 4. It can be seen from Table 4, hypotheses H1 to H8 are all supported, while only hypothesis H9 is rejected.

Table 4. Test values of model parameters and verification of research hypotheses

Model path		S.E	C.R	P	Research hypothesis
H1	SE→BE	0.068	5.160	0.000***	Supported
H2	SE→EE	0.057	5.440	0.000***	Supported
H3	SE→CE	0.075	6.793	0.000***	Supported
H4	PE→BE	0.061	4.255	0.000***	Supported
H5	PE→ EE	0.054	6.682	0.000***	Supported
H6	PE→CE	0.065	4.328	0.000***	Supported
H7	TS→BE	0.060	4.472	0.000***	Supported
H8	TS→EE	0.049	4.230	0.000***	Supported
H9	TS→CE	0.062	1.930	0.054	Rejected

*** $p < 0.001$.

The results of model hypothesis verification and path coefficient analysis are shown in Fig. 2. The relationship between students' self-efficacy and behavioral engagement ($\beta = 0.372$, $p < 0.001$), emotional engagement ($\beta = 0.344$, $p < 0.001$), cognitive engagement ($\beta = 0.496$, $p < 0.001$) had a significant positive effect on the three variables, and students' performance expectancy also had a positive effect on behavioral engagement ($\beta = 0.297$, $p < 0.001$), emotional engagement ($\beta = 0.429$, $p < 0.001$), cognitive engagement ($\beta = 0.294$, $p < 0.001$).

These results indicate that self-efficacy and performance expectancy are important factors to promote students' learning engagement in the smart classroom. Teacher support had a significant positive effect on behavioral engagement ($\beta = 0.293$, $p < 0.001$) and emotional engagement ($\beta = 0.238$, $p < 0.001$), but had no significant effect on students' cognitive engagement ($\beta = 0.121$, $p > 0.05$), which indicated that teacher support was closely related to students' behavioral engagement and emotional engagement in the smart classroom.

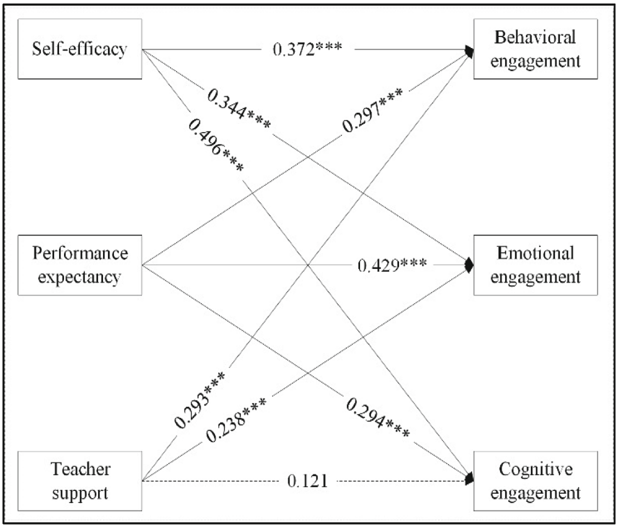

Fig. 2. Model hypothesis verification and path coefficient.

5 Discussion and Conclusion

This study analyzes the factors affecting junior high school students' learning engagement in the smart classroom environment through a questionnaire survey, and the structural equation model is used to verify and analyze the relationship between self-efficacy, performance expectancy, teacher support, and students' learning engagement in the smart classroom environment. The results show that students' self-efficacy and performance expectancy have a significant positive impact on students' behavioral engagement, emotional engagement, and cognitive engagement, while teacher support has a significant positive impact on students' behavioral engagement and emotional engagement in the smart classroom environment. To this end, teachers should make full use of the advantages of the smart classroom, use information technology to improve students' self-efficacy and performance expectancy, and provide timely feedback and support for students, to enhance students' learning engagement.

5.1 The Influence of Self-efficacy on Learning Engagement

It is found that students' self-efficacy is significantly positively correlated with their behavioral engagement, emotional engagement, and cognitive engagement. This result is generally consistent with previous studies. For example, Sağkal and Sönmez (2022) found that students' self-efficacy can affect their learning engagement [25]. The higher the students' self-efficacy, the higher the students' learning engagement. Sökmen (2021) found that middle school students' self-efficacy is a positive predictor of all aspects of their learning engagement [26]. The results of Lin (2021)'s study also showed a positive relationship between students' self-efficacy in science learning and learning engagement [27]. Therefore, it is necessary to improve students' self-efficacy in the smart classroom. It is suggested that teachers should consciously improve students' sense of self-efficacy and give students more opportunities for performance and demonstration when conducting classroom teaching in smart classrooms.

5.2 The Influence of Performance Expectancy on Learning Engagement

This study showed a significant positive correlation between students' performance expectancy and their behavioral engagement, emotional engagement, and cognitive engagement in the smart classroom environment. This result is consistent with the findings of previous studies. For instance, Alshabeb et al. (2020) found that performance expectancy predicted users' behavioral intentions when using e-learning technology [28]. Botero et al. (2018) pointed out that performance expectancy is one of the important factors for students to accept new technologies for learning [29]. Leng and Yi (2020) argued that students' use of technology can significantly improve their learning engagement [18]. Therefore, performance expectancy can indirectly affect students' learning engagement by influencing their use of technology in smart classrooms. It is suggested to promote the normalization of smart classroom teaching and improve teachers' and students' confidence and satisfaction with smart classroom teaching [30], to enhance students' learning engagement.

5.3 The Influence of Teacher Support on Learning Engagement

It is found that teacher support in the smart classroom environment has a significantly positive correlation with students' behavioral engagement and emotional engagement, but has no significant correlation with students' cognitive engagement. This finding is partially consistent with previous studies. For example, Luan, Dong, and Liu (2022) found that teacher support strategies have positive and significant impacts on students' cognitive engagement, emotional engagement, behavioral engagement, and social engagement in online English learning [31]. Sadoughi and Hejazi (2022) pointed out that teacher support can help improve students' engagement in the learning process [32]. Liu et al. (2018) also found that teacher support had a direct and significant effect on all three aspects of math learning engagement [33]. In addition, Lu et al. (2021) found that teacher support perception in the smart classroom can significantly affect students' cognitive engagement [34]. The possible reason is that teacher support is a complex structure including cognitive support, autonomous support, and emotional support. It is suggested that teachers increase the interaction between teachers and students, reduce the pressure brought by teachers' authority, and make students feel more of teachers' help, understanding, and support [35].

5.4 Limitations

It should be noted that the present study has certain limitations. Firstly, participants in this study were limited to junior high school students in a public school in northwest China, so the applicability of the findings needs to be further improved. Therefore, more students from different levels of education and different schools are encouraged to participate in future studies. Secondly, this study only examines three factors that affect students' learning engagement in the smart classroom. More influencing factors, such as teacher-student interaction, peer relationships, and cognitive load can be considered in future studies.

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Integrating Digital Citizenship into a Primary School Course "Ethics and the Rule of Law": Necessity, Strategies and a Pilot Study

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Abstract. Information technology has made modern life accessible and abundant, but it has also led to cyberbullying, online fraud, and other technology abuses. Enhancing digital citizenship can help solve these issues. This paper aims to figure out how to integrate digital citizenship into a primary school course named "Ethics and the Rule of Law" so that students can become good digital citizens in the new age. This paper first examined the need for this integration. Secondly, several strategies were proposed, including: content strategy (being closely linked with teaching materials), method strategy (innovating teaching methods), real-world strategy (connecting to real-world scenarios), and evaluation strategy (improving the evaluation criteria). Finally, a strategy-based pilot study was conducted. The results demonstrated that integrating digital citizenship into a moral education course could help students develop good digital ethics, behaviors, and habits.

Keywords: Digital Citizenship · Primary School Course · Ethics and the Rule of Law · Teaching Strategies

1 Introduction

With digital media and technology developing at an alarming rate, today's youth live a deeply networked existence. According to a recent study [1], children are regularly exposed to electronic devices between the ages of 0 and 8, and as they enter adolescence, their electronic device use grows more diverse and in-depth. Teenagers make up a sizable portion of the online population today and value the Internet as a resource for learning, socializing, and entertainment. However, because of their immaturity and poor judgment, they are prone to getting involved in negative incidents like cyberbullying, online fraud, privacy leaks, and other negative incidents [2, 3], as a victim or a perpetrator. Therefore, it is necessary to control and regulate people's online actions to preserve the stability and security of the online community.

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Primary school is a crucial phase in the development of children's consciousness, and it is essential for their healthy development – they learn the habit of utilizing technology in a safe, moral, and ethical way while they are there. Adults have a responsibility to educate children about digital citizenship, to teach them how to deal with ethical issues in digital life so that they can become qualified digital citizens who use technology responsibly for learning and creating, which is a preparation for the future where digital life is increasingly integrated with real life [1]. In recent years, researchers have launched many digital citizenship education practices, such as Common Sense Media's development of a digital citizenship curriculum [4], which was piloted to evaluate its efficacy in increasing digital citizenship knowledge and decreasing cyberbullying and online attacks [5].

However, digital citizenship education in China has not yet gotten enough attention. In terms of primary education, related contents exist in academic lectures, topic class-meeting, and safety learning materials, leading to a fragmentary and unsystematic status. Due to the significant relevance of digital citizenship to the content of primary and secondary school curriculum, its components are also included in other areas of primary education to improve teaching and learning outcomes [6]. For example, a moral education course called "Ethics and the Rule of Law" (shorted as ERL course) links much with the elements of digital citizenship, so integrating digital citizenship into this course sounds practical for students to understand and abide by the "morality" and "law" of the digital society, which ultimately helps the development of qualified digital citizens in the new era. Nevertheless, it is not yet clear how to achieve this goal. This study, therefore, aimed to address this uninvestigated area by clarifying the necessity, proposing some strategies and conducting a pilot study, which also served as a reference for the localization of teaching digital citizenship in China.

2 Literature Review

2.1 Digital Citizenship and Digital Citizenship Education

A qualified digital citizen is "able to use digital information and resources safely, legally, and ethically," according to the International Society for Technology in Education [7]. Mike Ribble describes digital citizenship as "behavioral norms associated with the use of digital technology" and organizes digital citizenship for youth into three categories: digital respect, digital education, and digital protection, with nine subdimensions in each category (digital etiquette, digital access, digital law, digital communication, digital learning, digital commerce, digital rights and responsibilities, digital safety, and digital health) [8], which is widely recognized and used in the industry. With the rapid growth and widespread adoption of technology, digital citizenship education is garnering increasing attention, and many nations have issued national programs to promote digital citizenship, such as the Cyber-wellness Program in Singapore [9], CyberSafe Program, and Click Wisely Campaign in Malaysia [10], and the Cyber Culture and Ethics Curriculum and the Create a Beautiful Cyber World Campaign in South Korea [11]. The Common Sense Education Institute in the United States, in collaboration with the Harvard Graduate School of Education, has developed a K 12 digital citizenship curriculum covering a variety of topics including privacy and security, relationships and communication, cyberbullying and digital drama, creative credit, and copyright, etc., which is widely implemented in elementary and secondary schools [12]. Digital citizenship can be taught in a wide range of settings, including elective or supplementary classes such as health and wellness, technology, library, STEM, character development, or advisory times, or it can be integrated into the subject curriculum [1]. For instance, Basarmak et al. discovered that the majority of digital citizenship content is covered in computer science, democracy, and human rights courses [13]. Digital citizenship curriculum is increasingly being implemented in schools and is seen as an important foundation for digital learning [1]. In contrast, pedagogical practices for implementing digital citizenship curricula in schools are absent from the available studies on digital citizenship education in China.

2.2 Moral Education in Schools

Moral education refers to the deliberate instillation of particular values, attitudes, and dispositions into students to promote their pro-social and moral development [14]. Schools play an increasingly important role in fostering children's sense of morality and shaping their moral identity [15, 16]. When children are exposed to moral principles at a young age, they are better able to develop the moral knowledge and awareness necessary to deal with a variety of social situations as they grow [17]. Implementing moral education in elementary schools is crucial for the physical and mental health of children and the stability of society. Puspitasari et al. did a critical discourse analysis of moral values in three Indonesian elementary schools' English textbooks, and the findings indicated that integrating character education into the language classroom is an effective strategy to instill moral values in children [17]. Regarding the separation between teaching and learning and ethics in the classical school curriculum (CSCC), Segev published a study and proposed an integrated approach [18]. Jie & Desheng outlined the principal advances in the reform of moral education curricula in primary and secondary schools in China, such as the use of "actual" occurrences as materials to connect children's moral development with their lives [19]. Moral education is frequently interwoven into other curricula, and in China, there is a required course called "Ethics and the Rule of Law", which is advocated by the Ministry of Education as a vehicle for integrating other subjects to cultivate students' varied qualities. However, there has been little discussion regarding how to integrate digital citizenship into it, which would aid in the popularization and localization of digital citizenship education in the country.

3 Necessity of Integrating Digital Citizenship into the ERL Course

3.1 Responding to the Government's Calls for Raising People's Level of Digital Literacy and Strengthening Network Civilization

In recent years, China has issued several significant policies, including "Opinions on Strengthening the Construction of Network Civilization", "Action Plan for Enhancing Digital Literacy and Skills for All People" [20, 21], and the like. They all put emphasis on raising people's level of digital literacy and strengthening network civilization, which are closely related to character education and moral education in digital world. That's exactly what digital citizenship education preaches. In fact, as a basic and vital literacy that people should own from the beginning of using the Internet, digital citizenship should be cultivated from an early age. In other words, these policies necessitate digital citizenship education in school. Taking the ERL course as an initial example to integrate with digital citizenship, this paper responds to the above calls. And the promulgation of these normative documents in turn provides direction for the localization of digital citizenship education in schools.

3.2 Enhancing the Security and Stability of the Digital Society by Good Online Behavior

It can be argued that peoples' poor level of digital citizenship leads to online fraud, privacy infringement, or other misconduct, which is against the security and stability of the digital society. For instance, cyberbullying on social media is closely related to one's level of digital citizenship [22]. Training digital natives as early as possible in primary school can improve their digital citizenship, foster healthy online behavior habits, and guide them to become cyberspace purifiers from early stage. In other words, digital citizenship education can be viewed as an "online" extension of how people perceive and behave in traditional life (the content of EFL course), helping to shape students into qualified digital citizens who use technology effectively, creatively and responsibly [23]. Integrating with digital citizenship makes ERL course more integral. Cultivating good online behavior will reduce the abuse or misuse of information technology, and enhance the security and stability of the digital world.

3.3 Implementing Digital Citizenship Education Practice is Necessary for Students' Healthy Growth

Elementary school students are vulnerable to various online threats such as cyberbullying and predatory contacts, and their insufficient self-control can easily lead to addiction to online games as well. All these can have a lasting negative impact on their future [24]. It was found that teenagers' online actions are guided by moral theories [25]. They make moral decisions everyday about what they post, share, praise and comment on [26]. Integrating digital citizenship into ERL course is beneficial for students to establish a positive and healthy attitude toward life and values so that they can restrain their behavior with higher standards to resolve digital dilemmas, and become physically and mentally healthy digital citizens.

3.4 Integrating Digital Citizenship is an Efficient Way to Meet the Curriculum Standards of ERL Course

The Curriculum Standards for Ethics and the Rule of Law in Compulsory Education (2022 Edition) emphasizes the cultivation of right values, essential character, and key competencies for future development [27]. In addition, it highlights the significance of students' moral cultivation, which requires that they learn basic online ethics and behaviors. This development objective aligns with digital etiquette, digital rights and responsibilities, and other facets of digital citizenship. That is to say, many aspects of digital citizenship can be integrated into primary school ERL course in terms of pedagogical content. Therefore, it becomes easier and more efficient to achieve the curriculum standards of ERL course.

4 Integration Strategies

4.1 Content Strategy: Try to Explore the Shared/Closely Linked Contents Between Digital Citizenship and ERL Course Through In-Depth Examination of the Teaching Materials, then Integrate Them

The curriculum integration is not a straightforward superimposition of two disciplines; such a rigid approach would create a sense of fragmentation among the students. When integrating digital citizenship into primary school ERL course, teachers should take ERL as the main subject, and then carefully examine the content of teaching materials (e.g., textbook), select the portions that are relevant to digital citizenship, and finally start combining some shared contents or extending to their counterparts in the digital society. For instance, the lesson "Proper Understanding of Advertising" in Unit 3 of the first booklet of Grade 4 is strongly related to digital etiquette, digital health, and digital business in digital citizenship. For Unit 2 "Be a smart consumer" in the second booklet of Grade 4, teachers can introduce online shopping as an add-on to help students develop healthy digital citizenship behaviors, such as avoiding consumer traps, preventing the disclosure of payment passwords, and protecting the rights of online consumers.

4.2 Method Strategy: Try Innovative Teaching Methods Such as Gamification or Role-Playing to Stimulate Students' Interest in Learning and Enrich their Learning Experience

Innovative teaching methods are essential to inspire and develop students' spirit and enthusiasm for learning [28]. When incorporating digital citizenship into ERL course, teachers should try to forget the traditional lecture-based approach and try a variety of teaching methods instead. For instance, using technology and multimedia resources to augment classroom activities or resorting to digital games can fully excite students, enliven the classroom environment, and allow them to study enjoyably. In addition, role-playing is a lively and immersive method. For example, teachers can establish an Internet fraud scenario to make students feel physical and mental harm through role-playing, and deepen their emotional experience, which not only improves students' verbal skills but also enhance their collaborative learning skills. Other similar teaching methods can be flexibly adapted to make the class more interesting and interactive, cultivate students' critical thinking and develop their ability to think independently and solve practical problems.

4.3 Real-World Strategy: Try to Link the Classroom and the Real World to Arouse Students' Awareness of Practicing Qualified Digital Behaviors

Dewey believed that education is not a preparation for life, but a process of living [29]. The best outcome of schooling is the propensity to learn from life itself and to create conditions in which everyone will learn while they are living [30]. The Curriculum Standards for Ethics and the Rule of Law in Compulsory Education (2022 Edition) state explicitly in the curriculum philosophy the unity of subject logic and life logic, the integration of subject learning and student life, and the need to improve the relevance and realism of teaching content based on students' real life. Chinese President Xi Jinping also stated that "we should focus on inspiring teaching, guide students to discover, analyze, and solve problems, and let them reach conclusions naturally in constant inspiration" in a symposium for instructors of ideological and political theory courses in schools [31]. It requires linking the classroom and the real world, combining theory and practice all the time, and encouraging students to practice what they have learned in the real world. For instance, teachers can incorporate current events or news related to Internet misuse into their lessons, using real-world examples to show that the Internet has its own rules that we should conform to. In this way, students can develop good behavioral habits by gradually cultivating life-like thinking by interacting with life.

4.4 Evaluation Strategy: Try to Improve the Evaluation Criteria by Applying Information Technology, Formative Assessment, or Multiple-Subject Assessment

As a moral education course to establish morality and cultivate people, ERL course is unique and different from those score-based courses. When integrating with another quality-oriented education (digital citizenship education), teachers should try to improve the evaluation criteria by applying information technology, formative assessment, or multiple-subject assessment. For instance, paper-and-pencil tests can be machine-marked, which greatly reduces the workload of manual grading and helps generate learning reports. Moreover, various assessment tools such as classroom observation forms, student worksheets, and daily behavioral records can be included to support formative assessment. Last but not least, teachers, peers, or even parents are welcome to act as evaluators to help students reflect on their online behaviors and develop critical-thinking skills, which will make them more accountable for their learning [32].

5 A Pilot Study

5.1 Case Introduction

The participants of our experiment are 9-year-old students in the fourth grade. After checking the textbook of their ERL course, we found that Unit 3 with the theme "cyberspace, a connected new world" is closely related to Netiquette (a new word representing Network Etiquette, also an important element of digital citizenship). Specifically, this unit aims to: (1) help students recognize the importance of the Internet; (2) train them to abide by the convention on network civilization and act properly online, especially when they encounter issues such as inappropriate word use in online socializing; and (3) help them distinguish right from wrong in online games and enhance media literacy. Therefore, we chose this unit to conduct our experiments. The purpose of integrating Netiquette into this unit is to nurture students' correct values of Internet ethics and etiquette from childhood and raise their awareness of using polite words when socializing online. The breakdown of our learning activities can be found in Table 1.

Table 1. Learning activities for the ERL course integrated with netiquette

Lessons	Learning activities
Lesson 1. Proper understanding of netiquette	Group singing: A four-character song "Be polite online"
	Introduction: Traditional etiquette and new-age Internet etiquette (netiquette)
	Interactive digital game: Matching real-life scenarios and netiquette rules
	Summary: the impact of netiquette on individuals, society, and national image
Lesson 2. Polite words	Exploring: the use of words in online socializing
	Exploring: the use of emojis in online socializing
	Digital game: Be an "online socialite" when chatting with people of different identities
Lesson 3. Etiquette on the Internet	Exploring: etiquette in online socializing
	Discussion: etiquette in online learning
	Introduction: Laws and regulations on netiquette
Lesson 4. Proper participation in online games	Scenario: pay attention to verbal violence in online games
	Analysis: How to deal with verbal violence in online games
	Digital Game: *an alien called D01 learns on the Earth*
	Summary: To be a qualified digital citizen (pay attention to netiquette, and be polite, respectful, and friendly to others)

The first lesson concentrated on the understanding of Internet etiquette, leading students into a connected new world. Students got to know what netiquette is and the impact of netiquette on individuals, society, and national image by learning the concepts and rules through activities such as group singing and interactive game. In the second lesson, students mastered the rules of using words and emojis in online social networking through two exploring activities. By practicing communication skills in an interactive game, students learned how to be an "online socialite" in actual situations. In the third lesson, students explored and discussed how to behave properly in online socializing and learning, and got familiar with the laws and regulations on netiquette through real-case study. In the fourth lesson, students learned about verbal violence in online games and how to deal with it correctly. Through a 10-min digital game named *"an alien called D01 learns on the Earth" designed and developed by us*, students learned how to treat others with respect and friendliness, and how to deal with online verbal violence. In the series of lessons, students learned how to become a qualified digital citizen in terms of Internet etiquette.

5.2 Methodology

Participants and Experimental Procedure. The participants in the experiment were 82 fourth-grade students from Yunshan Primary School in Yuexiu. Figure 1 shows the experimental procedure. Before the experiment, we conducted a netiquette pre-test to collect data about students' online ethics and netiquette literacy, which lasted about 8 min. In the following 4 weeks, there were 4 online lessons due to the COVID'19 pandemic (once a week, and each lasted about 20 min), i.e., Proper understanding of netiquette, Polite words, Etiquette on the Internet, and Proper participation in online games. At the end of the experiment, the students were asked to complete a post-test on Netiquette within 8 min to find out whether their online ethics and literacy had improved.

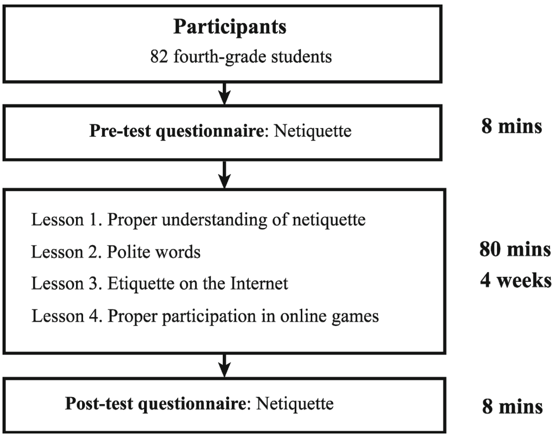

Fig. 1. Procedure of the experiment

Instrumentation. As can be seen from Fig. 1, a single group pre-post quasi experimental method was adopted in this experiment. The questionnaire was adapted from the rules of etiquette, online regulations concerning polite word choice, and the Respect behavior online [33], taking into account the characteristics of digital society. It was divided into four dimensions, i.e., etiquette awareness, polite words, respectful behavior and active participation, with a total of 17 questions. Statistical result shows that the questionnaire had a reliability of 0.889 (Cronbach's alpha value) and a validity of 0.858 (KMO).

5.3 Results

The mean of the pre-test was 67.18 (out of 85), which was at a moderate level. The mean of the post-test was 70.87, which was 3.69 points higher than before. Making an independent-sample t-test on the pre- and post-tests, we got a significant positive increase ($p < 0.05$), as shown in Table 2.

Table 2. Results of the independent-sample t-test on the pre- and post-tests

Groups	Mean ± SD	T	Sig
Pre-test	67.18 ± 10.092	−2.220	.028*
Post-test	70.87 ± 11.132		

* $p < 0.05$

Due to the pandemic and time limitation, we only conducted a pilot study. Preliminary results show that the participants had a deeper understanding of the ethics of the online world and were more inclined to behave in a manner consistent with the norms of netiquette.

5.4 Discussion

Reviewing the pilot study, we find that several strategies work in this small-scale case.

Firstly, being closely linked with the teaching materials (i.e., textbook in our case) is the key to course integration. It was criticized in [34] that the content of the integrated course was too complex for the teachers to follow the schedule, so the students did not perform well. On the contrary, our study made an in-depth analysis between digital citizenship and ERL textbooks in order to find highly correlated content. For example, the ERL course advocates fundamental Internet ethics and responsible online behavior. While in our integrated course with digital citizenship, students learned basic netiquette in daily life and how to use emojis properly when socializing online, which links closely with the ERL course and matches its curriculum standard. In other words, Content Strategy is applied in our study.

Secondly, innovative teaching methods help stimulate students learning enthusiasm. For instance, Kalyani and Rajasekaran suggested innovative teaching and learning methods in the classroom, so they believed that by adopting new methods, students would be more engaged and retain knowledge longer [35]. Our study complies with this opinion by using a variety of innovative teaching methods (e.g., group singing, role-playing, digital-game playing, etc.) to change teacher's leading role into student-centered activities, which greatly enhances students learning enthusiasm. In other words, Method Strategy is applied in our study.

Thirdly, linking the classroom and the real world helps students understand those boring concepts and principles. In this way, teachers can give students a more vivid and specific explanation or illustration of the learning contents. Our study selected life-related materials and provided a mission-oriented digital game, which could help the students put the theoretical knowledge they learned in the classroom to practice. This is consistent with Gleason and Von's suggestion that there is a need for digital citizenship curricula to emphasize the real-life experience of young people themselves [36]. In other words, Real-world Strategy is also applied in our study.

However, because of the pandemic and short-term experiment, a relatively simple evaluation (a post questionnaire) was performed in this study. Whereas in other similar research [37], a formative assessment including student evaluation of their own work was conducted and proven to be effective in promoting meaningful learning. In other words, Evaluation Strategy is hardly applied in our study.

6 Conclusion

With the advancement of digital technology, our social interactions and ways of life have significantly changed, causing us to become more reliant on cyberspace. Therefore, the ability to use the Internet responsibly in daily life, adhere to Internet ethics, and safeguard personal information is crucial for all of us. Born in this information age, teenagers are more likely to get involved in cyberbullying, online fraud, or other negative events. Adults have the responsibility to train them to become qualified digital citizens from an early age. This paper discussed how to integrate digital citizenship into a primary school course named "Ethics and the Rule of Law". Firstly, we figured out some key points about the necessity of the integration, then proposed four strategies, i.e., content strategy, method strategy, real-world strategy, and evaluation strategy. On this basis, a 4-week pilot study at Yunshan Primary School was conducted. The preliminary results showed that students' digital citizenship literacy on netiquette has significantly improved. This first-round practice has proved that integrating primary school courses with digital citizenship education practically works. And the proposed strategies can greatly help achieve this goal as well. There are limitations that leave room for future work. First, only the first round of teaching practice was conducted and follow-up experiments would provide more insight into the effects of integrating digital citizenship into primary school courses. Second, pre- and post-tests of two groups (experimental group vs. control group) could be involved to determine whether game-based learning makes significant differences. Third, Evaluation Strategy should be taken into account to draw broader conclusions.

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From ICT Utilization to Student Learning Achievement: Mediation Effects of Digital Literacy and Problem-Solving Ability

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Abstract. The impact of information and communications technology (ICT) on students' learning achievement has attracted increasing attention from researchers and policy makers. However, we still have limited knowledge of its underlying mechanisms. This study examined the chain mediating roles of digital literacy and problem-solving ability on the relationships between ICT utilization and learning achievement. Participants included 1633 middle school students from central and southern China. Results indicated that ICT utilization had a significant positive effect on learning achievement, and digital literacy played a mediating role in the relationship between them. Further, ICT utilization affected learning achievement through the chain mediating role of digital literacy and problem-solving ability. However, our findings showed that problem-solving ability cannot mediate the relationship between them. These above findings revealed the mechanism through which ICT utilization may influence students' learning achievement and contributed to an in-depth discussion regarding the reasons behind the relationships. Finally, we adduced practical implications for how to help students better benefit from ICT utilization for learning and proposed the future research directions.

Keywords: ICT Utilization · Learning Achievement · Digital Literacy · Problem-solving Ability

1 Introduction

In the information age, the increasing use of information and communications technology (ICT) has aroused wide concern in many sectors, including education. Numerous studies have shown that ICT utilization in learning is positively related to students' learning achievement [1, 2]. The availability of ICT makes it possible for students to learn at their most convenient time and place at their own pace [3]. Also, students may benefit from the use of ICT by increasing access to a wider range of resources and information for learning [1].

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While the positive relationship between ICT utilization and students' learning achievement has been demonstrated extensively, few studies have investigated its underlying mechanisms, which could constitute a crucial concern for teaching and for policy making. In recent years, some studies have pointed out that students' ICT motivation factors (e.g., ICT self-efficacy, attitude towards ICT, perceived ease of ICT use) could influence the effects of ICT utilization on academic performance [4–6]. In addition to these studies guided by psychological constructs, given the new demand for talent cultivation in the information age, researchers have acknowledged that the core literacy of 21st-century (e.g., digital literacy and higher-order thinking capacities) may also have important association with students' ICT utilization and learning achievement [7, 8]. However, relevant research is still lacking.

Digital literacy, as one of the essential core literacy, may be an important factor mediating the relationship between ICT utilization and learning achievement. The experience of using ICT enables students to feel the benefits of it and improve their proficiency in using it, thus providing a foundation for students' development of digital literacy [9]. Moreover, research has indicated that digitally literate students can access, screen, manage, evaluate and communicate information appropriately and accurately, which in turn enables them to learn more in ICT-mediated activities and perform better academic achievement [10].

In addition, problem-solving ability, as an important kind of higher-order thinking capacity that affects students' learning quality, may also be a key mediating variable. In recent years, researchers increasingly pay attention to the cultivation of students' problem-solving ability, and found that ICT-based learning media provides a promising approach [11]. Students with higher problem-solving ability are more able to think flexibly and deal with challenges independently, whilst improve their learning performance [8].

However, the underlying mechanisms has not yet been fully examined. To bridge these research gaps, this study adopted digital literacy and problem-solving ability as mediating variables, as they are essential core literacy in the information age and closely related to students' learning, to investigate the potential mechanisms linking ICT utilization to learning achievement.

2 Literature Review and Hypotheses

2.1 ICT Utilization and Learning Achievement

A great number of studies have investigated the impacts of ICT utilization in learning on students' learning achievement. These studies can be classified into two groups: the first group is experimental and quasi-experimental studies. For example, Birgin et al. indicated that GeoGebra software can be used to help middle school students improve their mathematics achievement by providing opportunities for their graphical drawing, graph interpretation and conceptual learning [12]. Moreover, some studies employing other technologies for teaching, such as digital storytelling and dynamic web technologies, also revealed that they can bring greater academic benefit than traditional teaching without ICT support [13, 14]. The second group is empirical analyses based on large international data sets such as PISA and PIRLS. In general, these studies focused on the analysis of cross-sectional data from these surveys. For example, Xiao and Sun, using data from PISA-2018 for America, obtained that students who use ICT moderately across all aspects performed better academically [2]. Similarly, several regional studies also supported the results of the PISA-2018, showing that ICT usage can lead to higher learning achievement [15].

Despite these findings, we still have limited knowledge of how ICT use affects students' academic performance. Further investigation is necessary to reveal the underlying mechanism and contribute to an in-depth discussion regarding the reasons behind the relationships.

2.2 Digital Literacy as a Mediator

The growing importance of digital literacy is recognized widely, but there are multiple perspectives on its meaning. Gilster first proposed digital literacy and defined it as the ability to understand and use information from various digital sources [16]. Martin emphasized digital literacy as developing the awareness and attitude to appropriately use digital technologies; identifying and accessing digital resources; managing, integrating, evaluating, analyzing and synthesizing digital resources; constructing new knowledge and creating new information [17]. Walton defined it as the ability to find, evaluate, share and create using digital technologies and the Internet [18]. In general, digital literacy can be described as the awareness, attitude and abilities to use digital resources. It contains four dimensions: (1) ICT awareness involves knowing about the existence and importance of digital technologies and their application [19]. (2) Computational thinking is the thought processes involved in formulating problems and expressing solutions through computational steps and algorithms [20]. (3) Digital learning and innovation includes the skills and qualities that one possesses in making full use of various digital technologies and resources to carry out independent learning and group collaboration, and to constantly create and innovate new content [21]. (4) Information society responsibility can be understood as the social norms and codes of conduct that individuals should fulfill in the information society [22].

Although little research has explored the factors mediating the relationship between ICT utilization and learning achievement, the literature points to the possibility of digital literacy. Research has shown that the frequent use of ICT was positively related to scientific literacy scores [3]. The accessibility of ICT could affect students' attitudes towards it and their proficiency in using it [9]. Students with more experience in ICT are better able to control their behavior in ICT activities. For example, the more comfortable students are with digital hardware and software, the more comfortable they will be in using ICT to constructing new knowledge and create new information. Additionally, students who frequently use ICT are more familiar with the norms of Internet behavior and more able to regulate their own online behavior. On the other hand, in recent years, researchers have paid great attention to the important role of digital literacy in learning. A meta-analysis study of 45 relevant literature suggested that students with greater digital literacy often had substantially higher academic achievement, as they can manage and organize ICT information more effectively, whist learn more efficiently [10].

2.3 Problem-Solving Ability as a Mediator

Problem-solving is a process, which involves the application of mental and physical abilities in finding an appropriate solution or way to reach the desired goal [23]. It can be speculated that students' problem-solving ability may play a mediating role in the relationship between ICT utilization and learning achievement. Problem-solving ability involves a higher order thinking skill**,** which may affect students' academic learning. For example, Beyazsacli claimed that problem-solving ability has a fundamental role in students' success in academic, as it is closely related to students' reasoning, decision making, critical thinking, and creative thinking [8]. Some other studies have also supported this research findings [24]. As one of the skills, which individuals need throughout their study/lives and they need to gain it from young ages, problem-solving ability has received increasingly attention. Researchers and teachers suggested that the use of ICT for teaching and learning could be a promising approach to develop students' this skill. For example, Zhang et al. found that the use of Hawgent dynamic mathematics software can improve students' problem-solving ability through directing them with various representations, and through enabling the concepts to be concrete and easier for understanding [25]. Herdianto also claimed that students who use ICT-based learning media have better problem solving skills [11].

2.4 The Chain Mediating Roles of Digital Literacy and Problem-Solving Ability

At the same time, digital literacy has been revealed to have an important relationship with students' problem-solving ability. Recently, some researchers has pointed out that digital literacy is not merely about the ability to make effective use of digital resources, but involves the essential capacities of effective collaboration and communication, flexible knowledge transfer, and problem solving [26]. For example, Greiff et al. conducted an empirical analysis and found that digital literacy was weakly or moderately related to complex problem solving [27]. In contrast, students with low digital literacy may tend to form a psychological dependence on ICT when using it to solving problems, as they cannot rationalize the use of ICT. This may even solidify students' thinking and reduce their problem-solving skills, which may negatively affect their academic performance. As a consequence, we can infer that students' digital literacy and problem-solving ability may play chain mediating roles in the relationship between ICT utilization and learning achievement.

2.5 Research Hypotheses

Based on previous studies, we hypothesized that digital literacy and problem-solving ability would mediate the relationship between ICT utilization and learning achievement both directly and in series. The research model is presented in Fig. 1. And the research hypotheses are proposed as followings.

H1: ICT utilization is directly and positively related to students learning achievement.

H2: Digital literacy plays a mediation role between ICT utilization and learning achievement.

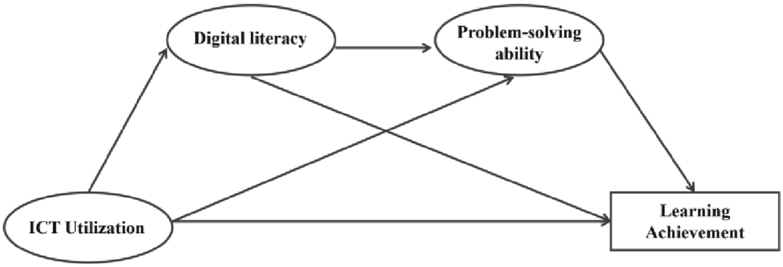

Fig. 1. Theoretical model

H3: Problem-solving ability plays a mediation role between ICT utilization and learning achievement.

H4: ICT utilization has predictive effects on learning achievement through the chain mediating roles of students' digital literacy and problem-solving ability.

3 Method

3.1 Data Collection and Samples

This research was conducted in middle schools in three provinces (Hunan, Hubei and Guangdong province) in central and southern China. A total of 1637 students participated in the research and completed a questionnaire online. Students were aware that their participation was voluntary and that they could withdraw at any stage. To protect the privacy of participants, the responses were anonymous. Cases of incomplete response were removed from the data set, reducing the sample size to 1633. Of the valid respondents, 797 (48.8%) were male and 836 (51.2%) were female. Nearly half of the valid respondents were 7th graders (42.7%, n = 697). The percentage of 8th, 9th and 10th graders was 13.6% (n = 222), 27.7% (n = 453) and 16% (n = 261) respectively.

3.2 Measures

ICT Utilization. ICT utilization was measured by two variables, the frequency of using Internet for learning (calculated based on 2 items) and the frequency of using digital devices for learning (calculated based on 12 items). An example item was "The number of times per week I study through online platforms (such as TAL app, Homework help app, etc.)." Each variable was rated on a six-point Likert scale.

Digital Literacy. The digital literacy scale consisted of four variables that are ICT awareness, computational thinking, digital learning and innovation, and information society responsibility. The construct of the scale was adapted from previous research with slight modifications, or self-developed according to curriculum standards or documents. The instrument of ICT awareness was developed according to China 2022 Curriculum Standards of Information Science and Technology for Compulsory Education. It contains 15 items and one example item was "I can think of finding information on the Internet to solve the problems encountered in study and life." The Cronbach's alpha for ICT awareness scale was 0.952, indicating good internal consistency. The instrument of computational thinking was adapted from the instrument developed by Shute et al. [28], e.g., "I can create a series of ordered steps to solve a problem." It consists of 19 items and the Cronbach's alpha was 0.980. The instrument of digital learning and innovation and information society responsibility were adapted from the DigComp 2.1 [21]. They consisted of 10 and 11 items respectively, and the Cronbach's alpha were 0.959 and 0.976 respectively. The Cronbach's alpha of the whole digital literacy scale is 0.984. All items were measured using a 5-point Likert scale from "strongly disagree" to "strongly agree".

Problem-solving Ability. Problem-solving ability was measured using eight items adapted from the Problem-solving Ability Scale developed by Zhang et al. [29]. Example items were: "I can focus on solving a problem for a period of time" and "I can summarize my experience in problem solving in order to solve new problems." They were scored on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. The Cronbach's alpha was 0.963.

Learning Achievement. In order to make the academic performance of students in different schools comparable, this study adopts their total score ranking to measure the learning achievement. The item was "the rank of my total score in the grade." It was scored on a 6-point Likert scale, and the possible options are: 1 = bottom 25%, 2 = top 75%, 3 = top 50%, 4 = top 25%, 5 = top 10%, 6 = top 5%. The higher score means the better learning achievement.

3.3 Data Analytic Procedures

Data analysis included the following steps. First, analysis of statistical description and correlations of all study measures were calculated with SPSS21.0 software. Second, structural equation modeling (SEM) was conducted to examine the relationships between all study measures using Mplus 7.4 software. Third, a bootstrapping method was used to test the mediating effect of digital literacy and problem-solving ability.

4 Results

4.1 Common Method Bias Test

Common method biases may happen due to self-report methods, so Harman's single factor analysis was carried out to test the common method biases. Results showed that a total of four factors were extracted and the first factor explained 35.53% of the variance variation, which was less than the critical standard 40%, indicating that common method bias in this study was not obvious.

4.2 Descriptive and Correlation Analysis

Table 1 demonstrates the descriptive statistics and correlation results prior to the main path analysis. The mean scores of digital literacy (m = 3.93) and problem-solving ability (m = 3.72) were higher than the average level (3) based on a 5-point Likert scale. However, the mean score of ICT utilization was lower than the average level. In addition, the descriptive statistical data shows that the mean value of all variables is higher than the standard deviation value so that there are no data anomalies and we can continue the analysis.

Table 1. Descriptive and correlation analysis

	Range	M	SD	1	2	3	4
1. ICT utilization	1–6	1.88	0.65	–			
2. Digital literacy	1–5	3.93	0.60	0.238**	–		
3. Problem-solving ability	1–5	3.72	0.68	0.152**	0.665**	–	
4. Learning achievement	1–6	3.36	1.40	0.159**	0.207**	0.232**	–

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

Pearson product-moment correlation coefficients were computed to assess the relations among the four variables. ICT utilization was found to be positively and significantly correlated with students' digital literacy (r = 0.238, p < .01), problem-solving ability (r = 0.152, p < .01) and learning achievement (r = 0.159, p < .01). Digital literacy was positively and significantly correlated with problem-solving ability (r = 0.665, p < .01) and learning achievement (r = 0.207, p < .01). Significant positive correlation was also found between problem-solving ability and students' learning achievement (r = 0.232, p < .01).

4.3 Structural Equation Modeling

We used structural equation modeling (SEM) to further examine the relationship between all study measures. First, measurement models were examined. ICT utilization was indexed by two dimensions; digital literacy was indexed by four dimensions; problem-solving ability was indexed by eight items. Learning achievement was used as the outcome variable. All the factor loadings ranged from 0.61 to 0.90 and were significant, indicating that all the measurement indicators could be well-explained by the latent variables.

Next, we analyzed the structural model to investigate the research hypotheses. The results indicated an acceptable model ($\chi 2 = 1654.499$, df = 196, p < .001, CFI = 0.928 > 0.9, TLI = 0.923 > 0.9, SRMR = 0.038 < 0.08). To examine the mediating effects, we used Model 6 in the SPSS PROCESS macro, developed by Hayes [30], to obtain confidence intervals (CIs) for the indirect effects using a bootstrap approach. If the bias-corrected (BC) 95% CIs for the path coefficient does not include 0, the mediating effect is significant. Our research findings are as followings:

First, students' ICT utilization was found to be significantly positively related to their learning achievement ($\beta = 0.2512$, p < .001), which confirms H1.

Second, the results showed that ICT utilization was significantly positively related to digital literacy ($\beta = 0.2190$, p < .001), and that digital literacy was significantly

Table 2. The summary of direct, indirect, and total effect of proposed relationships

	Proposed Relationship	Effect Size	Boot SE	95% BC CI	
				Boot CI Lower	Boot CI Upper
Direct Effect	ICTU→LA	0.2512	0.0528	0.1476	0.3548
Indirect Effect	ICTU→DL→LA	0.0338	0.0168	0.0016	0.0677
	ICTU→PS→LA	−0.0025	0.0072	−0.0171	0.0117
	ICTU→DL→PS→LA	0.0583	0.0125	0.0349	0.0845
Total Effect		0.3408	0.0525	0.2378	0.4439

Note: ICTU is ICT utilization; LA is learning achievement; DL is digital literacy; PS is problem-solving ability; ICTA is ICT awareness; CT is computational thinking; DLI is digital learning and innovation; ISR is information society responsibility

positively related to learning achievement (β = 0.1544, p < .01). ICT utilization showed an indirect effect of 0.0338 on learning achievement via digital literacy (Effect = 0.0338, 95% CI = [0.0016, 0.0677]). Thus, H2 is supported.

Third, ICT utilization was not found to be significantly related to problem-solving ability (β = -0.0071, p > .05). Problem-solving ability was significantly positively related to learning achievement (β = 0.3497, p < .01). The indirect effect on ICT utilization on learning achievement via problem-solving ability was not found to be significant (Effect = −0.0025, 95% CI = [−0.0171, 0.0117]). Hence, H3 is not supported.

Finally, we found a significant indirect effect serially via digital literacy and problem-solving ability (Effect = 0.0583, 95% CI = [0.0349, 0.0845]). Therefore, H4 is accepted.

Table 2 demonstrates the summary of the direct, indirect, and total effect of proposed relationships. The total effects of ICT utilization on learning achievement were 0.3408

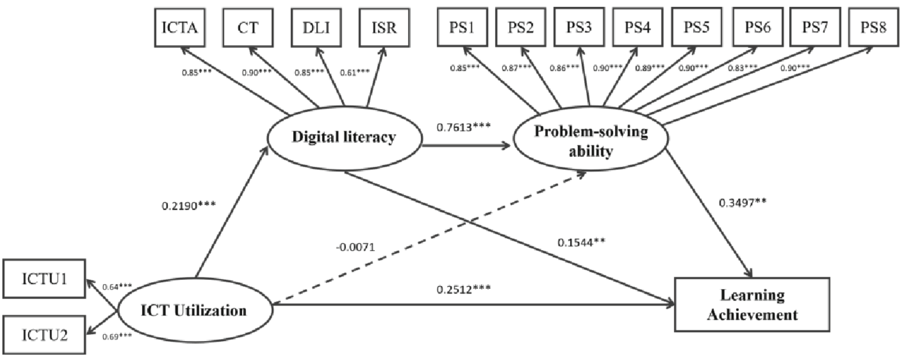

Fig. 2. Research model predicting students' learning achievement: Path coefficients.

and the total mediating effects were 0.0896. Furthermore, Fig. 2. Provides a path diagram of the research model predicting students' learning achievement.

5 Discussion

Consistent with previous findings, ICT utilization is directly and positively related to students' learning achievement [1]. More importantly, we revealed the mechanisms underlying the relationship between them by adopting digital literacy and problem-solving ability as mediating variables. It extended previous models confined to the examination of simple direct relationship.

Digital literacy was found to mediate the relationship between ICT utilization and students' learning achievement in the present study. For one thing, this result implied the importance of ICT resource as a first step and its role in improving students' quality of ICT use. Specifically, the more students accessed ICT resources, the more proficient and appropriate they were in using ICT, and the more aware they are of the convenience and flexibility that ICT bring to learning [31]. For another, this result could support previous research highlighting the importance of digital literacy in digital learning environments [32]. As the rapid development of ICT is expanding its influence in education, it is inevitable for students to take part in the digital learning environments. Digitally literate students are able to adapt more quickly to the changes and better seize the opportunities that digital learning brings.

However, as suggested by our results, problem-solving ability cannot mediate the relationship between ICT utilization and learning achievement. On the one hand, ICT utilization was found to be not related to students' problem-solving ability, which is not consistent with some experimental studies [11, 27]. One possible reason is that in these studies, teachers often consciously guide students in the treatment group (teaching with ICT) to use ICT to develop problem-solving skills. Nevertheless, when students use ICT to carry out self-directed learning, they may only focus on obtaining answers to questions, but fail to develop the ability to solve a series of problems due to the lack of positive guidance from teachers. However, on the other hand, our results showed that students' problem-solving ability can positively predict their learning achievement, which is in alignment with existing research [24]. Problem-solving ability is related to gaining conceptual understanding, defining problems and examining possible solutions, which involves a higher level of thinking. Students with higher problem-solving ability can automatically proposed a suitable learning strategy and creative thinking that would affect their learning achievement [8].

Finally, our findings revealed the chain mediating roles of digital literacy and problem-solving ability in the relationship between ICT utilization and learning achievement (i.e., ICT utilization→digital literacy→problem-solving ability→learning achievement). Its significance indicates that when students tended to use ICT in learning, mastered advanced digital competence, followed by flexible ways of thinking and higher problem-solving skills, which led to positive impacts on academic achievement. According to Kim, digital literacy is more than the ability to make use of digital resources, and has been considered a catalyst for core competencies because it may stimulate creative thinking and help to solve problems effectively [26].

6 Conclusion

6.1 Practical Implications

There are several implications for practice based on our study findings. First, for students, they should be aware of the important role of ICT on achieving better and thus make full use of it in learning. Specific examples include: (a) actively sharing and discussing knowledge with others through communication technology; (b) searching for rich and attractive learning resources to achieve broader and deeper learning. Second, the findings remind teachers to take students' digital literacy and problem-solving ability into consideration when implementing ICT in student learning, such as: (a) consciously providing guidance to students on the proper use of ICT during teaching process; (b) adopting appropriate teaching methods (e.g., problem-based learning) to develop students' higher-order thinking capacity. Third, designers of educational platform/software are advised to develop more innovative features so that learners can exercise their minds and develop digital literacy, and thus perform better achievement. Possible ways include: (a) embedding features in educational platform/software that facilitate knowledge sharing; (b) providing opportunities for learners to explore solutions to problems on their own.

6.2 Limitations and Future Research Directions

There are still some limitations of the present study that should be addressed in future research. First, although we are confident in the instruments used, future research could consider using more objective rather than self-reported methods to collect data, such as by collecting records of usage of digital devices to obtain students' ICT use. Second, to provide comprehensive understanding of the effects of ICT use on learning achievement, it is worth conducting a multi-group analysis using a sample stratified by demographic and personal variables (e.g., gender, family socioeconomic status).

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Online and Distant Learning

The Effect of Corpus-Based Writing Practices on EFL Learners' Lexical Diversity and Lexical Sophistication

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Abstract. Corpus-based Language Learning brings many pedagogical benefits to EFL learners. Since learners' written texts are always predominated with simple and repetitive words and vocabulary knowledge is closely related to corpus use, this article applies Versatext in writing instructions and explores its effects on students' lexical diversity (LD) and lexical sophistication (LS) in their essays. Sixty-eight Chinese senior high school students participated in this experiment. The experimental group (n = 33) was asked to finish writing tasks with Versatext, while the control group (n = 35) wrote on the same topics alone. Two tests (i.e. pretest and posttest) and specific lexical analysis are used to test students' improvement. Then a questionnaire survey was conducted to explore students' perceptions. The results revealed that Versatext certainly has a significant effect on students' lexical diversity and sophistication in writing. Participants show positive perceptions of it.

Keywords: Corpus-based language learning · Versatext · Lexical diversity · Lexical sophistication · Writing

1 Introduction

Corpus-based language learning (CBLL), refers to the process of using tools and techniques of corpus linguistics for second language learning [1]. Corpus tools share some similar functions including searching for concordance, keywords, frequency, and collocations embedded in the popular corpus [2], with which students learn to observe, explore, and summarize language features and usages from real-world contexts [3]. Many researchers apply various popular corpus query tools for language teaching and discovered that CBLL has many advantages in the following aspects. Specifically, the corpus can provide students with authentic language input that naturally occur in corpora reference resource and encourages students' active participation in the learning process, as it enables students to observe linguistic rules independently and summarize the usage of the target language based on the concordance results [4].

With regard to writing, a well-written essay necessitates a writer's purposeful selection and use of words [5]. LD and LS have been well acknowledged as indicators to

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mirror learners' writing proficiency since texts with sophisticated, diverse vocabulary reveal learners' high level of writing capacity [6, 7]. Nevertheless, Johnson et al. [8] suggested that students prefer to confine themselves to basic and familiar terms rather than bother themselves about finding synonyms or more sophisticated words. As a result, their written texts are always predominated by simple and repetitive words. Vocabulary knowledge is closely related to corpus use and analysis, for it can help learners recognize authentic texts, and notice lexical frequency patterns and the use of words in examples [9]. Therefore, the present study applied Versatext and put forward a design of corpus-based writing practices, aiming to explore its effects on students' lexical use (i.e. LD and LS) in writing. Specifically, this study attempts to answer the following research questions:

(1) Do corpus-based writing practices have a significant influence on EFL learners' LD and LS ?
(2) What are EFL learners' perceptions of corpus-based writing practices?

2 Literature Review

2.1 Corpus-Based Language Learning

Corpus is defined as "a large collection of natural texts sampled to be representative of a variety or a genre of a language, which is now almost always in machine-readable form [10]." It was used to explore the innate features of the language, the intrinsic connection, and dependence between grammar and lexis, the register behind language use, and most importantly, the frequency of language patterns [11]. Learners can deduce language rules and patterns from concordances by themselves [10]. Corpus tools can assist learners in developing diverse language skills, including vocabulary [12], collocations [13], grammar [14], reading [15], and writing [16, 17].

Nowadays, many researchers have reported its positive effects on overall writing performance, error correction, lexical and grammar knowledge, certain linguistic structures. For instance, considering EFL students struggle to make paraphrases to satisfy their writing requirements, Chen et al. [18] developed PREFER, an online corpus-based paraphrase support system, and conducted an empirical study on its effectiveness with 55 Chinese EFL college students. The findings showed that PREFER had the greatest impact on learners' writing performance. Students of less proficiency also made significantly more progress in the paraphrasing exercise and most participants held a positive attitude towards PREFER. Crosthwaite and Steeples [17] examined the improvement of receptive and productive knowledge of passive voice structures employed in writing scientific research reports at a secondary school in Australia. The results indicated that learners' utilization of corpus tools was effective in enhancing passive voice use in science writing, providing evidence for the application of corpus-based writing instruction among young learners. Although the effects of CBLL in writing practices have been discussed by many researchers mentioned above, there is a lack of studies focusing on its influence on learners' lexical features, which is the research gap the present paper trying to fill.

2.2 Lexical Diversity and Lexical Sophistication

Lexical sophistication and lexical diversity have been acknowledged as effective ways to mirror learners' writing proficiency and development [5].

Lexical diversity (LD), also known as lexical variation, is commonly defined as "the range of different words used in a text" [19]. Texts of high quality are distinguished by a wide variety of words rather than a restricted range of words used repeatedly [5]. A traditional way to calculate LD is the type-token ratio (TTR) [20], in which the total number of different words (types) is divided by the total number of words (tokens). However, it has been doubted for its sensitivity to text length. Many researchers have proposed other measures to reduce text length influence, including vocd-D [21], HD-D [22], and MTLD [23], among which the "measure of textual lexical diversity" (MTLD) appears to be the most robust in terms of text length variations [19]. Therefore, MTLD was used in this study to measure participants' LD scores, with higher scores indicating greater diversity.

Lexical sophistication (LS), as an aspect of lexical competence, generally refers to "the proportion of relatively unusual or advanced words in the learner's text" (Read, 2000). Studies revealed that high-proficiency learners used more advanced words that are not commonly used, so-called low-frequency words [6, 24]. Kyle and Crossley [24] have summarized the various ways in which LS has been measured in earlier studies including how widely a word or a word family is used (range), the frequency of n-grams, the frequency of words and units from academic lists, as well as psycholinguistic properties of words. However, the most common approach still seems to be the examination of frequency bands, which is the product of lexical frequency profiling (LFP) [6], which compares each term created by L2 learners to the total number of word family members in a corpus of the target language. Four frequency levels are identified, the first 1,000 most frequent words, the second 1,000 most frequent words, Academic Word List, and off-list words. According to Laufer and Nation [6], low-frequency words are conceptualized as words in AWL and off lists (Beyond 2000 words). Therefore, the proportion of low-frequency words in the text was measured as the indicator of LS in the present study.

3 Research Design

3.1 Participants

The participants involved in the quasi-experiment of the present study are Grade Two students from a senior high school in Zhaoqin, Guangdong. There are altogether 68 students aged between 15 and 17 (mean age = 16.32, SD = 0.67). Speaking Chinese as their mother tongue, all of them have learned English as their foreign language for about 8 years. They were randomly divided into two groups, the experimental group (EG; N = 30) and the other as the control group (CG; N = 30). Evaluated by the Oxford Placement Test (OPT, Version 1.1, 2001), all the participants were at the intermediate level (i.e. scored between 30 to 50).

3.2 Instrumentation

Versatext. Versatext (https://versatext.versatile.pub/) is a web-based corpus tool, which can provide a word cloud, a concordance, and a text profiler of the input text (Fig. 1). It was chosen for its user-friendly interface. A word cloud (see the first picture in Fig. 1) can help users notice the frequency patterns of their essays and find out the unnecessary repetitions [25]. As for concordance, clicking the target word, a format known as Key Word in Context (KWIC) would be generated, which allows users to observe the paradigmatic features of the keyword. When learning from the corpora of good essays collected and provided by their teachers, they may find it easy for them to summarize the collocations and usages with it (see the second picture the Fig. 1). The Profiler would offer some lexical statistics about the text, including word lists of different frequency bands (see the third and fourth picture in Fig. 1). Since more proficient writers used less high- frequency words [10], students can look up more sophisticated synonyms to replace some words from the Top 1000 list and 1000 to 2000 list to improve their writing quality and shift attention to the advanced words used in good essays from Academic Word List and Text-specific Word list.

Fig. 1. The distinctive affordances of Versatext

Writing Tasks. Two tests (pretest and posttest) were arranged, taking argumentative writing as the writing genre. To ensure the comparability of the tests, task difficulty was rated by participants and results showed that topics in the pre-test and post-test are similar in difficulty ($t = 0.93$, $p = 0.977 > 0.05$). Additionally, there are four writing topics designed for training. All topics in the current study are closely related to students' daily life at school, including living in the school dormitory, wearing school uniform, joining school clubs, etc.

Questionnaires. Referring to Yu et al. [26], a questionnaire for the present study has been developed to investigate participants' perception of the use of Versatext in writing. It includes 14 five-point Likert scale items (1: strongly disagree, 2: somewhat disagree, 3: No opinion, 4: somewhat agree, 5: strongly agree) about perceived usefulness (Q1 to Q5), ease of use (Q6 to Q9), satisfaction (Q10 to Q12) and acceptance (Q13 to Q14). The reliability of the questionnaires was calculated by SPSS version 26.0. The statistical results showed that the questionnaires were reliable (Cronbach's alpha = 0.865 > 0.7) enough to be applied in the present research. In order not to hinder the students' understanding of the questionnaire, it will be translated into Chinese by the authors.

3.3 Procedure

The quasi-experiment lasted for 10 weeks. It includes a pretest, Corpus-based writing experiment, a posttest and a questionnaire survey.

Pretest. Participants were required to finish a 100-word argumentative essay in 40 min in the classroom without the aid of any reference materials.

Experiment. Four training sessions were organized from week 2 to 9 correspondingly. In the first week, the author gave instructions about how to use Versatext to improve lexical use in writing to EG, with explanations of some terminology associated with it, including word cloud, concordance, KWIC, Academic Word List. After the instructions, the participants from EG were assigned a writing task once two weeks. Since the participants were not allowed to use the Internet at school, participants from EG were required to revise their drafts and observe the corpora of good essays collected by the author from two groups with Versatext. To make sure that all the participants from EG used this tool, they submitted the screenshots of word clouds and word lists from their first draft and final draft after revision to show the changes in lexical use (see Fig. 4 for a sample screenshot by a participant that shows the changes of lexical use before and after using Versatext). This procedure was repeated for four consecutive sessions. Alongside the EG, the CG also received instructions on how to polish writing from the lexical aspects, without the introduction of Versatext or any other corpus tool. Similarly, the participants from CG were assigned the same writing tasks with the same requirements every two weeks. They revised their essays manually without any corpus tool and read good essays on their own.

Posttest and Questionnaire. After four writing sessions, participants were assigned the writing task for the posttest with the same requirement as the pretest. Then, the questionnaire survey was conducted in EG.

3.4 Measures

Participants' essays in the pretest and the posttest were analyzed immediately with regard to lexical aspects. As for LD, the measure of textual lexical diversity (MTLD;

McCarthy, 2005), was calculated by textinspector.com [27], while the proportion of low-frequency word types in a text by referring to Lexical Frequency Profile is a common way to examine LS [5]. This index is available through a web-based program called VocabProfile.

4 Results

4.1 Results of LD and LS

To answer the first question, firstly, the data of LD were submitted for an independent-sample t-test. The aim was to explore the impact of corpus-based writing practices on participants' LD in writing. As shown in Table 2, no significant difference between EG ($M = 72.45$, $SD = 16.84$) and CG($M = 70.67$, $SD = 17.46$) was found ($t = 0.43$, $p = 0.670 > 0.05$), indicating the comparability of two groups before the treatment. However, there was a statistically significant difference between the LD indices of EG ($M = 81.38$, $SD = 16.84$) and CG ($M = 73.42$, $SD = 17.46$) in the posttest ($t = 2.21$, $p = 0.031 < 0.05$), which implied that the corpus-based writing practices have strongly affected LD scores.

Besides, a pair-sample t-test was also conducted to compare the changes of two groups from the pretest to the posttest. Table 3 illustrates a significant increase in the LD scores of EG from the pretest ($M = 72.45$, $SD = 16.84$) to the posttest ($M = 81.38$, $SD = 16.18$) after the treatment of corpus-based writing practices ($t = -3.43$, $p = .002 < .01$). Although the mean score of CG has slightly rose by 1.32, the difference was not statistically significant ($t = -1.00$, $p = .324 > .05$).

Table 2. Results of independent samples t-tests of LD.

Tests	Groups	N	Mean	SD	t	p
Pre-test	EG	33	72.45	16.84	.43	.670
	CG	35	70.67	17.46		
Post-test	EG	33	81.38	16.18	2.21	.031*
	CG	35	73.42	13.49		

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

Table 3. Results of paired samples t-tests of LD.

Groups	Tests	N	M	SD	df	t	p
EG	Pretest	33	72.45	16.84	32	−3.43	.002**
	Posttest	33	81.38	16.18			
CG	Pretest	35	70.67	17.46	34	−1.00	.324
	Posttest	35	73.42	13.49			

Participants' LS scores, demonstrated by the low-frequency word type ratio, were also analyzed in a similar way. Table 4 shows the results of independent-sample t-tests of two groups in two tests, respectively. It presents similar levels of sophisticated word choice of participants from both groups ($t = .81$, $p = .421 > .05$) in the pretest. But those from EG ($M = 10.38$, $SD = 3.00$) used a significantly greater number of advanced words than CG ($M = 8.35$, $SD = 2.70$) in the posttest ($t = 2.94$, $p = .005 < .05$).

In addition, the changes in the proportion of low-frequency words in the essays written by participants from both groups have been compared. Table 5 presents the significant improvement concerning sophisticated word choice in EG ($t = -4.32$, $p = .000 < .01$), while no statistical difference could be found in CG ($t = -1.62$, $p = .114 > 0.05$). It can be inferred that Versatext is also effective in enhancing participants' LS in writing.

Table 4. Results of independent samples t-tests of LS.

	Groups	N	Mean	SD	t	p
Pre-test	EG	33	8.16	2.61	.81	.421
	CG	35	7.68	2.30		
Post-test	EG	33	10.38	3.00	2.94	.005**
	CG	35	8.35	2.70		

Table 5. Results of paired samples t-tests of LS.

Groups	Tests	N	M	SD	df	t	p
EG	Pretest	33	8.16	2.61	32	−4.32	.000**
	Posttest	33	10.38	3.00			
CG	Pre-test	35	7.68	2.30	34	−1.62	.114
	Posttest	35	8.35	2.70			

4.2 Results of Questionnaire Survey

Addressing the second question, the scores of each item in the perceptual questionnaire have been compared by a one-sample t-test with three (the midpoint from 1 to 5), shown in Table 6. In terms of perceived usefulness, participants believed that using Versatext can improve their English writing proficiency (item 1, $t = 3.20$, $p = 0.003 < 0.01$), draw their attention to repetitive words (item 2, $t = 7.40$, $p = 0.000 < 0.01$), encourage them to use more sophisticated words (item 3, $t = 4.67$, $p = 0.000 < 0.01$), and help them learn expressions from the corpora of good essays written by peers (item 4, $t = 5.80$, $p = 0.000 < 0.01$). Generally, they agreed that Versatext was an efficient tool for language learning (item 5, $t = 6.16$, $p = 0.000 < 0.01$). Regarding perceived ease of use, they believed CPDT could promote communication among group members (item 6, $t = 2.41$, $p = 0.023 < 0.05$), which enabled them to learn others' ideas. Regarding perceived ease of use, They thought it difficult to use the built-in functions of Versatext (item 6, $t = -3.03$, $p = 0.005 < 0.01$) and not so easy to understand the results of it (item 7, $t = 0.52$, $p = 0.609 > 0.05$). However, they found it easier to find lexical problems in their writing (item 8, $t = 2.35$, $p = 0.025 < 0.05$) and summarize the collocations and usage of expressions in good essays with Versatext (item 9, $t = 3.46$, $p = 0.002 < 0.05$). As for satisfaction, they are not quite satisfied with their improvement (item 10, $t = -1.18$, $p = 0.245 > 0.05$). They found it hard to paraphrase sentences or find appropriate synonyms for the repetitive or simple words (item 11, $t = -2.69$, $p = 0.011 < 0.05$), which showed participants didn't have a high level of satisfaction. Finally, encouragingly, participants still showed a willingness to continue to write with it (item 14, $t = 2.78$, $p = 0.009 < 0.01$). To sum up, participants had positive attitudes towards corpus-based writing practices in this experiment, but they were still confronted with some problems, including difficulties in operation, data interpretation, and finding synonyms for replacement.

5 Discussion

The goal of the present study was to explore the effect of corpus-based writing practices on EFL learners' lexical use (i.e. LD and LS) in writing and their perceptions of it.

RQ1 was addressed by examining whether corpus-based writing practices have significant effects on participants' lexical development in writing. The results suggested that participants achieve significantly better performance in lexical use with regards to both LD and LS with the help of Versatext, implying that using corpus tools for polishing writing enabled learners to accumulate more varied and sophisticated words for writing practices. Firstly, the improvement of LD scores can be explained by the potential benefits of word clouds. According to Filatova [25], the application of word clouds as an instructional tool can result in students using more varied vocabulary. With the information on word frequency visualized by word clouds, participants can easily identify repetitive mistakes, which encourages them to look up synonyms to avoid unnecessary repetitions and improve receptive and active vocabulary learning [24]. This possible reason can also be supported by participants' responses in the perception questionnaire which demonstrates the usefulness of Versatext in helping them find out repetitive words and improve lexical diversity. What's more, the significant increase in participants' LS scores found by this study is consistent with Harb's finding [28] that online corpus can positively affect EFL learners' refining and sophisticating their word choice. He stated that online corpus can provide EFL learners with a reliable lexical reference that helps EFL learners deepen their lexical knowledge and select a variety of sophisticated terms. Corpus tools help EFL learners enhance lexical sophistication in their writing by comparing the word frequency levels and choosing the low-frequency synonyms and the more sophisticated terms [9]. When writing with Versatext, they can refer to the word frequency lists and easily identify the simple words, which can encourage them to use more advanced words to replace them, as shown by the results of the questionnaire. Besides, with the help of the concordancer of Versatext, it is more convenient for them

Table 6. Results of the items in the perception questionnaire.

Item	M	SD	t	p
Perceived Usefulness				
1. I believe that using Versatext will improve my English writing proficiency	3.48	.87	3.20	.003**
2. Versatext is useful in helping me find out repetitive words and improve lexical diversity	3.82	.64	7.40	.000**
3. I am more likely to be encouraged to use sophisticated words when writing with Versatext	3.58	.70	4.67	.000**
4. Versatext helps me learn expressions in good essays	3.79	.78	5.80	.000**
5. Versatext is an efficient tool for language learning	3.88	.82	6.16	.000**
Perceived ease of use				
6. The built-in functions of Versatext are easy to use	2.42	1.09	−3.03	.005**
7. The results from Versatext are easy to understand	3.09	1.01	.52	.609
8. It's easier for me to find lexical problems in my writing with Versatext	3.33	.82	2.35	.025*
9. It's easier for me to summarize the collocations and usage of expressions in good essays with Versatext	3.45	.75	3.46	.002**
Satisfaction				
10. I am satisfied with the improvement of my lexical use and writing performance with the help of Versatext	2.81	.88	−1.18	.245
11. I am able to paraphrase sentences or find appropriate synonyms when I find repetitive or simple words	2.55	.97	−2.69	.011*
12. I am satisfied with polishing writing and learning with the data from Versatext	3.33	.95	2.00	.054
Acceptance				
13. I will recommend Versatext to my friends who have difficulty in EFL writing	3.27	.98	1.60	.119
14. I will continue to write with Versatext in the future	3.52	1.06	2.78	.009**

to observe the expressions from the corpora of good essays, during which they can accumulate some advanced and useful words and learn the usage of these words for writing in the future.

RQ2 concerns learners' perception of corpus-based writing practices via Versatext which differs from the traditional method of writing. According to Hsu (2015), when learners are willing to employ CALL-based instruction, its potential benefits cannot be in vain. Therefore, it is worthwhile to explore learners' attitudes and acceptance of it. The results of the questionnaire survey showed that participants generally hold positive perceptions of corpus-based writing practices, which is in line with many previous studies focusing on the learners' perception of CBLL in writing instructions [17, 29].

They appreciated the usefulness of Versatext in improving their lexical use and overall writing proficiency. However, because Versatext is an English website for text analysis, participants, as senior high school students, still find it not easy to use the built-in functions of this website and understand its data. It is supposed that they may get stressed when navigating a website that is not in their mother tongue, which necessitates further evidence from qualitative research. What's more, as mentioned above, although Versatext text can immediately draw their attention to the repetitive and simple expressions in their essays, they may have some trouble with paraphrasing sentences or finding appropriate synonyms for replacement, constrained by their English proficiency and limited vocabulary. It prevents them from achieving a higher level of writing performance.

6 Conclusion and Limitations

The present study conducted a 10-week quasi-experiment with Chinese EFL learners to explore the impact of corpus-based writing practices on their lexical development (i.e. LD and LS) in writing and their perceptions, contributing to the growing knowledge of CBLL. Firstly, the results of this study reveal that corpus-based writing practices have a significantly positive effect on students' varied and advanced word choice in writing by providing some information on word frequency and helping them identify repetitive and simple expressions, and helping them accumulate useful expressions from the corpora of good essays. These findings provide empirical evidence for the pedagogical value of CBLL. Secondly, participants generally hold positive attitudes towards corpus-based writing practices via Versatext. They perceived it as an efficient tool for writing and admitted the advantages of this process. However, It is worth noting that students' improvement under corpus intervention should not be taken for granted. Because of the troubles they have during this process, such as difficulties in operation, data interpretation, and finding synonyms for replacement, they failed to achieve a higher level of satisfaction with corpus-based writing practices. So teacher support may play a critical role in corpus-assisted writing instruction.

Admittedly, some limitations of this study also deserve attention. Firstly, this study is limited by a small sample size of participants of the same language proficiency (i.e.intermediate level). As L2 learners with different writing proficiency may have some variation in the use of writing strategies and writing performance [30], more EFL learners at different language proficiency levels could be involved in future research to compare how they perform differently during corpus-based writing practices. Besides, LD and LS scores can only account for the range of words used in participants' essays because these two indices primarily focus on the depth of lexical knowledge. As a result, the quality of the lexicon concerning how accurately and appropriately the words have been used was ignored by this study. Future studies could explore the impact of corpus tools on the depth of knowledge in addition to the size of their vocabulary.

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On the Reflection of Online Distance Instruction into Blended Teaching and Learning

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Abstract. The paper aims to compare online distance and blended instruction from students' point of view. The main objective of the research is to discover whether teachers enriched their blended lessons with tools that they had exploited in online distance instruction during covid-19 pandemic. In the Czech Republic, online distance instruction ended after 18 months in June 2021, been replaced by blended lessons since September 2021. Data were collected in autumn 2021, and one year later, in autumn 2022, by two online questionnaires. Each consisted of 35 items that required Likert-scaled, multiple-choice, and open answers. The research sample included 488 respondents who attended selected upper secondary and higher education institutions in the Czech Republic. The results were considered according to the type of institution (upper secondary or higher education) and structured using four criteria: (1) First contact and communication, (2) Learning content acquisition, (3) Learning content delivery and assessment, (4) Student's final feedback on online distance instruction. We anticipated that teachers would enrich their blended lessons using online distance experience; however, our expectations did not prove. Higher rate of autonomy in higher education students was detected with minor exceptions.

Keywords: Online Distance · Blended Learning · Upper Secondary · Higher Education · Questionnaire · Students Feedback

1 Introduction

In the last three years, substantial changes can be seen in the process of teaching and learning. Due to the covid-19 pandemic restrictions, teachers and learners had to adapt to live, teach, and learn under social distancing restrictions and most lessons were conducted online distance. As a consequence, new knowledge and skills were required from teachers and learners. Once the skills were gained, teachers and learners should not waste them, but use them for education after the restrictions [1].

In the context of this paper, the term face-to-face teaching and learning means the present form of instruction, when lessons are held in classrooms and teachers and learners meet in person. Online distance instruction includes lessons carried on a device without a direct teacher-learner or learner-learner contact, when teachers and learners are separated

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by place. Blended teaching/learning is understood as a didactic approach that integrates face-to-face and online distance teaching methods. As such, blended learning was applied before the covid-19 pandemic. Since the new normal era in education started after the pandemic [2], teachers have had the opportunity to widen a range of tools exploited in online distance instruction, thus enriching the previous blended learning experience. However, the question is whether teachers have really been doing so. In other words, *have they enriched the range of teaching tools, have they implemented tools that they used during online distance instruction in current blended teaching? The main objective of the paper is to answer these questions from the point of view of upper secondary school and higher education students.*

2 Theoretical Background

2.1 Online Distance Instruction in the Czech Republic

In the Czech Republic, in total, online distance instruction (ODI) lasted 18 months and was structured into three main periods:

(1) *March 2020 – June 2020: The first period.* It started suddenly, unexpectedly, and no one expected it would last more than two to three weeks. In half of June, graduation exams were carried out under strict restrictions at upper secondary schools and universities.

July – August 2020: Summer holidays. All schools were closed. During this period, the Ministry of Education, Youth, and Sports aimed to prepare some rules, both legal and didactic. From the former, the most important was that the learners' attendance of online distance lessons was compulsory [3, 4]. This rule required to improve school equipment so that learners from socially weak families could borrow notebooks from the school. From the latter, the Ministry prepared a set of didactic recommendations on how to teach online; however, the documents were not helpful and schools and regional didactic centres organized training courses for teachers themselves.

(2) *September 2020 – January 2021: The second period.* The lessons were held face-to-face for two weeks at the beginning of this period, so teachers put much effort to teach students how to learn online distance, and schools provided notebooks to those who needed them. However, the costs of the Internet access for learners from socially weak families and technical support to all learners and teachers were the problems that caused problems in this period. Some learners discovered how to cheat or avoid learning. 31 January 2021 was the end of the first half of the school year at upper secondary schools and the end of exam period at higher education institutions.
(3) *February 2021 – June 2021: The third period.* The lessons were held online distance without a break from the beginning of February. Teachers and learners were tired of ODI, demotivated by numerous problems in learning, by technical problems with hardware, lack of social contacts and many others, including the stress from high amounts of covid-19 infected patients; however, statistics were slightly

improving step by step. As a year before, graduation exams were carried out under strict restrictions at upper secondary schools and universities.

July – August 2021: Summer holidays. New directions were published on ODI that might have been more helpful [5–8]. Fortunately, covid-19 statistics improved during the summer and the new school year started traditionally, that is, face-to-face lessons were held only. Since September 2021, ODI is acceptable as an approach at universities, mainly in reading lectures to large groups of students, or other appropriate situations. At upper secondary schools, the preference is given to face-to-face lessons; practical lessons are held only face-to-face.

2.2 Teacher Training in Online Distance Instruction

As face-to-face lessons were stopped suddenly and unexpectedly, neither teachers nor learners were prepared for online distance teaching and learning. Although digital technologies have penetrated many fields of our lives, they are still not exploited for educational purposes to the maximum extent.

Within the institutions included in the research, the first steps to train teachers were made by their colleagues – IT teachers, administrators, and university students. This support aimed at those who lacked basic knowledge and skills. Seminars focusing on teaching and learning were held during the summer holidays of 2020. They included both theoretical knowledge and practical skills, that is, 10 face-to-face lessons at school (45 min each) were supported by autonomous learning from home (90 min per day as minimum, five days). These lessons were designed by all authors and taught by one of them.

In online distance instruction, identical didactic principles were followed that are defined for face-to-face lessons. These principles form the basis of the Czech educational system and were defined centuries ago by Jan Amos Komensky (Comenius; 1592–1670). He wanted everything to flow freely, without violent disruption, to everyone through all available channels [9]. In other words, he designed learning materials that are illustrative, appropriate to learners' age and level of knowledge, and introduced the learning content step-by-step in a systematic manner [10]. Currently, these principles are implemented in various educational theories. If they are not applied, learners cannot succeed in learning much.

In addition to the 'historical' principles by Comenius, there are two others that reflect the appearance of digital technologies in education: (1) TP(A)CK framework (Technological, Pedagogical, Content Knowledge) [11] that shows teachers knowledge as the intersection of several areas and (2) the SAMR model (Substitution, Augmentation, Modification, Redefinition) targeted towards digital transformation [12]. In particular, it distinguishes between first two levels where new technology is replacing or has replaced an older technology, but with little gain that does not change the quality of learning. Levels three and four enable activities that were previously impossible in the classroom without technologies.

2.3 Literature Review

Due to the covid-19 restrictions, teachers exploited a wide range of tools to carry the lessons online distance. However, the question is whether they still use the wide range of them in current face-to-face instruction so that they enriched these lessons. In the Czech Republic, a new era of face-to-face instruction without restrictions started in September 2021. In autumn 2021, a survey was conducted to monitor the state after the online distance instruction. One year later, in autumn 2022, another survey was carried out.

During the second year of the covid-19 pandemic, some studies appeared that focused on various fields of the education process in the post-covid-19 era. In particular, students' future imaginations about blended learning based on the perception of ODI, experience, and preference of selected tools were published, proposals for changes in curricula and blurring the boundaries between face-to-face and ODI, and recommendations for the future. For example, Jamilah and Fahyuni [13] collected journal articles from selected databases (Lens.org, Google Scholar, Research Gate, DOAJ) published in 2019–2021 using key words "Online + learning", "face-to-face learning", "blended learning" and "post COVID". They conducted a systematic review and found 320 results. Most of them (76%) emphasized that online learning needs to be developed further on as a 21st century ability and should be implemented into a blended learning method, that provides flexibility in learning (60%). This is what we have done in the Czech Republic.

Similarly to Faltynkova et al. [14], Cahapay [15] attempts to rethink education in the post-covid-19 era through the perspectives of curriculum studies, in particular, the goal, content, approach, and evaluation. The main problem is to define the essential content within the curriculum. The author proposes three criteria: significance, relevance, and utility. If the curriculum meets these criteria, it is appropriate for the post-covid era of education, the author concludes.

As in our research [14], Peimani and Kamalipour [16] explored students' perception of online teaching and learning activities, feedback and assessment, and digital platforms based on their experience during the subject delivery period in the 2020–2021 academic year. In addition, students considered synchronous communication through effective interaction among peers to be quite challenging in small-group online reading seminars. The majority of respondents also reported that attending live online lectures was more helpful than watching pre-recorded lectures. Online formative feedback and synchronous interim reviews also allowed them to reflect on their progress and develop their projects further before their summative assessment.

Compared to this, Onyeukwu et al. [17] focused on the impact of the use of Zoom, Google Meet classroom, and social media on students learning capabilities. Their results state that students prefer the combination of face-to-face and online methods of teaching and learning. But the cost of acquiring data, availability of network and lack of access to digital tools are the factors prevailing against the digital method of teaching and learning. Respondents were also undecided about the impact of the Zoom and Google Meet classroom method on the learning content and skills acquisition, but they disagreed with the positive impact of the social media in education.

3 Methodology

3.1 Research Question and Objective

Due to the covid-19 restrictions, teachers took advantage of a wide range of tools to conduct the lessons online distance. However, the question is whether they still use this wide range of them in current blended instruction to enrich the lessons. In the Czech Republic, a new era of face-to-face instruction without restrictions started in September 2021. In autumn 2021, a survey was conducted to monitor the state after the online distance instruction. One year later, in autumn 2022, another survey was carried out. The data are considered from the viewpoint of students of upper secondary and higher education institutions. During the 18 months of the pandemic, some learners graduated from upper secondary school and enrolled at university; therefore, we were interested whether there are differences between these two groups that might be connected, for example, with their autonomy in learning.

The main objective of this research is to compare the data collected in autumn 2021 and autumn 2022 and consider whether teachers enriched their blended learning lessons with tools that they had exploited in online distance instruction during the covid-19 pandemic.

3.2 Research Expectations

To compare the data collected in the two periods mentioned above, identical expectations were set [2] and identical criteria were applied to the data processing as in the first research carried out in 2020 [14] and in the second one carried out in autumn 2021 [2]. Furthermore, we expect that the didactic principles defined by Comenius are followed in both observed periods and at both types of institutions. It is generally accepted in the Czech education system that learners can achieve the required knowledge defined in the syllabus if the instruction is designed and carried out by qualified teachers and the design of lessons arises from the didactic principles. The collected data were considered under the following criteria:

(1) *The first contact and communication.* Learning begins with the first teacher-learner contact. Therefore, we anticipate that communication will start at the very beginning of online distance instruction (ODI) and blended learning (BL). Communication is expected to be more frequent in ODI to bridge the distance between teachers and learners. Frequency in communication will be higher in upper secondary (US) school learners compared to higher education (HE) students – they are expected to be more autonomous in learning and therefore they do not need so much support from teachers.

(2) *Learning content acquisition.* Motivation to learn should be supported in ODI and BL, in US and HE students. In addition, we expect that US and HE students in ODI will be advised on how to study online, mainly how to communicate with teachers and other students, how to efficiently use study materials, presentations, and video-recordings, ask and answer questions, discuss problems, how to do tests and submit assignments, work in teams, etc. Furthermore, we also anticipate that new tools will appear in BL of both groups.

(3) *Learning content delivery and assessment.* We expect that one or two main channels through which the learning content was delivered in ODI, will be enriched with some new tools in US and HE institutions. In assessment, individual progress and what to focus on in further learning were two areas the teachers were expected to provide feedback on learner's performance in ODI. In BL, we anticipate that oral exams will be added to various types of online exams and tests, or their combinations, in both US and HE institutions.

(4) *Student's final feedback on online distance instruction.* Students expressed their agreement/disagreement with four statements dealing with how much effort teachers invested in planning and carrying the lessons, how much effort was required from the students to succeed in the course, whether they appreciate (or not) the online distance learning, and how much they learned. We anticipate that students' opinions will not be as much decided as they were immediately after the end of ODI in autumn 2021 irrespective of the type of institution. We think the ODI was helpful experience for them that they may utilize in the future.

3.3 Research Method, Tools, Sample

The ex-post-facto method was applied to detect the frequency of occurrence in selected features. Data were collected by two questionnaires. Each questionnaire included 35 items (20 Likert-scaled items; three multiple-choice items; eight multiple-choice items with multiple answers; two open answers). The items were structured into four areas described above. The first questionnaire was distributed in autumn 2021. It was piloted before the first use by 20 randomly selected students of the US school and HE institution (10 + 10), and by six teachers working for both institutions. The second questionnaire was exploited in autumn 2022; it was piloted in the same way by another group of 10 students (5 + 5) and four teachers (2 + 2). No changes were needed. The research was carried out at the Upper secondary school for medical staff (US), Olomouc, Vocational school for higher medical staff (HE), Olomouc, and Faculty of Education, Department of Information Technologies, University of Ostrava (HE), Ostrava, Czech Republic. This is a convenience sample, in which authors conducted a long-term research and participated in teacher training. The research sample included 488 respondents (N = 228 in Questionnaire 1; N = 260 in Questionnaire 2; male 23%).

4 Results

The collected data are structured into four subchapters according to the criteria defined above. The results are presented in figures, described, and interpreted.

4.1 First Contact and Communication

The first contact and communication between teachers and students are monitored from three viewpoints: (1) when the first contact was made, (2) which tool was used for the first and for further teacher-student contacts, (3) whether the contacts were regular and how frequent they were. The results are displayed in Fig. 1.

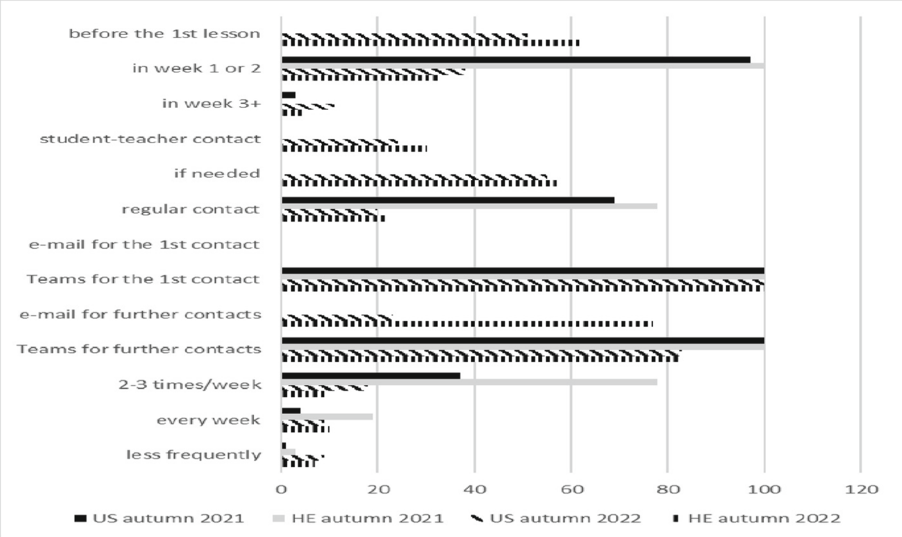

Fig. 1. The first contact and communication: the first contact, tool, regularity, frequency (%).

In autumn 2021, the first contact was established during the first or second week of the semester at most US (97%) and HE (100%) institutions. In autumn 2022, it was discovered that 51% of teachers at US schools and 61% at HE institutions contacted learners before the first lesson. The reason was that they intended to inform them that the lessons would be held face-to-face, not online distance as they were months ago. In open answers, learners appreciated that teachers confirmed that face-to-face lessons were back again. Approximately a quarter of students from US and a third from HE started the communication to obtain the information as soon as possible.

In autumn 2021, regular contacts were held during the whole semester with 69% of US students and 78% of HE students compared to 20%, respectively 22% in autumn 2022. It is logical that the frequency is lower if students are in face-to-face contact with teachers and peers during BL. Furthermore, more than half of the respondents (55% of US; 57% of HE) describe the frequency as if needed, which we consider positive.

MS Teams was the only tool used for the first contact and communication in both periods and institutions. Further contacts in autumn 2021 were also conducted through MS Teams in US and HE institutions (100% each), but in autumn 2022, BL was supported by MS Teams (83% each institution), and partly by some marginal activities in LMS Moodle. In this period, e-mail was again exploited for further contacts by 23% of US students and 77% of HE students, which must have been demanding for teachers to answer the messages from various channels.

While the frequency of communication was twice-three times per week, which usually followed the schedule of the course in a week in autumn 2021, it decreased substantially with BL and oscillated around 10% in autumn 2022.

4.2 Learning Content Acquisition

Data describing the learning process acquisition dealt with motivation to learn, how to study online, various forms of teacher-student communication on the learning content, forms of study materials, exercises, tests, and other sources. The results are displayed in Fig. 2.

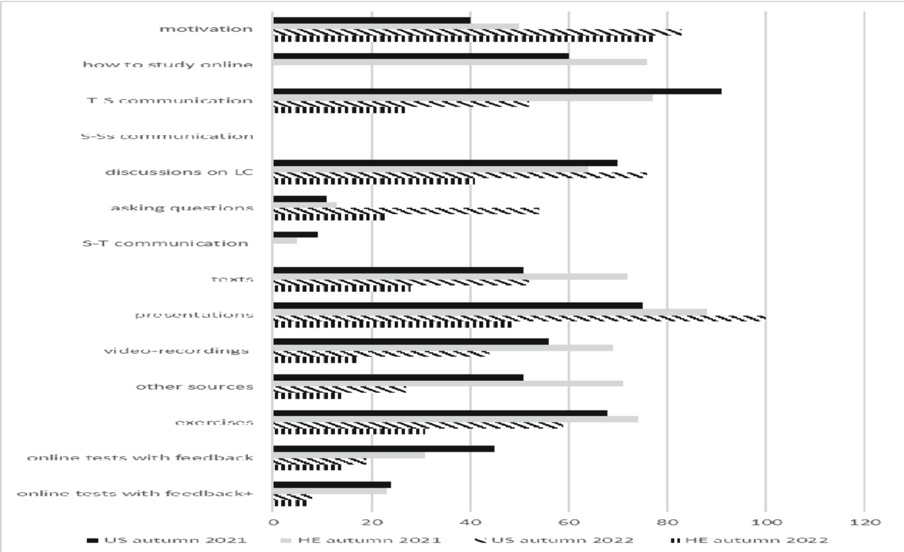

Fig. 2. Learning content acquisition (%). (T: teacher; S: student)

During the whole process of ODI, teachers knew it was necessary to motivate learners to everyday learning, to overcome technical and didactic problems, to continue learning how to study online, etc.: 40% of teachers in US schools and 50% in HE institutions did that, as the data in autumn 2021 discovered. In autumn 2022, many more teachers motivated their students: 83% in US schools and 77% in HE institutions. As students stated in open answers, they were tired of ODI, despite it finished a year before in June 2021, and stressed by the missing knowledge they discovered step by step, so the motivation to learn was needed and beneficial for them. Directions how to study online, that were highly needed and provided by teachers during ODI (60%; 76%) were useless in autumn 2022.

The frequency of teacher-student communication detected in autumn 2021 was high (91% in US lessons; 77% in HE); student-teacher communication was low (9% in US; 5% in HE). Logically, teacher-student communication decreased in BL, to 52% in US; to 27% in HE in autumn 2022. No student-student(s) communication was detected in either period or group.

The frequency of using texts was the same in both periods in US schools (51% and 52%) but it decreased sharply in HE institutions from 72% in autumn 2021 to 28% in autumn 2022. Neither the results nor students in open answers provided any explanation of this change. Moreover, decrease in the frequency of using other tools is clearly visible in HE students in autumn 2022 without being replaced by other ones. As mentioned above, the only area where the frequency was higher in HE students compared to autumn 2021 was motivation; however, US students received higher motivation from their teachers in autumn 2022.

In autumn 2022, all teachers (100%) in US schools and half of them in HE institutions (49%) used presentations compared to autumn 2021, when the frequency was also high (US 75%; HE 88%). Identical course was detected in other tools: from rather high frequency in autumn 2021 (higher in HE than in US schools), there was a half decrease or even more, for example, the frequency of using video-recordings decreased from 56% in US schools and 69% in HE institutions in autumn 2021 to 44% in US and 17% in HE in autumn 2022. A rather sharp decrease was discovered with using other sources in autumn 2022 (27% in US schools; 14% at HE institutions) compared to autumn 2021 (51% US; 14% HE). The use of online tests and exercises showed an identical course. When considering all the decreased frequencies in HE institutions in autumn 2022 including the fact that the frequency of using other sources was five times lower in autumn 2022, we can only speculate about the causes of the state. We cannot say that one tool was substituted by another and that this can/not be applied to a teaching or learning strategy. In open answers students of HE institutions explained that they mostly learned from practical lessons (medical or teaching practices). These lessons were not held during the pandemic at all; therefore, the first step, when the schools opened again, was to provide students with the missing practice.

4.3 Learning Content Delivery and Assessment

Data to describe the learning process delivery and assessment dealt with the use of various tools to deliver study materials, exercises, online tests, organizing final exams, assessing student's progress and further development in learning. The results are displayed in Fig. 3.

In autumn 2021, study materials, exercises, and online tests were delivered to students in both types of institutions and used through MS Teams as the only channel, as it was recommended by the Czech Ministry of Education [3]. However, in autumn 2022, the range of tools used in blended learning became wider: e-mail was used by 62% of US teachers and 33% of HE teachers in combination with MS Teams (92% US; 45% HE) and LMS Moodle (21 = US; 19% HE). The frequency of final face-to-face oral exams increased twice in autumn 2022 in both types of institutions (from 18% to 39% in US schools; from 34% to 70% in HE institutions). Logically, the frequency of online oral exams decreased, as well as of final online tests. However, in autumn 2022, after two blended learning semesters, almost half of US school teachers (48%) assessed student's progress in learning and proposed further learning development (46%), which is more than 20% increase compared to autumn 2021. A similar increase was also detected in HE institutions in these criteria.

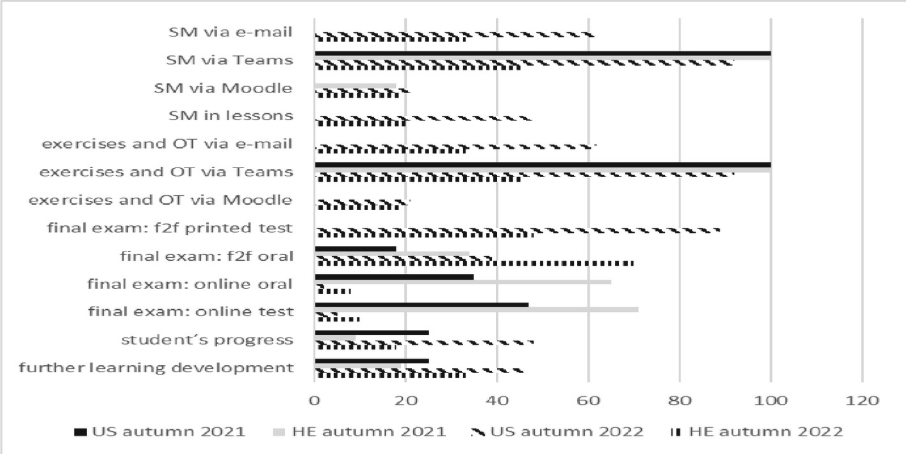

Fig. 3. Learning content delivery: study materials, exercises, final exam (%). (SM: study materials; OT: online tests; f2f: face-to-face)

4.4 Students' Feedback on Online Distance Instruction

Student's feedback covers four fields. Respondents' opinions are expressed in the form of statements, student express their dis/agreement of four-level Likert scale. The results are displayed in Fig. 4.

While in autumn 2021, 67% of HE respondents think that teachers invested much effort in preparation and teaching online distance, in autumn 2022, their amount decreased to 50%. In US respondents, the process went in the opposite direction – in autumn 2021, 51% fully agreed with the statement, and their amount increased to 62% in autumn 2022. Additionally, in this period, there were more than 20% of those who rather disagreed in both groups.

Student's effort was similarly appreciated by both groups in autumn 2021 (37% fully agreed; 47% in US; 51% in HE) but in autumn 2022, approximately a third of them in each group expressed partial disagreement compared to 10% and 14% in autumn 2021. These results show that the data collected in autumn 2021, that is, closely after the long period of online distance instruction, might have been impacted by negative emotions of respondents, their stress and exhaustion from ODI, and the tension in the society in general. One year after, they are calm, less passionate, able to consider the state objectively.

The appreciation of ODI did not show any important changes. In autumn 2022, there is an increase in full agreement with the statement, but the groups of those who rather agree are almost identical in both periods. In autumn 2022, the number of non-supporters slightly decreased.

While in autumn 2021 more than three quarters of US students think that they did not learn much in ODI, HE students disagree in the same period. This is, we think, the proof supporting our expectation of more autonomy of HE students and consequently better results and more satisfaction from ODI. Contrary to this, there was a group of HE students in autumn 2021 who rather agreed with the statement, which means that they

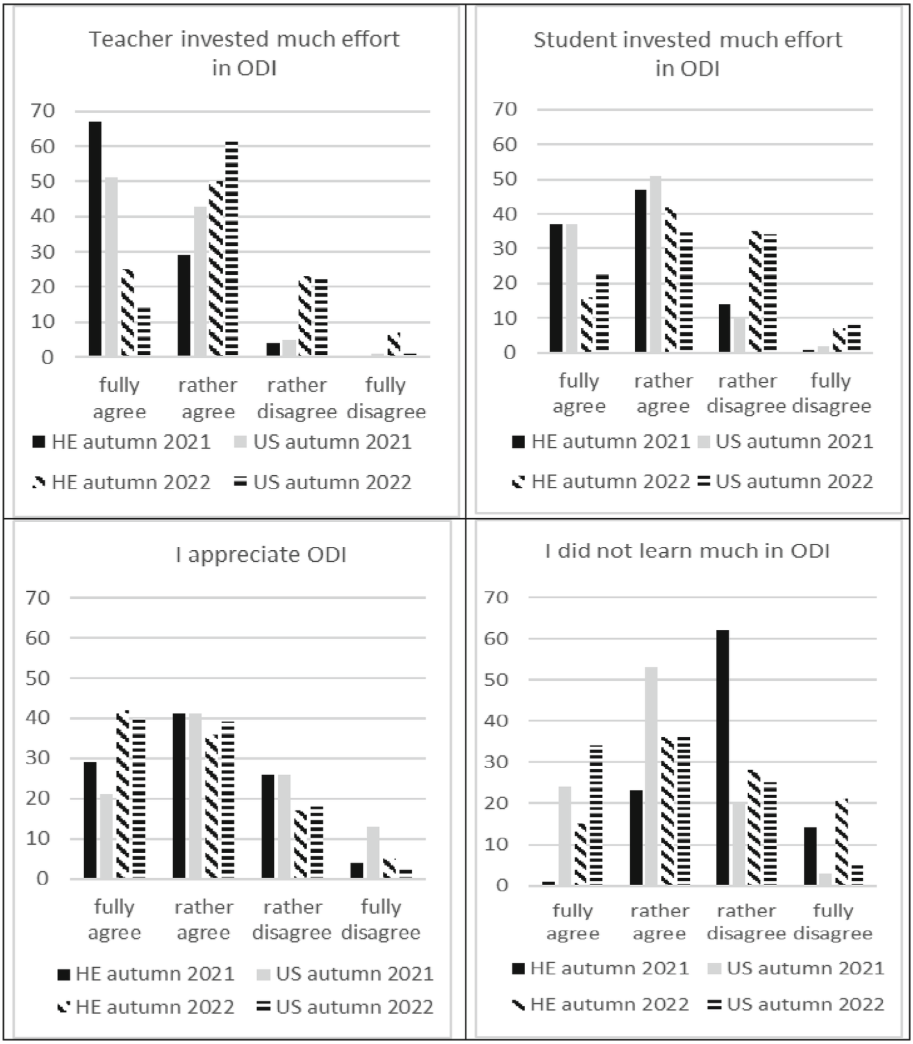

Fig. 4. Students' final feedback on online distance instruction (%). (ODI: online distance instruction)

were not satisfied with their learning outcomes and/or results. However, one year later, in autumn 2022, the opinions of both groups are moderate.

5 Conclusion

5.1 Students' Reflection on the Expectations

Students' opinions were not in accord with our expectations. They are summarized as follows:

(1) The first contact and communication started at the very beginning of the semester, as detected in autumn 2021, or even earlier, as shown in autumn 2022. As expected, the frequency of communication decreased in autumn 2022, when blended learning was applied. However, a higher frequency of communication in US students compared to HE was not discovered, so our expectation that US students need more support, for example, to be as autonomous as HE students, did not prove.
(2) In learning content acquisition, combining much knowledge gained in face-to-face lessons, a little from online learning, and a wide range of skills developed in practical lessons seemed to be an optimal model of learning in autumn 2021. In autumn 2022, students of both types of institutions considered the contribution of online learning even lower.
(3) After the unrivalled use of MS Teams in ODI, other channels and tools were included in the blended lessons, but we are not sure whether it can be called enrichment of the process. In reality, more channels and tools make orientation in the environment more complicated.
(4) Both positive and negative opinions of the respondents on ODI were worn away during the year of blended learning; no strong supporters and opponents were detected in any area.

The anticipated problem of autonomy in learning, which could be connected with some observed items, did not appear. The frequency of motivation changed in autumn 2022 (Fig. 2), but the increase was unexpectedly detected in HE students. Illogical was also the decrease in the use of various tools in blended learning in this group (Fig. 3). These features showed that we cannot generally, without conducting research, anticipate the expectations in particular groups.

Furthermore, it is difficult to discuss the received findings. The main reason is that a unique set of criteria was applied in our research to get the results. In the literature, we can find surveys focused on one or more of them, see, for example, Atwa et al. [18], Zhang [19], Cheung et al. [20]. However, the combination used in this research has not been found.

5.2 Limits and Future Research

The results of the research are limited by the structure of the sample – it is not gender-balanced (female 70% in Questionnaire 1; 83% in Questionnaire 2). However, this structure follows the occurrence of female staff among Czech teachers and students of teaching study programmes. From this point of view, the sample reflects the gender structure of teachers in the Czech Republic [21].

Future research should target at a larger sample, the result of which could be generalized for the Czech Republic as minimum. In case of potential restrictions in the future, a model of hybrid instruction will be applied. In the Czech education system, hybrid teaching and learning is defined as a combination of face-to-face and online distance lessons that seems to be similar to blended learning [7]. However, the combination means that some learners are taught face-to-face in the class, the others synchronously online distance from their homes. We think that this approach is even more demanding than the online distance instruction that we experienced during the pandemic. Furthermore, didactic training is needed in hybrid teaching (and learning) that differs from ODI, and new digital technologies are being developed that teachers should acquire as they appear on the market. Therefore, no time should be wasted and teachers should be trained in teaching with the support of latest technologies, either to enrich their blended lessons, or to work under hybrid conditions. To paraphrase Hamlet (Shakespeare), 'the readiness is all'.

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Camera Shy in Online Synchronous Class: A Qualitative Study in College Students

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Abstract. Over the past two years, online synchronous video class has been the mainstream of higher education in China. However, college students had less trust in cameras and were reluctant to switch them on. This study employs grounded theory to describe students' emotional experience and behavioural discipline on cameras, and offers an explanatory understanding based on medium theory and Foucault's analysis from Discipline and Punish to build a model of camera shyness of college students in online class. The qualitative data results indicated, college students' attitudes toward cameras are primarily influenced by social factors, characters of curriculum and personal factors. Students are prone to being nervous, worried, distracted on cameras, as well as constantly self-examining and peeping at others. Writing-centered behaviours are shaped by the online synchronous class scene and transformed into screen-centered and lens-centered behaviours. This paper provides a benchmark for improving the future application of online instruction in higher education.

Keywords: Online Synchronous Class · Camera · Video Conferencing · Higher Education

1 Research Background

Due to the pandemic, online classes have become the dominant mode of instruction in colleges. Teachers were coerced to move to online videoconferencing platforms, and students would switch on their cameras only at the request of teachers, switching off one after another as the class progressed. Some students have never turned on the cameras. In addition, accidents and negative news about cameras in online classes have increased the wariness of students and teachers.

Studies revealed some reasons for students' reluctance to switch on the cameras in online classes, which mainly contain two aspects: on the one hand, some studies showed that the experience of switching on the cameras in online classes is not as good as offline, and the novelty of seeing each other soon wears off as time goes on [1]. Another study of factors affecting students' comfort with online synchronous learning based on a single class shows that the main reasons for students not turning on their cameras were that they did not want to dress up and they felt they did not look good [2]. On the other hand, a study of ethical issues in educational data found that students were unaware of

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which videos were collected, who would have access to the videos, what the classroom videos would be used for, or whether videos would be uploaded to the Internet [3]. These information asymmetry are causing stress, disruption, and anxiety in students [4]. Additionally, Dost et al. also found out that a poor internet connection and family distractions [5] as barriers to online learning.

2 Theoretical Framework

The majority of studies that have been conducted on the camera problem in online classes use theoretical analysis and are lacking in qualitative studies to depict a storyline and are not concerned with specific college students with various disciplinary backgrounds. Hence, it's necessary to build a model for college students to illustrate the mechanism and impact of camera shyness in online synchronous classes.

From the traditional offline classroom to online classroom, each evolution in communication forms, accompanied by shifting sense of place, has involved a shift in social boundaries and hence a shift between self and others [1]. In a traditional classroom, teachers and students are in the same place. Teachers can see the expressions and behaviors of any student at any given moment, constituting Foucault's panopticon in Discipline and Punish [6]. In online classroom, mediated by cameras, teachers and students are simultaneously "present" and "face-to-face" [7]. The "presence" here is lens-mediated, and the camera as a medium is setting the stage for social interaction [8], carrying the effects of discipline power to students in new ways [9]. Len-mediated panopticon as an imposition of a 'particular conduct' on students, shapes their emotional experiences and coping behaviour in online classes.

In terms of a medium-theory perspective, cameras in online classes blur the boundary between formal learning places and private places, and reconstruct the classroom scene [10]. Electronic-based classes are no longer directly associated with formal learning places such as classrooms but with private places. Putting on a camera in online classes suggests the forward movement of the "backstage" in Goffman's theatrical metaphor. Because of the medium, the private places of teachers' and students' that used to be the "back stage", become the "middle ground", where audiences witness every move.

In terms of student discipline, cameras, screens and Internet platform as medium provide a broader perspective of the "whole" for students in online classes as Latour's oligopticon, an extension of Foucault's panopticon. An oligopticon sees something small, but what it sees, it sees well. "From oligopticon, sturdy but extremely narrow views of the (connected) whole are made possible as long as the connections hold" [11, 12]. Cameras form the relational network depending on many connections that link students to their representations which are their images on screens. Students are empowered and enrolling in the social network because they can zoom in on a specific image of any other student in this social network at any time.

Based on the previous research and viewpoints supplied by medium theory, panopticon and oligopticon, this research aims to answer the question: why do college students resist switching on the cameras in online classes? How do camera-shy students react when the cameras are switched on? What are their coping strategies? This study presents a theoretical contribution to a model of camera shyness in online classes based on medium theory, Foucault's analysis from Discipline and Punish as well as the concept of oligopticon. More broadly, this study aims to contribute to the future application of online classes in higher education investigating the reasons for students' camera shyness.

3 Research Method

3.1 Research Method

The main focus of this research is to reveal the reasons of college students' camera-shy or reluctant to switch on cameras in online class through qualitative research. To this end, grounded theory [13] offered a comprehensive means for generating a theoretical account for camera shyness. Research participants were selected on the basis of holding a negative attitude towards switching on cameras in online classes, as well as their initial interest and agreement to participate in the research. Aiming to ensure the variety of college students from different education levels and different disciplines and to respond to ethical data protection issues regarding their consent, a two-stage process was applied to identify the interviewees.

3.2 Data Collection

Firstly, a short questionnaire was collected through a convenience sampling method, asking college students for basic information, the frequency, as well as their attitude toward using cameras in online classes. Gender distribution of respondents is 26.88% male and 72.04% female. 75.27% are currently pursuing undergraduate studies, 21.51% are pursuing graduate studies, and 3.23% are pursuing doctoral studies. In addition to asking about students' willingness to share their experiences regarding the usage of cameras in online classes, Students reluctant to switch on cameras were invited to participate in the follow-up interviews to share their experience in greater detail.

93 college students responded to this survey; 12 had never switched on cameras, 60 occasionally switched on cameras, and 21 always switched on their cameras. For the attitude towards cameras in online class, 27 of them were willing to switch them on, 40 were on neutral, 26 were reluctant to switch on their cameras, and 11 students out of 26 agreed to participate in the follow-up interview. Researchers contacted students personally via Wechat and invited them to give interviews. The process for identifying research participants helped not only to ensure a variety of experiences and interviewees' willingness to share their experiences but also to guarantee research validity. In order to increase reliability, researcher has reported the coding results in the text and shared results with participants to examine and confirm.

A qualitative approach was used to collect 11 interviews with college students who were reluctant to switch on their cameras in online classes. 70 of the research participants are undergraduates, 20 of them are postgraduates, and 3 of them are doctors. 72% of interviewees were female; 26% were male. Research participants covered over 6 study fields: natural sciences, education, politics, computer science, communication, and psychology.

Secondly, semi-structured interviews were used to collect data. A preliminary interview based on the literature review was carried out among specialists and two students. In formal interviews, nine of the participants were interviewed by Tencent meetings, and two were interviewed in person. Before the interview, research participants were introduced to the ethical procedures to ensure the confidentiality of their identities. Interviewees made open-ended statements about this, and researchers followed up on the interviewees' responses. The length of the interview ranged from 50 to 90 min. Interviews were audio-taped and transcribed right after the interview. Each interviewee was appointed with a code (#01, #02, #03…).

3.3 Analyzed Data

Following the procedures of qualitative data analysis, interviews were re-read multiple times, the main segments of texts were coded, and codes were reviewed and grouped into subcategories and categories.

Open Coding. First, open coding was applied to the original interview transcripts through line-by-line coding, looking for nuances, explicit statements, and implicit meanings. As new data were collected and additional analyses were conducted, understandings were amended to fit new or diversified conceptualizations presented by interviewees. Data collection and analysis proceeded simultaneously, and two extra interviews were carried out after data saturation. 585 codes were reached in total, leaded to 69 concepts. Eventually, until concept saturation had occurred, 13 categories were clustered. A partial result of open coding is provided in Table 1.

Axial Coding. Consistently reviewed, 13 categories from open coding were yielded into 5 categories, which are emotional experience, coping behavior, social norm, character of curriculum, and personal factor. The result of axial coding is provided in Table 2.

Selective Coding. Finally, selective coding was used to identify relationships between the main aspects that affect the camera shyness of college students in online classes. Overall, we provide an explanatory model of college students' camera shyness in online classes that encompasses well-established processes such as social norms as well as characteristics of the curriculum and personal factors as the central process by which students are reluctant to switch on cameras (see Fig. 1). Emotional experiences and coping behaviors on camera lead to the development of camera shyness. Coping behavior is influenced by emotional experiences and can, conversely, affect those experiences.

Table 1. Partial result of opening coding.

Code of participant	Quote	Category
#08	I get tense in formal situations like classes and conferences	Nervousness
#04	I don't feel comfortable with people staring at me, and I have social phobia	Stress
#07	I feel like I was wasting time because I need to spend an extra hour to put on my makeup	Boredom
#03	There was a routine - the first and last class of every semester were usually with the camera on	Preparation
#08	When I was absent-minded in class, I would check on myself	Self-examination
#07	I would see what others looked like and take screenshots of some of my classmates to make memes	Peeping
#02	I wanted to respond to the teacher's requests	Respect for teachers
#08	I just followed the other people. I turned the camera off when everyone turned it off, and basically turned it on when everyone turned it on	Conformity
#01	I usually opened camera in a class....The class was a small one, with more than 20 people	Student capacity
#06	When I was in the last year of middle school…because of the heavy burden, I barely would notice the existence of camera	Information richness and frequency of interaction
#01	If I find the content of the class not helpful, or teacher doesn't attract me, I won't listen to it, no matter it's online or offline	Motivation
#05	I'm concerned about my appearance	Appearance anxiety
#02	I have had the experience of being cyber-stalked and am more concerned about privacy	Distrust of technology

Table 2. Result of axiel coding.

Category	Theme	Explanation
Nervousness	Emotional experiences	Nervousness, anxiety, restraint on camera
Stress		Worry, stress, fear on camera
Boredom		Boredom and weariness on camera
Preparation	Coping behaviour	Arranging the room, position the camera, make-up, etc.
Self-examination		Checking on one's own image and movements in camera
Peeping		Peeping at others, observing their living environment and images
Respect for teachers	Social factors	Follow instructions from teachers or make up for teachers' awkward
Conformity		Group effect in students and excluding outliers
Student capacity	Character of courses	Number of students in the online class and the amount of people potentially accessible to video
Information richness and frequency of interaction		Information richness and frequency of interaction in different courses
Motivation		Students' motivation to learn in different courses
Appearance anxiety	Personal factors	Often dissatisfaction of one self on camera
Distrust of technology		Perception that cameras and platform-related technologies are untrustworthy and out of control

4 Results

4.1 Factors

Social Factors. Social factors refer to respect for teachers and student conformity. In online classes, students only switch on their camera with teachers' requests. Participants in every interview believed that very few of students would voluntarily switch on their cameras if the teacher never request or encourage them to do so.

Attitudes of teachers to students' cameras varied between individual. Some participants suggested that students using cameras supported teachers, such as giving feedback on their teaching in real time, being role model for other students, or at least thoughtfully helping with giving some response.

Teacher must be pleased to see someone answering. (#03).

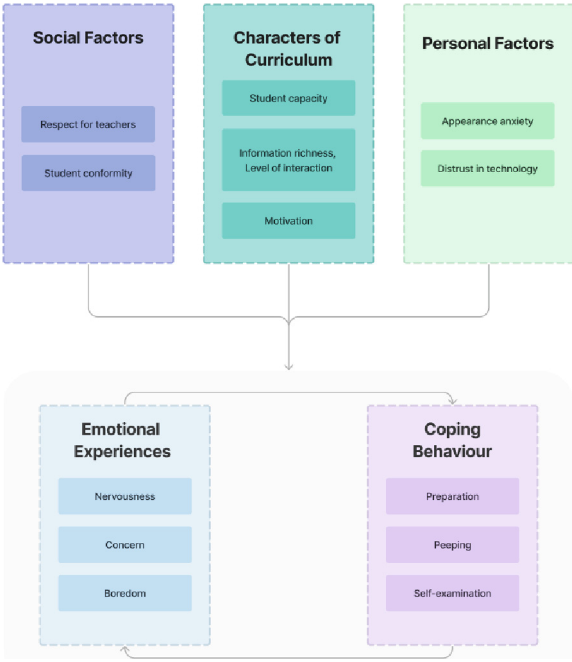

Fig. 1. A conceptual model of college students' camera-shyness in online synchronous class.

Others suggested teachers didn't care whether their students switched on cameras or not. They are more concerned teaching itself than getting feedback from the students via cameras.

Teachers are more focused on their own performance. (#01).

The power relationship between teachers and students [14] in online classes is further shaped by cameras as a medium. Teachers exercised their power while requesting the use of students' cameras and getting approval from students.

Due to conformity, students were less willing to switch on the camera. The camera was off by default when students entered the online platform; those who actively switched it on became outliers. Hence, most of the students chose to conform to their peers. Participants believed that outliers were confident and active and that "showing up" was because they strongly wanted to draw the teacher's attention. Participants generally felt contemptuous and helpless toward the outlier.

Was you up to anything?Do you want to make the teacher to remember you and be benefited in the process? I would say your purpose is not pleasing. (#04).

For example, the teacher requests to switch the camera on. The first one to switch it on are usually to be blamed because others don't want to do so. (#10).

Characters of curriculum. Student capacity, information richness, level of interaction, as well as **students' motivation**, affect students' attitudes toward using the camera. A larger class size with more peers leads to more uncertainty. In online classes, cameras reveal information that used to be unaccessible in traditional classrooms, such as the layout of a dormitory or home, interaction between family members, and the behavior and emotions of the participants in a private setting. Private places used to be the backstage for students; in comparison, the online classroom was the "front stage" on which students needed to get prepared and perform. Integration of the off-line classroom and private places leads to "backstage" moving forward. Hence, online classes create a "middle ground." Peers and teachers as observers now have more access to the information "backstage". Therefore, due to the risk of revealing backstage information, the larger the online class, the more undesirable it is for students to switch their cameras on. Additionally, camera-off can be easily noticed by teachers in a small class, and the participant didn't want that to happen. (#01).

We had sixty people in that class. I was the only one who teacher knew and was asked to switch the camera on to answer a question. I switched on my camera so the teacher saw an unkempt me, answering her question.... All my classmates saw me, and remembered me as an unkempt person... It was really painful. (#08).

Courses with high information richness and high frequency of interaction can help students concentrate more quickly and stay focused in the class rather than being distracted by stress or nervousness.

Motivation affects students' emotional experiences and behaviors. Less motivated courses lead to boredom on the camera. Half of the participants (N = 5) denied that turning the camera on was a significant factor in helping them concentrate more. Similar to Wang H.'s findings, students motivation to learn and teachers' styles were the main factors affecting the learning engagement of students.

If I think the content of the class is useless, or the teacher isn't attractive, I won't concentrate wherever I am. (#01).

Personal Factors. Reluctance to use cameras was also due to personal factors such as appearance anxiety and distrust in technology. Social appearance anxiety is the fear that one will be negatively evaluated because of their appearance [15]. Nervousness and stiffness in front of the camera were attributed to appearance anxiety, unsatisfied with the way they look on camera, they constantly self-check, maintain facial expression, and keep adjusting the camera position.

I am a little bit anxious and worried about my appearance. When I switch on the camera, I can not help to keep wondering what I should do to make myself less weird, not too much different from I usually do. (#06).

Trust in technology is defined as a person's belief that a technology will not fail them [16]. Participants experienced three types of distrust in technology about the camera: Firstly, unintentionally switching on the cameras leads to unprepared exposure to private places. Secondly, accidents might happen when the camera is on, such as family members wandering into the camera's range. Thirdly, student videos or images are captured and widely distributed without consent. The majority of participants distrustful of cameras have experienced or witnessed such incidents.

I don't want to be photographed and made into memes. (#11).

4.2 Coping Behavior

Preparation. Based on medium theory, electronic medium divides place with people's activity by dividing information accessibility with attachment in certain place [17]. College students are physically in a private place until they are at home or in the dormitory, but they operate socially in what used to only belong to certain public areas,such as attending class on campus.

College students get prepared in anticipation of classes that require them to switch on their cameras. One participant described a pattern that required cameras to be switched on.

The first and last class of the semester are usually need to switch on the camera. In the first session you have to introduce yourself and in the final class the teacher will encourage students to switch on their camera to say goodbye. A presentation or a test in the middle of the semester will also need to put on camera. (#03).

Participants performed a particular sequence to prepare for switching on the camera, including freshening up and arranging the room. A decent, pleasing look is the necessary condition for switching the camera on. Whether they need to wash their hair, put on make-up, get dressed, turn on a filter, and put light near their faces depends on the habits and standards they set for themselves.

You also need to dress something nice and blow on your hair if it's floppy. It's also very important to open a filter. (#03).

Arranging the room includes positioning the camera, arranging space in the range of the camera, and using a virtual background. Nearly all of the participants (N = 9) believed that their personal life scene is their privacy, including personal belongings, living environment, and their cohabitants. Classroom scenes are embedded by cameras into students' life and raise privacy concerns. Therefore, positioning the camera and arranging the space exposed in the range of the camera are important for managing the information presented to other people in online class. Some participants (N = 3) often used virtual backgrounds, while others were unwilling to do so. Since they had already arranged their space, using a virtual background was not necessary. Additionally, the virtual background frequently didn't work well.

Peeping. Based on the concept of oligopticon, the cost of participant peeping at each other [11] has been largely reduced by online space. Considered impolite behavior for staring at others in the classroom, as well as easily noticed (because others may be in the same state of peeping), students in the offline classroom often peep at peers in a secretive way. Regardless of the purpose, students can scroll the screen, zoom out anyone, and observe them with much less difficulty in an online class.

Anything I do can be seen by my teachers and my classmates. It is different from offline classes where everyone is facing to the teacher and the students don't notice each other. Teacher can't really watch you all the time, but everybody is on this screen in online class. It's very easy for everyone to see what others are doing, and it's uncomfortable. (#07).

Over half (N = 7) of the participants noted that they regularly peeped at other people during the class, particularly friends or individuals making unusual movements. Peeping at others, conversely, leads to self-monitoring so that they can maintain a decent state in case they are observed as panopticon by Foucault.

I love observing people. Given a scenario, there are a few interesting people and I peep at them to make assumptions about their character. (#01).

Self-examination. In online video classes, college students are constantly peeping at others and simultaneous being watched. They know that they are being watched, so they internalized conscious, ongoing self-discipline [6].

Self-examination includes checking facial expression, posture, and checking whether camera or microphone has been erroneously switched on or off. Most participants noted that they constantly cheek their behaviour and appearance on the screen, leading to stress and boredom.

As long as I'm not talking, I go through (the screen, and peep at others). (#10).

I've always (self-censored). I always using virtual background and filter,adjust parameters to make myself less bizarre. I constantly look at myself, check on every move and my appearance on screen, trying to adjust myself. (#06).

4.3 Emotional Experiences

Students on camera are the focus of teachers and peers, leading to **nervousness, anxiety, and fear**, triggered by limited information in class, low levels of class interaction, and appearance anxiety. The initial activation of the camera instigates a heightened state of anxiety among students, as instructors are still engaged in the preliminary stages of the class and have not yet begun the information-dense and interactive aspects of the lesson. Hence, students manifest appearing on camera essentially distracts them from fully engaging in class. A participant compared his emotional experiences in online synchronous class with a debate competition.

When I engage in a debate, I tend to focus on presenting my own argument and less concern with how other participants were feeling. (#04).

Distrust of technology and the large size of the class leads to students' concerns about privacy, making them feel **uneasy** on camera. As Gu et al. found, the recording and collection of student behavior or learning activities with multimedia such as cameras and lenses led to stressed, unsettled, and anxious students [4]. For instance, one of the participants felt **awkward** on camera since camera signal lights are associated with concerns about surveillance.

A light is on all the time when the camera is on, reminding me of the red dot on the CCTV, which makes me feel awkward and bizarre" (#02).

Affected by social factors, curriculum characters, and personal factors as well as their own behavior in front of the camera, college students tend to see the camera as a **nuisance**, and consider that turning on the camera during class is unnecessary.

Turning on the camera makes me feel hampered, troubled, and distracting. (#02).

5 Discipline of Online Class

College students' general camera shyness further develops discipline in an online synchronous class. When college students in an online class are physically in a private place without the camera on, they tend to behave as if they are in a private place rather than in a classroom, attending the class in a comfortable position rather than sitting straight, such as sitting on the bed (#04) or eating fruits (#11). The involvement of the camera in blurring the boundary between scenes of private life and classrooms shapes students' behavior. A new scene leads to new behavior and social discipline [17]. Due to the lens-mediated presence, students tend to behave as if they are in the classroom when the camera is on. The panopticon of the classroom developed the discipline that students should look at the blackboard, make eye contact with the teacher in time, and frequently bend their heads to take notes. Thus, due to the oligopticon in online classes, students' gazing into screens and frequent responses to teachers mean that they are concentrated. A large majority (N = 7) of participants noted that they intentionally maintained a stable, oppressive, and proper posture and expression in a synchronous online video class, reducing personal characters that may be perceptible. Participant #01 depicted herself as putting head in hands, with back straight, and regularly straightening her clothes.

Try to stay calm and just keep poker-faced, therefore I feel a bit safer. (#06).

Usually, I'm poker-faced on camera. When I turn on the camera, I feel like I'm unconsciously poker-faced, with less exaggerate facial expression. (#09).

Since cameras positioned above or below the laptop's screen varied between devices, students' images have different postures recorded from different angles. In additionally camera cuts out body movements, especially motion of the hands. Thus, teachers in an online synchronous class can't tell whether a student is taking notes or checking the phone. Head movement become the most intuitive evidence to suggest whether or not a student is concentrating. Therefore, normal and even praiseworthy behaviors in a traditional classroom, such as bending the head and writing, may be confused with distraction in an online synchronous class.

I'm a little embarrassed to take notes, probably because I'm affected by conformity and I care about judgement from others. When everyone was on the camera, I heard the teacher talked about something and thought that was interesting, and I'd like to write it down. But then I thought, "Why isn't everyone writing it down? Then I'd think, "I was restrained. I'll just memorized it". I'd write it down later when everyone started writing. (#08).

Previously developed and internalized writing-centered behaviours in the classroom [18], such as taking notes while listening to lectures, shaped and unified by the online synchronous class scene and transformed into screen-centered and lens-centered behaviours. A new discipline for synchronous online video classes is gradually developed by college students gazing at the screen or the camera.

6 Discussion

Globally, pandemics have forced colleges to move to online video conferencing platforms and altered students learning behaviors. The results of this study are in accordance with previous studies [2, 4], which found that appearance anxiety, the process of dressing up, distrust of technology, and conformity are the reasons for students' camera shyness.

This study showed the mechanism and impact as well as a model to explain why college students are reluctant to switch on their cameras. It showed that conformity and excluding outliers who volunteer to switch on their cameras lead to students' reluctance to switch on cameras. Respect for teachers or teachers' requests are the positive factors in promoting students to switch on cameras. It also showed that a high level of information richness, class interaction, and learning motivation in a specific class helped to relieve students' camera shyness. In contrast, appearance anxiety and distrust of technology were the personal factors aggravating camera shyness. Additionally, these negative factors lead to coping behaviors and emotional experiences. Coping behavior includes preparation before class, self-examination, and frequently peeping at others. These behaviors exaggerate emotions such as stress, worry, and boredom, which creates a vicious cycle that increases the frequency of self-examination.

In an online synchronous class, the screen and lens were transformed into the center of behavior. Students keep a fixed stance in front of the camera purposefully and consistently, believing that it will impress the teacher and peers that they are intensely engaged in the class. They consciously correct any natural posture to face and stare at the camera, regardless of whether this posture is their most comfortable and efficient learning position, whether they are actually engaged in or simply pretending. According to interviewee, people in the computer screen resemble a "passport photo" wall.

7 Conclusion

Cameras in online synchronous video class help students to concentrate, while also generating negative factors. Teachers shouldn't take it for granted that students who are willing to switch the camera on are doing a better job. Downsizing the class and enriching the information and interaction in online video classes can release the stress of students with camera shyness and help them adjust to webcam-based classes.

Opening camera in online class platform is simple or even no need for manual operation. Students' cameras switch on automatically in some platforms when teachers want to check the state of a student or it's their turn to take the "stage". Cameras on other platforms must be manually switched on, but by simply clicking the button, the camera is on. In addition, most laptops don't have a notable reminder for cameras. As a result, platforms should remove the private information of students as much as possible and seek consent from participants on camera if they use it for research or play in the public domain. [19]. Interests of individual privacy and data confidentiality should be balanced against the social benefits of higher education research access and use [20]. Colleges should provide detailed instruction and notes to deepen students' understanding of technology in a synchronous online video class.

Several limitations of this study were considered. Data for this study came from a small number of students who filled out the questionnaire and were willing to be interviewed. While this may limit representativeness, This model needs to be examined in larger samples. Furthermore, there was sex ratio imbalance (72.7% female to 27.3% male) in the survey. Additionally, the survey was coded by a single researcher without the permission of investigator triangulation. In order to reduce bias, researcher has reported the coding results in the text and shared results with participants to examine and confirm. It would also be beneficial to combine quantitative research methods to verify the exploring model and further measure the extent of different influential factors in this research.

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Investigating Demographics and Behavioral Engagement Associated with Online Learning Performance

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Abstract. In recent years, online learning has become a viable alternative for learners worldwide to pursue higher education and gain advanced technical skills. In this work, we focused on data analysis to scrutinize the features associated with online learning performance and course selection. In particular, we investigated and compared how student demographic characteristics and behavioral engagement associated with academic performance based on a publicly accessible Open University Learning Analytics dataset (OULAD). We find that neighborhood poverty level, education background, active learning days and interaction times are positively associated with final learning results. In addition, students with different genders had bias in online course selection, where female students tended to favor social science courses and male had a preference for STEM. Students who performed well mainly came from learners with a well-educated prior background.

Keywords: Educational Data Analysis · Online Learning Performance · OULAD dataset · Virtual Learning Environment

1 Introduction

Distance education has facilitated students to get educated in online environments, and virtual learning through various online platforms has become a complementary means in off-campus education. In addition, virtual learning environment (VLE) with the support of online platforms like Massive Open Online Courses (MOOCs) helps transfer courses to the Internet, where students can register their interested courses, submit their assignments and get feedback from

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course instructors and peer learners. However, online education suffers a higher rate of student dropout than traditional on-campus education. In particular, the percentage of students who enrolled in online courses and successfully completed the course in the end was only 15%[1] on average or even 5% reported in [7].

With the advancement technologies and tools, the rapid growth of the accumulated educational data has stimulated the emergence of several research communities, such as learning analytics focusing on analysis of learners' interaction with VLE for the sake of improving their learning experience by providing timely guidance. In particular, learning analytics aims to predict student academic performance [5,12,13], indicate possible at-risk [2] students or early dropout [6] learners. In addition, the performance of predictive models by using machine learning techniques sometimes depends on the quality of data sources and appropriate selected features. For example, in distance education, data sources include student demographic information and the records from student's VLE interactions. However, how to identify appropriate features before feeding them into the machine learning model is nontrivial and it relies on expert domain knowledge and further data analysis.

In the context of predicting student academic performance, the final result corresponds to outcome variable while student demographics as well as engagement features are related to student variables. The work in this study is to explore associations in twofold, association between learning outcome and student variables, and association between module selection and learner demographic. In blended learning, some researchers [1,11] investigated which demographic characteristics can potentially contribute to successful learning outcomes. This work not only investigated online learning performance associated with student demographic and behavioral engagement, but also explored associations between demographic information and course selection.

2 Literature Review

2.1 Student Learning Performance Prediction

There are some studies related to student academic performance prediction published to date. These studies mainly focused on exam performance analysis in educational institutions and aimed to solve different binary classification tasks in terms of classifying students into two disjoint groups, 'dropout' or 'non-dropout', 'pass' or 'fail'. Kotsiantis et al. [8] applied six machine learning algorithms, such as k-Nearest Neighbours (KNN), Naive Bayes (NB), to accomplish the task of binary classification of dropout student. Considering prediction accuracy and training cost, NB was the most appropriate classifiers in their experiment and NB was capable of identifying dropout-prone student by using student demographic [8]. Huang [5] compared four mathematical models to predict student academic performance in undergraduate compulsory courses. Their experiment results showed that support vector machine (SVM) outperformed three other models in general [5]. In these works, traditional supervised machine learning

[1] http://www.katyjordan.com/MOOCproject.html.

techniques were applied in student performance predictor but no one specific model can always beat others. The reason may be due to different datasets setting and different selected input features.

2.2 Research on OULAD

In recent years, OULAD [9] was adopted as one of the most comprehensive publicly available dataset due to its rich information including student demographic, results of student's assessment, and clickstream data from interaction between students and VLE. Hlosta [4] utilized assignment submission information and found that the first assessment was a good predictor of the overall success in the course. Chui [2] proposed a SVM-based classifier to predict at-risk and marginal university students and their experiment results demonstrated that the proposed model RTV-SVM preserved accuracy in the large-scale dataset. Tomasevic et al. [12] gave a comprehensive analysis and comparison of six supervised machine models for student final exam performance prediction. In both classification and regression tasks, artificial neural network (ANN) outperformed other methods by feeding the student engagement and past performance data [12].

3 Methodology

The dataset OULAD [9] provides both student demographic data and interaction records with the university's VLE , which fits our goal in this investigation. In particular, OULAD, published as a subset of the Open University (OU) student data from 2013 to 2014, includes seven courses (called modules), where each module can be further divided into multiple presentations during the year. Further detailed information related to the dataset OULAD can be referred in [9]. Overall, we conduct the investigation with the aim of answering the following research questions:

RQ1 How is the online learning performance associated with student demographics and behavioral engagement in the module-presentation?
RQ2 What is the difference in terms of course selection and final performance between female and male students in online courses?
RQ3 What is the difference in terms of course selection and final performance among students with different prior education background in online course learning?

Each data point is defined as a vector consisting of variables extracted from fourfold information: (1) student demographic x (2) module m (3) final result y (4) student-module engagement record in VLE e. The label y denotes the final result of the student academic performance[2]. The demographic variable x is described as follows:

[2] Four types of final result: withdrawn, fail, pass, distinction.

- x_1: Gender: gender of the student.
- x_1: Prior Education: indicated the highest level of education of the learner.
- x_3: IMD band: specified the index of multiple deprivation (IMD) band of the place where learner lived in the process of module-presentation.
- x_4: Age: identified the age band for each student.
- x_5: Disability: indicated whether the student declared a disability.

The selected module and student-module engagement variables are as follows:

- m_1: Module ID: each ID denotes the corresponding module. [3]
- m_2: Module Type: each module is grouped into social science (SS) or STEM[4] discipline.
- e_1: Registration date: indicated the day of student's registration for the module presentation.
- e_2: Total number of days: indicated the total active days while a student study her selected module during the presentation.
- e_3: Total number of clicks: indicated the total number of visits to learning materials via the VLE.

In this work, we use conditional probability to measure the association between two variables. In RQ1, for the final result y, e.g., 'pass', the association between this result with one student demographic variable x_i can be calculated as follows:

$$Pr(y|x_i) = \frac{Pr(x_i, y)}{Pr(x_i)} = \frac{count(x_i, y)}{count(x_i)} \tag{1}$$

where the function $count(\cdot)$ is a counter by returning the number of records if the input condition satisfied. Similarly, for the task of exploring RQ2 and RQ3, the association between course selection and gender (or prior education level) variable can be computed as:

$$Pr(m_i|x_i) = \frac{Pr(m_i, x_i)}{Pr(x_i)} = \frac{count(m_i, x_i)}{count(x_i)} \tag{2}$$

Intuitively, for the students who registered the same course, the distinction rate of students with good prior education background is higher than students without any formal qualification. It is in line with the experiment result in this study.

4 Experiment

In this section, we conducted the experiment with the aim of answering the research questions mentioned in Sect. 3. In the followings, we first present the experimental settings, followed by giving result analysis upon the research questions.

[3] Seven modules (A-G) are contained in OULAD.
[4] STEM: Science, technology, engineering, and mathematics.

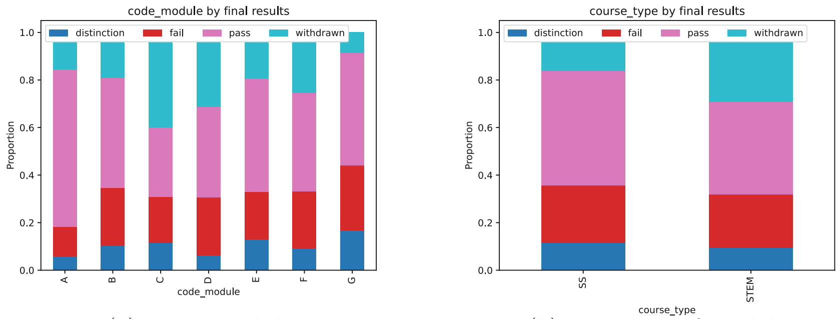
4.1 Experimental Settings

The experiment was conducted with the publicly accessible dataset: OULAD [9]. Since the goal in this study is to investigate the correlation between each selected dimension and the student's academic outcome in a course, we did some data preprocessing as follows: (1)We merged different tables into one main dataframe where each record contains threefold information, the demography of a student, one of her selected module-presentations including registration date and final result, and student behavior from the whole course duration (e.g., clicks to each material related this course). (2)We further cleaned the dataframe by dropping records with missing value in numeric columns and dropping duplicate rows. (3)We aggregated the number of days and clicks for each material according to different activity types to create some new columns, e.g., total number of days interacted with VLE, total number of clicks to materials during these active days. The statistics of the processed dataset is shown in Table 1.

Table 1. Dataset statistics.

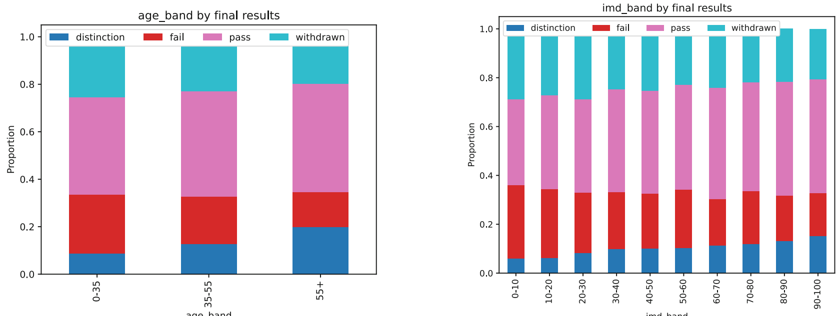
#records	#unique students	#modules	overall final result proportion
28174	22437	7	42% pass, 23% fail, 10% distinction 25% withdrawn

4.2 Result Analysis in RQ1



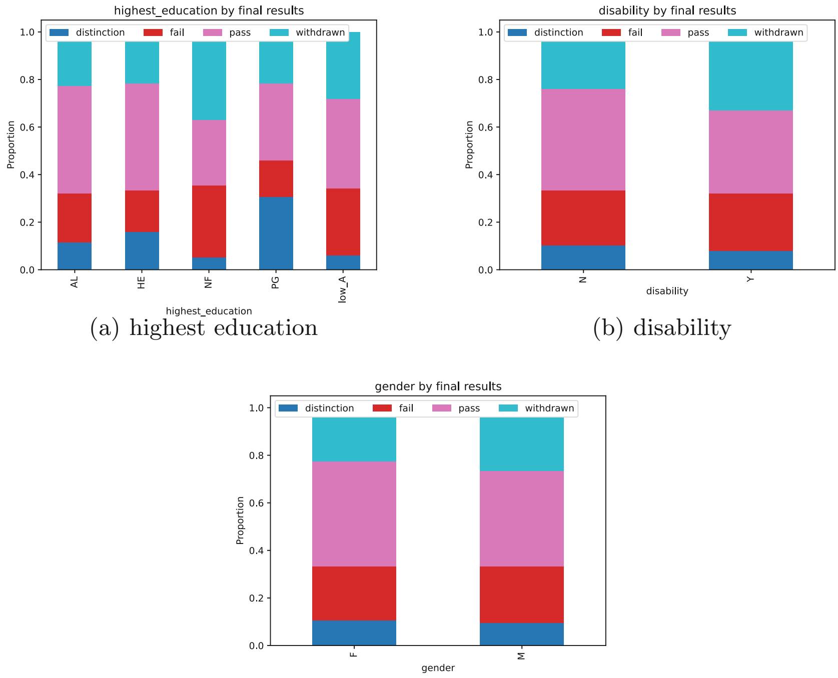
(a) seven modules (b) two types of modules

Fig. 1. Final results over modules



(a) age (b) IMD

Fig. 2. Final result



(a) highest education (b) disability

(c) gender

Fig. 3. Final result. AL: A-level or equivalent, HE: high education qualification, low A: lower than A-level, NF: no formal qualification, PG: postgraduate

To investigate RQ1, we divided the examined variables into categorical and continuous groups. In particular, module, age, highest education, disability, gender, IMD ban were selected as categorical variables, while date registration, total_n_days[5], total clicks were chosen as continuous variables.

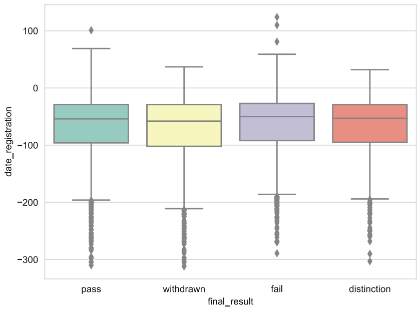
[5] The number of different days for a student interacted with VLE during her presentation.

From Fig. 1(a), course A was registered by fewest students but it had the highest pass rate and lowest fail rate among all modules. Students who enrolled in course C had the lowest pass rate and largest withdrawn rate in all courses. We further aggregated the outcome into two types of courses (SS and STEM) as shown Fig. 1(b). The fail ratio of social science and STEM approached. In addition, the pass rate of social science courses was higher than STEM course, but STEM courses suffered a larger withdrawn proportion. Regarding demographic information of age and living place, some positive outcome patterns related age band can be found in Fig. 2(a). For example, pass rate increased and fail rate dropped in age group. Moreover, the distinction rate in aged learners was two times as much as young students group. Similar pattern can be found in IMD band as shown in Fig. 2(b). The result indicated a positive relationship between good academic performance and IMD band, such that the higher the IMD band was, the higher the rates of pass and distinction became. These results are in line with [10] that neighborhood poverty level is a strong predictor of overall learning outcomes.

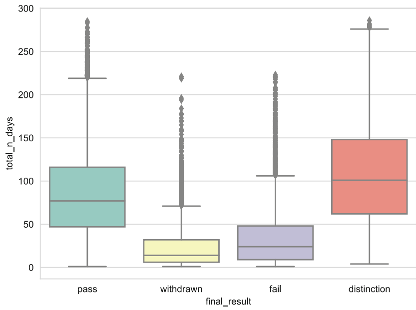
From Fig. 3(a), students who held no formal qualification had highest rate of fail and withdrawn, and lowest rate of pass. Similarly, the fail rate of students with lower than A-level education was 30%. On the contrary, postgraduate students had the lowest fail rate and largest distinction rate. For instance, the distinction rate in postgraduate students was six times as much as in students without any formal qualifications. In addition, about 50% students who were in A-level or equivalent degree or held high education qualification successfully passed their courses eventually. Even though these online modules offered by Open University are in the domain of off-campus education, students with disability still had higher withdrawn rate and lower pass rate as shown in Fig. 3(b). From Fig. 3(c), the learning performance from female and male students was closed in terms of similar rates of pass and fail.

According to Fig. 4(a), the quantiles of registration date related each distribution of academic outcome were approaching, which indicates that the registration date has week connection with the final result. Nevertheless, the experiment result in Fig. 4(b) indicates that the number of total interaction days implies a strong relation with the learning outcome. For example, most of the students who withdrew or failed the course interacted with VLE in less than 50 days. In contrast, most of the students who passed the course in the end had interaction records in more than 50 days. Moreover, some outstanding students (i.e., distinction) interacted with VLE in up to 150 days. Similar positive pattern shown in Fig. 4(c) can be found in the statistics of total number of clicks to course materials in the module-presentation duration. The mean of total clicks among students who withdrew or failed was much less than 100. In comparison, most of the students who successfully completed the course had 250 click records in their study process. Particularly, the 75th percentile of total clicks from distinction students was over 500.

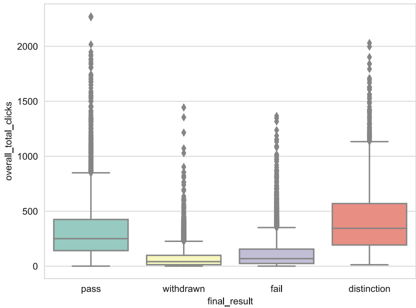
The correlation among some dimensions and final result are shown in Fig. 5. The correlation between registration date and final result was weak, while the correlation between total interaction days as well as total number of clicks and final result was much stronger. The results in Fig. 4 and Fig. 5 suggest that high performing student are more likely to click VLEs. This result is in line with [2–4, 12, 13] that interaction behavior in VLE are chosen as important indicator for identifying at-risk students and predicting learners' final exam outcome.



(a) registration date



(b) total interaction days



(c) total clicks

Fig. 4. Final result distribution

4.3 Result Analysis in RQ2

To investigate RQ2, we divided it into two subquestions as: (1) Whether female and male students have bias in selecting online courses (social science or STEM); (2) What is the performance of female students in STEM and male students in social science courses. For the first subquestion, the results are shown in Fig. 6. Almost half of female students favored course 'B', while less than 5% male students registered this course as shown in Fig. 6(a). Similarly, closed to one fifth female students selected course 'G' but it was not popular with male learners. A large proportion of male students had a preference for course 'F', while it was selected by less than one tenth female learners. Course 'D' was popular with both female and male students in terms of 20% registration rate in

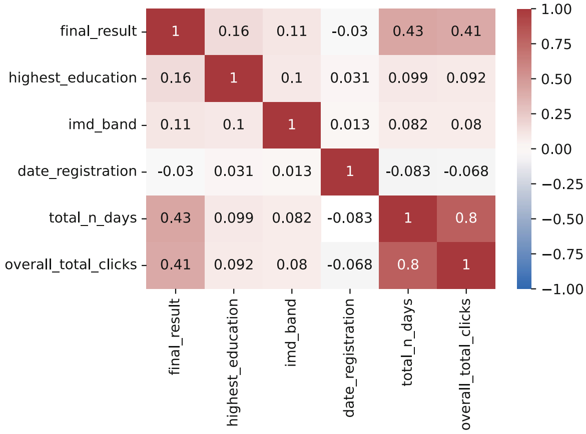
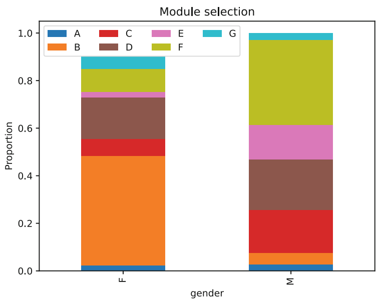


Fig. 5. Correlation Matrix

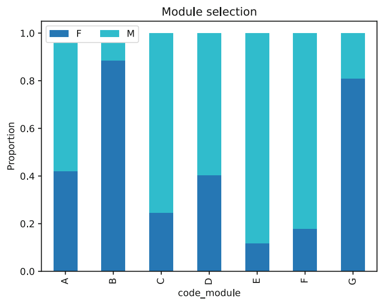
their groups respectively. From Fig. 6(c), over 90% male students favored STEM courses, while over 60% female students preferred social science. In addition, each STEM course ('C', 'D', 'E', 'F') was selected by more male students than female consistently as shown in Fig. 6(b). For the second subquestion, the results are shown in Fig. 7. Overall, female and male students were in the same level of passing both social science and STEM courses. Regarding the fail rate in STEM courses, female learners performed better than male. However, according to the withdrawn rate in both social science and STEM courses, it was higher among female students.

4.4 Result Analysis in RQ3

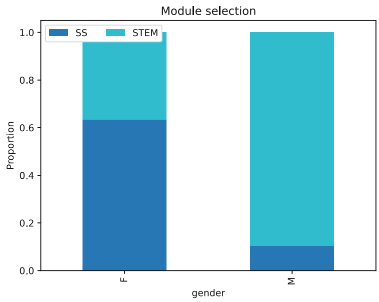
According to the education background impact, we put students into two groups, where A-level or equivalent, high education qualification, postgraduate are in group-1, lower than A-level and no formal qualification are in group-2. Similar to the investigation in RQ2, we divided RQ3 into two subquestions as: (1) Whether students with different prior education background have bias in selecting online courses (social science or STEM); (2) What is the performance of weak background students in STEM and social science courses compared to students in better education background. For the first subquestion, the result is shown in Fig. 8. According to Fig. 8(a), all the seven modules were selected by the two groups, and both strong and weak education background students considered courses 'B', 'F' and 'D' as their top-3 selections. From Fig. 8(b), all the seven courses got more registrations from strong background students than weak ones. In each group, the results shown in Fig. 8(c) suggest that students preferred taking STEM courses than social science in online platforms. For the second subquestion, the result is shown in Fig. 9. Overall, students with competitive education qualification performed better in both social science and STEM modules in terms of achieving higher pass and distinction rate as well as lower



(a)

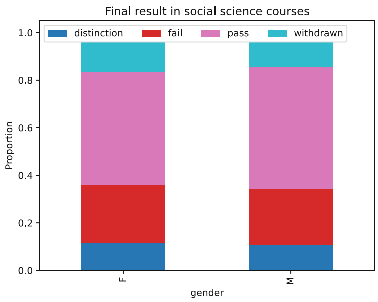


(b)

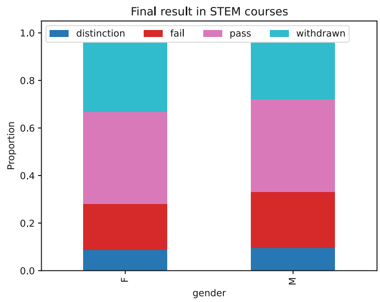


(c)

Fig. 6. Modules selected by female and male students



(a) social science



(b) STEM

Fig. 7. Performance: Female vs. Male

fail rate. The gap of pass rate between weak background students and strong background students became larger in STEM courses. The withdrawal rate in both groups for STEM modules doubled compared to social science courses. According to Fig. 9(a) and 9(b), in both social science and STEM courses, the distinction rate among students with a better prior education level was twice as high compared to students with a weaker educational background.

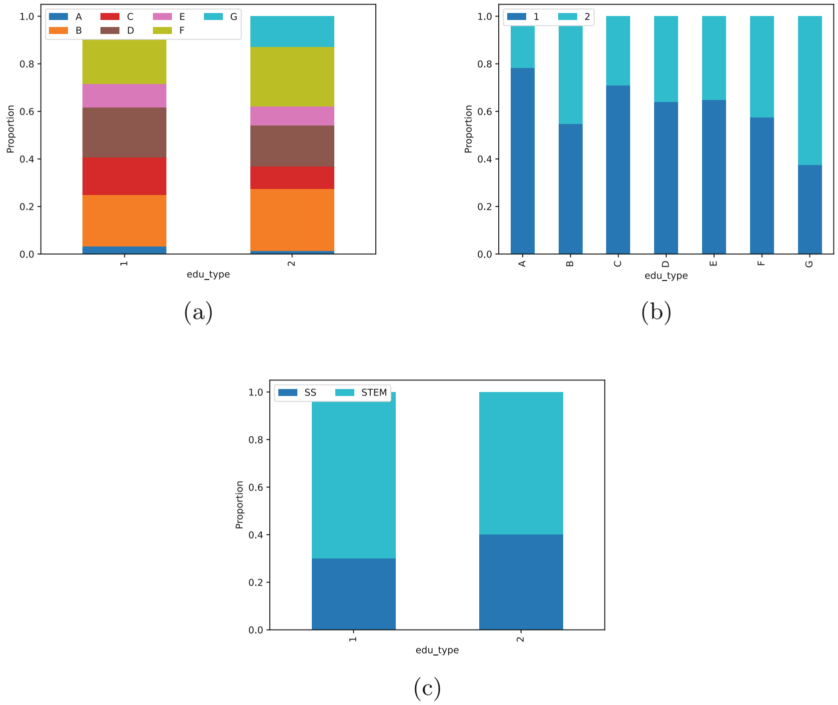


Fig. 8. Module selection grouped by different education background

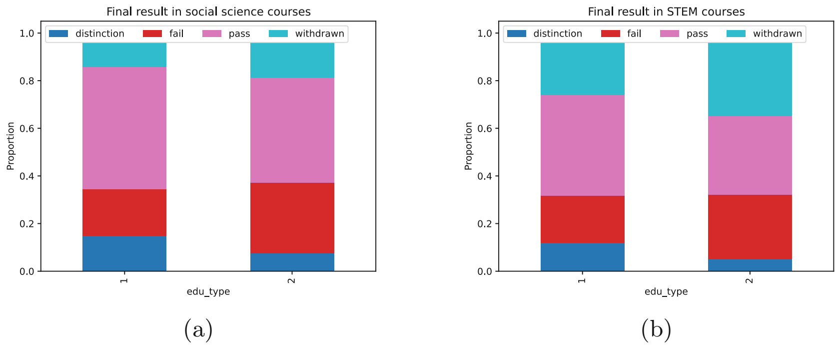


Fig. 9. Performance: strong vs. weak education background

5 Conclusions

The recent increase in open access to learning data has given educational data mining greater importance and momentum in understanding and optimizing the learning process. In this work, we conducted investigations to explore associations between final academic results and student demographics, as well as engagement behavior, using the publicly accessible dataset OULAD. In addition, this work investigated the difference in terms of students' course selection and final performance in different genders or prior education levels. The experiment results suggest that demographic characteristics in terms of neighborhood poverty level, prior education background, and student active participation during a module in terms of total interactive days and total number of clicks to learning materials, have positive association with online learning outcome. Moreover, regarding online modules selection, the experiment results suggest that female students favored social science while male learners preferred STEM. Meanwhile, the results suggest that high performing students mainly came from good prior education background. There are some limitations in this work. First, this study only investigates the association between final result and student demographic feature, but it would be interesting to explore the association between learning outcome including assignment assessment as well as final exam score and demographics. Second, this work lacks of exploring learning performance associated with student behavioral engagement in fine-grained granularity. As student's VLE interaction can be further classified into several activity types according to the role associated with module materials in OULAD, e.g., resource, homepage, forum[6], etc., some insights can be obtained from clickstream data by identifying temporal engagement patterns.

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[6] Resource activity type refers to a segment of text the student is supposed to read, forum points to forum space of the course.

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Content and Pedagogy Development for Blended Learning

Content Development of 'Literary Tourism' Within Blended Learning Concept – Case Study

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Abstract. The case study reveals the present state of the Literary tourism issue in the university setting at the Management of Tourism bachelor study programme. It demonstrates how to increase desired awareness and students' knowledge of this cultural heritage topic while utilizing a tried-and-true scheme of content development within the frame of a blended learning concept. The scheme might be perceived as a didactic tool built on the heuristic method, Socratic debate and constructivist approach that meets the requirements of student involvement and motivation to create and retain knowledge.

Keywords: Content development · Tourism management · Learning environment · Socratic method · Study

1 Introduction

Literary tourism has not only grown popular among travellers [1, 2], but it has also grown into a commercially significant phenomenon and has become a crucial component of the travel industry [3]. Literary tourism has so much to offer, which is reflected, e.g., in the destination management or hospitality industry [4]. Literary tourism is one of the niches in cultural tourism that both governmental and commercial organizations have been paying more attention to [5]. The importance of the cultural value of literary tourism should be discussed and incorporated into study materials provided to students of hospitality and tourism management at the secondary and especially tertiary level of education. Students of hospitality and tourism management should be professionally acquainted with this multifarious phenomenon and be able to see its power not only at the cultural level [6] but also at the environmental and economic levels [7].

Students in the Management of Tourism bachelor program at the University of Hradec Králové learn about literary tourism on a sporadic basis, just marginally; this topic is not explicitly anchored in the syllabi of any Culture of English-speaking countries subjects. The paper deals with the way of filling the empty space in the syllabus and developing content for this specific niche in cultural heritage topic. The content is developed, discussed and knowledge retained within the frame of a blended learning concept in both learning spaces: on the Blackboard virtual learning platform and in face-to-face classes in a newly introduced elective 6-semester 'Guide Activity in English' subject covering

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history, geography, and culture of the United Kingdom, the USA, Canada, Australia, New Zealand, India and selected countries of Africa.

Inhere presented case study reveals the present state of Literary tourism issue in a university setting at the Management of Tourism bachelor study programme. It shows ways to improve desired awareness and students' knowledge in this field within the frame of the blended/hybrid learning concept by applying a scheme of content development as a didactic tool.

2 Problem Background

In the Management of Tourism bachelor programme, the theme Literary tourism is mentioned in the 'Guide Activity in English' subject only within the topic 'Current culture', where literature, music and art are discussed. Literary tourism and religious tourism alike deserve more space due to their increasing roles in the tourism business, including destination marketing and sustainability of local and regional tourism sectors [8, 9]. There is a shift towards experience-based tourism. Visitors' needs and expectations influence the market [10]. Students have to be able to perceive and understand how unique Literary tourism, with its intangible elements of a sense of place and authenticity, is [11].

Students are supposed to be led to grasp and become familiar with the *interdisciplinary nature of literary tourism*. But then there is another important moment**:** the necessity of excellent *language skills* for a specialist in the tourism industry [12–14]. Currently, alongside standard communication skill dimensions like written, oral, listening, and non-verbal communication skills, the importance of developing digital communication skills is becoming more prominent [15].

The current situation in the Tourism Management Bachelor study program is still rather unsatisfactory, we are facing the problem of declining interest in the field. This decrease in interest is due both to the overall socio-demographic factors and to changes in the faculty policy in the Tourism Management Bachelor study program. The number of English language subjects significantly dropped when more economic and managerial subjects were introduced into the programme [16]. In addition to the previously noted decline in applicants, the effects of the changes imposed resulted in a considerable decline in the language proficiency of newly enrolled students because it was desirable to accept students who showed an interest in the field of management [17]. However, specialization in tourism requires language proficiency [18]. That is why teachers strive for the improvement of students' language competencies; they motivate and look for ways to develop language skills within a variety of language activities, from situational dialogues, reviews, and presentations to content evaluation and creating the content of individual chapters on selected subjects [19].

The scenario presented here is a contribution to the issue of student involvement in the creation of content for a professional tourism student focusing on literary tourism issues. In addition to content creation, there is an equally strong focus on supporting the development of language skills.

3 Literature Review

Encyclopedia of Tourism Management and Marketing opens a literature review [20]. This is the largest tourism management and marketing ontology ever assembled. It provides a comprehensive analysis of this interdisciplinary field. For academics, learners, and professionals working in the global tourism sector, it offers a wealth of references. The Encyclopedia of Tourism, curated by [21], is older, but its broad, holistic approach makes it a valuable reference source for students. It covers marketing, economic geography, cultural resource management, regional and spatial economics, organizational behavior, and IT in business. Quinteiro and Busby [5] contributed to Buhalidis' Encyclopedia with the chapter Literary Tourism and Education. They soberly perceive the importance of literary tourism. One decade ago, Ann Hoppen [22] claimed that literary tourism had grown into a commercially significant phenomenon. According to [5], there are stronger players in cultural tourism; literary tourism doesn't bring the immediate profit as other segments of cultural tourism. On the other side, there are researchers who consider literary tourism an embedded and swiftly developing part of the travel industry [3]. Hoppen et al. [4] define forms of literary tourism and explore its potential in destination branding and marketing in the geographic context of the United Kingdom.

Relevant sources on motivation, promotion, and sustainability in literary tourism will be gradually incorporated into the study, they will illustrate individual findings.

The involvement of students in content development is a widely discussed topic in the academic community. Learning as a cognitive process requires stimulation of affective determinants [23]. Students are not only recipients, but also creators; it all depends on how they are motivated, instructed, and evaluated. According to [24], the utilization of a virtual platform and creating their own materials there will help students learn more and better understand the subject matter. Students rank among the Internet-savvy millennial generation, researchers view working with Blackboard and internet sources as natural. The engagement of students ensures educational content [25]. From the standpoint of perceived value for academic objectives, Cheung [26] addresses open resources such as open textbooks, open reference books, online dictionaries, and online encyclopedias. They are used by students as reference books or alternative textbooks to help them learn new material and solidify their mastery of previously covered ideas. Students actively developed and evaluated the content, as part of their voluntary participation in the study. The accuracy, excellence, and comprehensiveness of content were found to be the main issues when utilizing open educational resources for educational purposes. Here is a parallel with our paper, we also strive to ensure the quality of the study content, which was created by the students themselves.

Many new platforms are emerging where students can create their own content, such as Canva, Scalenut, or Storybird educational content creation apps. In this study, we explicitly talk about content creation on the Blackboard LMS platform. The use of other platforms is tempting, but for reasons of maintaining consistency in the overall e-course design, this does not yet seem sensible.

4 Methodological Frame

The Methodological Frame covers the goal, applied methods and the research sample.

The authors present a content creation scheme as a didactic tool.

The goal of the paper is to propose a way of content creation for the Literary tourism topic by students with a possibility of subsequent updates within the utilized blended learning concept.

The sub-goal is to demonstrate another example of academics' endeavour to motivate and engage students into learning English language and lead students to their final language state exam.

A psychodidactic approach in the described educational process dominates. Students are motivated to create desirable content, which will be part of the chapter in the e-course in the Blackboard learning management system. They will orally present the content to the audience in a colloquium during face-to-face classes within the standard blended learning frame. The chapter will be Individual phases of the whole process, from the first stimuli to the presentation and justification of own technical content, including the design, are described together with applied approaches and methods:

1. Setting the task
2. Working out the task
3. Presentation, justification, discussion and evaluation
4. Aligning and consolidating acquired knowledge
5. Incorporation of students' work into the e-course as a part of a collaborative effort.

Key applied methods are the Heuristic method, the constructivist approach and the Socratic debate which often overlap in individual stages of students' content development process.

Last year (2021/22), 33 full-time students graduated from the Tourism Management program, with two failing. Six students also passed the state exams in English language in addition to the final state exam. Those who want to take also a state exam in English language have to attend an elective subject Guide Activity in English Language. Successful completion of the state exam in the foreign language is associated with a valuable award in the form of a certificate as a guide in the Czech Republic. In this qualitative research, a purposive sampling method was applied. The number of full-time students in the Management of Tourism bachelor programme in 2022/23 academic year is as follows: 1 year 42 students, 2 year 37 students and 3 year 39 students. This research was run with sophomore students who enrolled into the elective subject Guide Activity in English Language, in which the cultural heritage topic is covered in the syllabus. Out of the total number of 37 students, 10 students enrolled in this elective 4 credit subject. All enrolled students participated in the research.

5 Results

The chapter deals with individual phases of the content development concept. It puts students' findings into context with academic research findings.

5.1 Process of the Content Development

Comments on individual phases of the content development concept that is visualised in Fig. 1 follow.

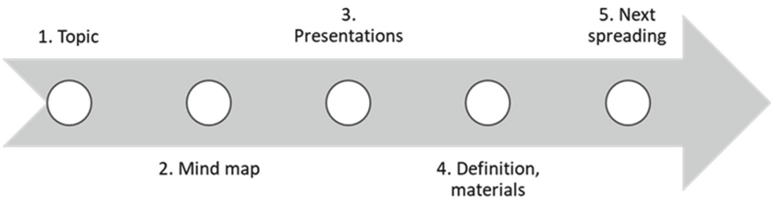

Fig. 1. Content development concept

Setting the Task

During the introductory lesson to the Guide Activity in English language course, students were introduced to the syllabus, the requirements for successful completion of the subject, and the accompanying supporting e-course. Students were instructed about the possibility of completing a *voluntary assignment*.

The assignment was: "As experts in tourism, what do you think the phenomenon of Literary tourism means?" The deadline was set 2 weeks before the end of the semester, the instruction on the assignment without any other specification like format was entered into the Blackboard LMS. The participation was on a voluntary basis.

The outcome was to co-create the content of the Literary tourism chapter as a niche in the cultural heritage theme.

Working out the Task

Students started with a *mind map*; they created their own mind map to show how they understood the issue and terms and what associations it created for them, thanks to which multiple perspectives on the topic could emerge [27]. It was entirely up to the students from which angle they would grasp the assignment. There was no starter track, even in the form of brainstorming.

The *Heuristic method* in a broader sense was applied; students arrived at new knowledge through their own activity led by self-determination [28].

They worked out the topic in their own unique way based on their knowledge, experience and affection. Selected examples of their outputs illustrate the diversity of approaches leading to the mosaic that makes up the multidisciplinary phenomenon of literary tourism.

Presentation, Justification, Discussion and Evaluation

When the task was accomplished, the teacher uploaded students' work into the Blackboard LMS, into the newly created Literary Tourism chapter in the e-course. Classmates could read, rate these contributions in the LMS using a five-star scale, and prepare questions for the colloquium run during face-to-face classes at the end of the semester. Then students-creators presented their work orally to the audience. The presenters discussed the raised questions, justified their work and explained the methods they applied, e.g., how they searched for information, whether they just searched horizontally on Internet websites or used scientific databases.

Aligning and Consolidating Acquired Knowledge
This phase overlapped with the previous one. The teacher conducted a *Socratic debate* to reach the desired goal on gaining, aligning and consolidating acquired knowledge on the Literary tourism topic.

One of the best proven ways to learn a new skill or to improve one's performance in a given activity is by practicing. The applied approach scheme supports Self-efficacy theory. It fosters the belief in students' abilities. Moreover, affective involvement dominates. People who have a high sense of efficacy are likely to view their state of affective arousal as an energizing facilitator of performance. Students get instant feedback can be one of the most important sources of building levels of self-efficacy. Receiving positive feedback while undertaking a complex task persuades students to believe that they have the skills and capabilities to succeed [29].

Definitions of keywords, e.g., heritage, literary tourism, and destination management were formulated and subsequently supported by the definitions of experts from the academic sphere. A set of about 20 discussed and recommended academic sources covering individual areas of heritage tourism was introduced.

The actual output was: visualization of key areas in a chart, the compilation of a set of keywords and definitions for the given issue, a set of scholarly papers together with a webography, and a gallery of students' contributions. All these parts were incorporated into the e-course as part of a collaborative effort.

Next Spreading
The newly created chapter was opened to part-time students, who can use it as a reservoir of study material. They can also contribute into webography, academic paper sources and tips related to this cultural heritage topic in the open communication section of the Discussion forum in Blackboard LMS.

5.2 Notes on Students' Contributions

In this sub-chapter, the findings of the students and the findings from academic research are put into context as they were discussed during the colloquium.

Together, a graph was created showing the connection of the main discussed categories, which is an introductory trailer of the newly created content, Fig. 2. The chart is accompanied by a set of relevant professional sources providing further clarification.

Key reoccurring words on Literary tourism in students' contributions could be divided into two groups: a) *emotions*: affection, entertainment, leisure, nostalgia, experience, and fun; b) *disciplines*: branding, marketing, and destination management.

Two recent scientific studies were presented to students as relevant additional literature sources supporting their findings [30, 31]. Anjo et al. [30] claim Literary tourism can only be perceived as a notion where perception, sensation, experience, and semiotics meet. The terms perceptions, sentiments, and emotions are present, but they still need to be anchored in the relevant fields, e.g., branding, marketing, and destination management. It's critical to identify the thoughts and emotions that are formed about a location and the experiences that are highlighted in literary works in order to establish branding strategies and initiatives that successfully target literary tourists [31]. Anjo et al. [30]

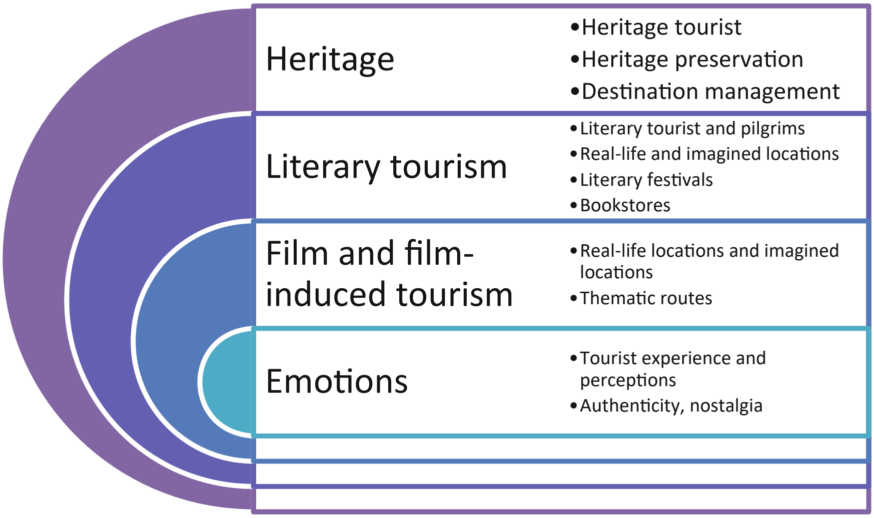

Fig. 2. Heritage tourism

speak of literary tourists and literary pilgrims and the necessity to explore the market and create solutions that correspond to tourists' expectations.

Another approach to the categorization of terms referring to literary tourism is based on visited *locations*. Literary tourism often distinguishes between *real-life locations* connected to writers' lives, e.g., their homes, gravesides, favourite places and *imagined locations* connected to literary works [1, 2]. [32] added two more forms of literary tourism—literary festivals and bookstores—to its most current market research study, in addition to those two already mentioned. Literary tourism provides numerous benefits to destinations when it is developed as a special interest tourism type. Çevik [33] speaks of the diversity of literary tourism, which can be classified based on certain characteristics; however, common forms may differ depending on the lifestyle and worldview perceived and accepted in individual countries or regions.

There is a noticeable increase in individual activities related to literary tourism, such as the growing number of literary routes, museums associated with authors and their works, and literary festivals. The development of literary tourism has been greatly assisted by film adaptations [5]. Film tourism is very closely intertwined with literary tourism [34]. In academic research, the film induced tourism is explored in the parallel spheres like literary tourism: motivation to travel [35], sustainability [36], or trends [37].

Commented Mosaic from Excerpts Taken from Students' Contributions

Three students worked out the task as a thesis on Literary tourism with an abstract, defined keywords, aims of the thesis, followed by a practical part with illustrative examples or comparisons and a set of references. They referred to sources from Google Scholar and the Web of Science databases in the theoretical part and to websites in the practical part, e.g., [1, 2, 4, 6, 38].

The abstract of the student (Diana K.) is given as an example: *This paper covers several aspects of literary tourism, including history, the problems of definition and* *categorization of the term and the most prominent research concerning this phenomenon. Besides, it touches a little bit upon its economic dimension and talks about and an exemplary literary tourism site, which is the Hardy Way.* Reasons why people visit literature locations they could see in the desire to learn and feel (Dagmar K.): *Tourists come to these places to feel the special atmosphere or they want to educate themselves more about each book story or about the lives of their authors.* Student Peter V. selected his choice of two authors on reason and affection: "*Literary Tourism is such a wide term. So, I decided to choose one author and place, which I consider to be the most important, namely - W. Shakespeare and then Sir Arthur Ignatius Conan Doyle, who is my favorite British author (not only for what he wrote but also for what he achieved in life), and describe them more detailed."* Although he respectfully acknowledges that Czech literature is not very well known, it does contain some well-known authors: "*Literary Tourism is also very popular in the Czech Republic. We probably don't have as many places in our country as in the UK, nor are they that famous, but for Czech people, that means a lot. Between the most famous Czech authors and places connected with literature belongs Karel Čapek, the author of the dystopian theatre play R.U.R. Karel Čapek invented the word ROBOT".*

Another student (Lenka H.) drew from an article on an internet website. This article contains all the attributes of literary tourism. She prepared a menu of 10 activities for the true literature lover: Auckland's literary walks—visiting real places connected with the author, Frank Sargeson's Cottage and Katherine Mansfield's birthplace, Home of the detective writer Dame Ngaio Marsh in Christchurch, Legends and storytelling Māori legends, meeting house, Walk the Haiku Pathway in Katikati, Bay of Plenty the largest collection of 'haiku stones' outside Japan that covered most of the literary tourism and film tourism characteristics as documented in the literature.

Matej S. worked out literary tourism topic from the perspective of visiting locations because tourists are interested in seeing how places have influenced writing while at the same time seeing how writing has created a place. *"To demonstrate this, William Shakespeare's birthplace, Stratford upon Avon, was chosen in the writing of this thesis"* (Matěj S.).

Lukas T. based his contribution on Cities of Literature and focused on Dunedin, a UNESCO Creative City of Literature.

Three students demonstrated the connection between literature and literary and film tourism and prepared thematic routes. J. K. Rowling and Harry Potter, Jane Austen, and the filmed locations of Pride & Prejudice, Sense and Sensibility, Irvine Welsh, and Trainspotting (http://www.scotlandthemovie.com/movies/train1.html).

Apart from contributions purely focused on authors and locations, three other perspectives were taken. A student (Tomas T.) looked at literary tourism from an economic point of view; literary tourism as the promotion of a country abroad. Investing in marketing will bring money to the budget. Shakespeare, Beatrix Potter, Charlotte Brontë and Roald Dahl, JK Rowling and Potter mania are proven attractions for inbound tourism.

The student who had the greatest success was a student who prepared a thematic tourist route based on the racing game Forza Horizon 4 he used to play. The racing game offers routes through the United Kingdom via real-life locations.

Last but not least was the environmental issue—the tourism impact on the environment. Eva M. stated: *"Tourism can't be practiced without environmental responsibility, as it may destroy what attracts visitors and what tourism depends on."*

6 Discussion and Conclusion

6.1 Applied Methods

The heuristic method seems easy when it is perceived as setting the task or formulation of the problem and letting students explore and work on their own. However, the opposite is true, as the tutor has to be resourceful in monitoring and commenting on students' progress and leading them to meaningful conclusions. Socratic debate might be demanding for a teacher who is not trained in this method. But the effort to learn how to thoughtfully formulate statements or questions when taking students through the topic pays off.

6.2 Education, Tourism and Augmented Reality

Researchers can see potential in augmented reality in education and give implications for practice in various fields of study, e.g., in learning English [39]. It is more important to educational researchers how technologies support and afford meaningful learning than how sophisticated they are Chang, H.-Y. et al. [40]. As for research in a cultural heritage field, there can be mentioned inspiring research in university setting conducted by researchers who designed an augmented reality based mobile touring system. The authors claim that results were encouraging in both students learning achievements and outdoor experiences [41].

The research sample in this study was formed by Generation Z students, and one would expect that they would grasp the issue utilizing some kind of virtual or augmented reality. However, there was only one contribution that used augmented reality technology.

6.3 Philosophical Output on Heritage Interpretation

The students' works produced a certain philosophical *output* that may be connected to the work of Ablett and Dyer [42], who provide the *hermeneutics paradigm* as an appropriate framework for ongoing development of interpretation in heritage tourist settings. Ablett and Dyer claim that cognitive psychologists are the main foundation for heritage interpretation; however, the cognitive model is rather constricting. They stand for a hermeneutics paradigm that is more appropriate. They support their assertion by analyzing the writings of Hans-Georg Gadamer and three more hermeneutic thinkers [42]. The social aspect—the role of language and history in relation to the particular place being discussed is of key importance. A holistic approach leads to an understanding of what shapes the heritage tourist experience. Because heritage interpretation is context-dependent and always occurs against a backdrop of preconceptions, it can cover a wide range of topics. The act of interpreting involves more than just cognitive effort. Instead, it affects our entire existence as it passes through a wide range of experiences in the natural and cultural worlds.

Heritage interpretation can be developed as a broadly inclusive, culturally contextual, dialogical, and critically reflexive art by using the hermeneutics framework. In legacy interpretation, an art in our narrower case, literary tourism promotes bridging the gaps between the sciences, humanities, and popular traditions.

6.4 Conclusion

This case study works with a limited number of participants attending the Guide Activity in English Language. The chosen way to work out the content of a newly introduced topic within the framework of the blended learning concept led to satisfactory results. Due to various approaches to the topic, a colourful mosaic was created reflecting the students' affection for culture and, more specifically, the literature and film tourism phenomenon, their knowledge in this field and ability and willingness to collaborate on the given task. The development of language skills was a significant benefit as well. Five students out of ten are on their way to the state exam in English language. Two students have found inspiration in this topic and selected it as their bachelor's thesis theme: Film-induced tourism and Literary walks.

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Using WPBL to Improve Engineering Undergraduates' Computational Thinking Performance in Flipped Classroom

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Abstract. With the continuous development of artificial intelligence, more and more attention has been paid to improving students' computational thinking capability in K-12 and higher education. Lots of research has shown that there is a close relationship between engineering education and computational thinking. Engineering thinking and computational thinking intertwine to some extent. The cultivation of engineering students' computational thinking ability could be integrated into engineering content learning. However, in current research, there is limited research on how to improve engineering students' computational thinking in an integrated way. Therefore, this study adopted Web Problem-Based Learning (WPBL) in a flipped engineering undergraduate course with the aim of enhancing students' computational thinking performance in an active way of engineering content learning. A total of 110 third-year undergraduates participated in this quasi-experimental study. The 55 students the experimental group who learned via WPBL in flipped classroom performed significantly better than the other 55 students in the control group who learned via Q and A, mini-lectures and data analysis as in-class learning activities in flipped classroom. Specifically, the experimental group scored significantly higher on the Abstraction and Algorithm Thinking dimensions.

Keywords: Computational Thinking · WPBL · Engineering

1 Introduction

Computational thinking is a term used to identify techniques that can help solve many of the types of challenges that appear when working with technology or dealing with complex or ambiguous problems [1]. It involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science [2]. The cultivation of computational thinking skills is crucial for the scientific and technological progress of the country as well as for the overall development of learners.

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Research in engineering education shows that there is a strong connection between computational thinking and engineering disciplines that can be developed synergically [2]. Moreover, computational thinking is often used to solve complex engineering problems [3]. Therefore, the integration of computational thinking training in engineering education could potentially help students to improve their computational thinking ability in engineering courses [4, 5]. However, most current research focused on improving students' computational thinking via programing learning activities [6]. Quite a few put forward ideas of developing students' computational thinking performance in the context of engineering education. Considering Web Problem-Based Learning (WPBL) is a widely used instructional model to facilitate students to learn subject content knowledge actively in problem solving in a technology enabled environment [7], this study adopted WPBL in a flipped undergraduate engineering course, in which the students learned the content knowledge prior to class and had active learning in class, with the aim of facilitating students' computational thinking in a way of solving authentic engineering problems. This study also aimed at investigating the effectiveness of WPBL on improving engineering students' computational thinking performance in an intelligent learning environment.

2 Literature Review

2.1 Computational Thinking (CT)

The specific definition of computational thinking was first proposed by Wing [2] and rapidly popularized in the field of education. Wing [2] believes that computational thinking involves the application of basic concepts of computer science to solve problems, design systems and understand human behaviors, including a series of thinking activities covering the breadth of computer science. There are also some other opinions about computational thinking, for example, Brennan [8] divided computational thinking into three key dimensions: computational thinking concepts, computational thinking practices and computational thinking perspectives. Shute, V. J., Sun, C., & Asbell-Clarke, J. [9] argued that computational thinking is more focused on a series of methods to solve problems using computers, whose core elements include abstraction, decomposition, algorithm, debugging, iteration and generalization.

After people realized the importance of computational thinking, researchers began to actively pay attention to the cultivation methods of students' computational thinking. Therefore, many innovative computational thinking cultivation strategies emerged, like the training strategy of using educational games [10], the training strategy of building programming environment [11] and the training strategy based on project-based learning [12].

The evaluation methods of computational thinking are rich and varied, including the evaluation based on scale [13, 14], the evaluation based on test questions [15, 16] and so on. There is no unified standard for the evaluation of computational thinking. Therefore, in practice, educators need to choose an appropriate way to evaluate students' computational thinking ability in a more comprehensive way according to specific situations.

2.2 Computational Thinking in Engineering Education

At present, the practice of integration of engineering education and computational thinking has been carried out through a variety of ways, such as STEM engineering teaching activities and informal engineering design activities [17, 18]. However, quite a few focused on the integration of computational thinking training into engineering learning. Yin designed maker engineering activities with the aim of improving students' capabilities on computational thinking and engineering learning [5]. Yue Yin developed seven maker activities, which included Electricity and Magnetism: Circuits, E-Textiles, Electromagnets, Simple Motors, Makey Makeys, Circuit Board Circuits, and Arduinos. The key learning outcomes of each activity were linked to the CT skills. These maker activities range from not integrating subject content knowledge to integrating more subject content knowledge, and from not involving computing at all to involving more and more computing. Yin's study showed that the cultivation of engineering students' computational thinking ability could be integrated into engineering content learning.

2.3 Web Problem-Based Learning (WPBL) and Flipped Classroom

WPBL is an instructional model that integrates network elements with Problem-Based Learning (PBL). Using the WPBL instructional model means that students can use rich online resources to learn, participate in the discussion of many problems and think deeply about the solutions. Compared with traditional teaching methods, WPBL has been proven to be a more effective instructional mode, especially in cultivating students' problem-solving skills, critical thinking, and collaboration skills [19–21].

Flipped classroom is an instructional model in which students make use of online resources to learn independently before class, interact with teachers and classmates in class, and finally solve problems [22–24]. Flipped classroom has been proven to be an effective instructional mode, especially in improving student performance and engagement [25–27]. WPBL is also frequently used as in-class learning activity in flipped classroom [28, 29].

2.4 The Present Study

This study aimed at investigating the effect of WPBL instructional model on students' computational thinking performance in engineering education. Specifically, this study adopted WPBL as the in-class learning activity in a flipped engineering course with the aim of cultivating the engineering undergraduates' computational thinking. This study examined the effect of using WPBL on improving engineering students' computational thinking performance.

3 Methodology

A quasi-experimental study was conducted to examine the effectiveness of using WPBL on enhancing engineering students' computational thinking performance in a flipped undergraduate engineering course.

3.1 Context

This study was carried out in a large research university in central China which ranked top on engineering education. The course "Application of Computer in Materials Science and Engineering" was selected as the context of this study. This course involved computer and engineering, which was an interdisciplinary course and required the integration of disciplinary knowledge in learning.

This course was taught in a flipped way that the instructor asked students to learn the subject content knowledge through viewing videos before class on Xiaoya, an intelligence learning platform (Fig. 1), and had student-centered active learning activities in class. The in-class activities the control group had included questions and answers (Q and A), mini-lectures and data analysis. While the experimental group had WPBL as the in-class activity, focused on creating an authentic problematic context for students to solve problems which might actually happen in engineering industry. The instructor, who had 11 years engineering education experience, collaborated with the researchers, who were faculty and graduate students in educational technology with rich experience in instructional design, on designing the WPBL activities based on the PBL activities designed by Wu Jing [30] as Fig. 2.

To achieve the purpose of improving students' computational thinking performance, the instructor provided problem situations for students in Xiaoya. Additionally, the students exchanged their viewpoints on problems in groups to promote the development of computational thinking. Moreover, through teamwork and teacher's guidance, students' computational thinking was further trained in the process of problem solving. Finally, the students also reflected and summarized their learning gains.

3.2 Participants

A total of 110 third-year undergraduates from in the School of Materials Science and Engineering voluntarily participated in this study. None of them had received any training in computational thinking or used any intelligent learning environment. Moreover, during the first two years of college, these students had limited experience in active learning. They were accustomed to having the lecture-based instruction. Among the 110 students, 55 were randomly selected as the experimental group ($n = 55$) and the other as the control group ($n = 55$).

3.3 Instrument

Bebras Contest As an international competition of computational thinking, the Bebras Contest addressing students from grade 1 to 12 and above was widely used to evaluate students' computational thinking. In this study, the Bebras Contest was used to evaluate students' computational thinking knowledge. The 10 questions with moderate difficulty and 10 difficult questions for students in grade 12 upper were selected for the study. The experts in engineering and computational thinking reviewed and revised the measurement and 32 engineering students participated in the pilot test. The measurement was furtherly revised after the pilot test. The finally revised 20 questions covered five

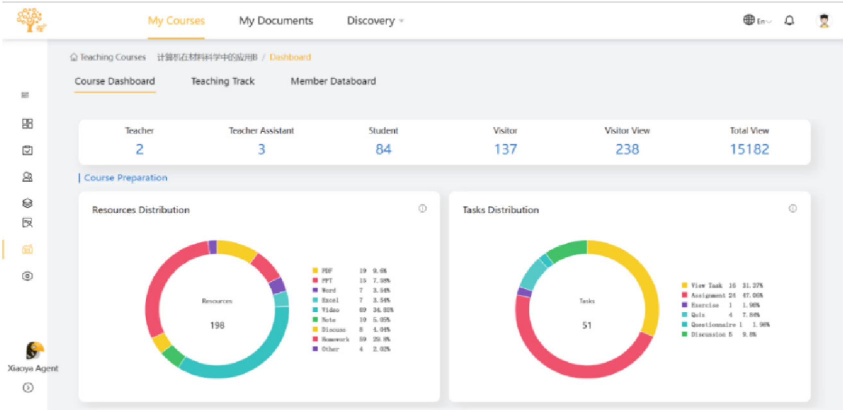

Fig. 1. Dashboard of Xiaoya

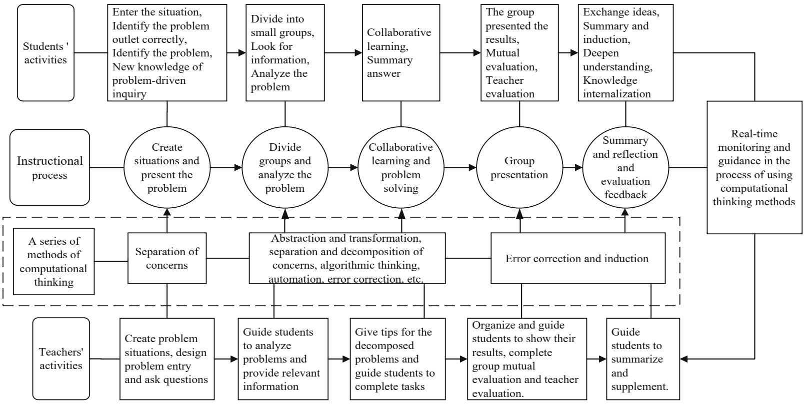

Fig. 2. WPBL instructional model for students' computational thinking training

dimensions of computational thinking which were Decomposition, Abstraction, Algorithm, Evaluation, and Generalization. There were 4 questions in each dimension, with a total score of 210, and the contest lasted 60 minutes.

Computational Thinking Scale (CTS) In this study, the Computational Thinking Scale designed by Korkmaz, Ö. et al. [13] was used to assess the level of students' computational thinking skills. The scale included 29 questions on 5 dimensions: 8 questions on Creativity, 6 questions on Algorithmic thinking, 5 questions on Critical thinking, 6 questions on Problem solving, and 4 questions on Cooperativity. The 5-point Likert scale was adopted, with Cronbach's alpha value of 0.852, indicating good internal consistency of the scale.

Computational Thinking Perspective Scale The Computational Thinking Perspective Scale developed by Kong, S. C., & Wang, Y. Q. [31] was used to evaluate students' perception ability and attitude towards the surrounding things through programming.

The scale was divided into 3 indicators: Ability to express, Ability to connect and Ability to question. It was a 5-point Likert scale, with 5 questions for each indicator and a total of 15 questions. In this study, some keywords in the index items in the original scale were modified. For example, "programming" was changed to "data analysis". Cronbach's alpha value of the scale was 0.944, indicating that the scale had good reliability.

4 Data Collection and Analysis

Before the experiment, the research team provided the Bebras Contest, the Computational Thinking Scale and the Computational Thinking Perspective Scale to all participants. The experimental group learned the flipped course with WPBL as the in-class activity. The control group had the flipped course with Q and A, mini-lectures and data analysis as the in-class activities. In order to ensure that the instructional style of the instructor did not affect the experiment, all students in the experimental group and the control group were taught by the same instructor. Besides, all students learned the same learning content. Students in the experimental group were asked to participate in 4 projects aimed to promote the students' computational thinking performance, namely Steel ladle, Cement heat release, Material engineering experimental design and Integrated task. Each project lasted 1.5 weeks and the whole instructional process lasted about 6 weeks. Then, all the students passed the post-test.

In order to explore the improvement effect of computational thinking of engineering undergraduates under the teaching model of WPBL, Analysis of Covariance (ANCOVA) was used in this study. In the specific analysis, the group was used as the independent variable of the analysis, the pre-test was used as the covariate, and the post-test was used as the dependent variable. At the same time, in order to more accurately explore the differences in computational thinking ability between the experimental group and the control group after intervention, as well as the differences in individual students' computational thinking ability before and after learning, ANCOVA was carried out for each dimension of the 3 tests.

5 Findings

A hypothesis test was conducted on the collected data before the formal covariance analysis. The data obtained were independent of each other, and there was no interaction in each group, which passed Levene's homogeneity test ($p > 0.05$).

As shown in Table 1, covariance analysis was adopted for students' Bebras Tasks scores, and it was found that the overall scores of students in the experimental group were higher than those in the control group ($F = 8.772$, $p = .004 < .05$). After further analysis of the five dimensions measured by Bebras Tasks, it was found that the scores of students in the experimental group in the Abstraction and Algorithm dimensions were significantly higher than those in the control group (Abstraction, $F = 5.720$, $p = .019 < .05$; Algorithm, $F = 10.300$, $p = .002 < .05$). In terms of Decomposition, Evaluation and Generalization, there was no significant difference between the experimental group and the control group.

Table 1. Results of covariance analysis of Bebras Tasks

Feature	Source	Type III Sum of Squares	df	Mean Square	F	Sig
Decomposition	Group	316.792	1	316.792	2.704	.103
	Pre-test	2498.617	1	2498.617	21.326	.000*
Abstraction	Group	847.121	1	847.121	5.720	.019*
	Pre-test	520.044	1	520.044	3.511	.064
Algorithm	Group	1169.576	1	1169.576	10.300	.002*
	Pre-test	1107.766	1	1107.766	9.756	.002*
Evaluation	Group	483.033	1	483.033	3.665	.058
	Pre-test	1951.262	1	1951.262	14.804	.000*
Generalization	Group	33.874	1	33.874	.196	.659
	Pre-test	2333.500	1	2333.500	13.500	.000*
Total	Group	14803.772	1	14803.772	8.772	.004*
	Pre-test	58990.857	1	58990.857	34.953	.000*

* $p < .05$

Table 2. Results of covariance analysis of CTS

Feature	Source	Type III Sum of Squares	df	Mean Square	F	Sig
Creativity	Group	211.702	1	211.702	12.587	.000*
	Pre-test	298.118	1	298.118	17.725	.000*
Algorithmic thinking	Group	248.444	1	248.444	9.793	.002*
	Pre-test	454.113	1	454.113	17.900	.000*
Cooperativity	Group	48.491	1	48.491	3.878	.052
	Pre-test	172.717	1	172.717	13.812	.000*
Critical thinking	Group	16.637	1	16.637	1.168	.282
	Pre-test	79.293	1	79.293	5.569	.020*
Problem solving	Group	48.411	1	48.411	1.537	.218
	Pre-test	281.044	1	281.044	8.926	.003*
Total	Group	1321.383	1	1321.383	10.068	.002*
	Pre-test	3503.585	1	3503.585	26.694	.000*

* $p < .05$

As shown in Table 2, the covariance analysis of students' CTS scores showed that the overall score of the experimental group was higher than that of the control group ($F = 10.068$, $p = .002 < .05$). Further analysis of the five sub-dimensions measured by CTS showed that students in the experimental group scored significantly higher in Creativity and Algorithmic thinking than students in the control group (Creativity, $F = 12.587$, $p = .000 < .05$; Algorithmic thinking, $F = 9.793$, $p = .002 < .05$). In terms of Cooperativity, Critical thinking and Problem solving, there was no significant difference between the experimental group and the control group.

Table 3. Results of covariance analysis of computational thinking perspective

Feature	Source	Type III Sum of Squares	df	Mean Square	F	Sig
Ability to express	Group	111.044	1	111.044	6.074	.015*
	Pre-test	177.214	1	177.214	9.693	.002*
Ability to connect	Group	55.384	1	55.384	4.017	.048*
	Pre-test	35.551	1	35.551	2.578	.111
Ability to question	Group	63.349	1	63.349	4.869	.029*
	Pre-test	100.812	1	100.812	7.748	.006*
Total	Group	656.101	1	656.101	5.526	.021*
	Pre-test	780.603	1	780.603	6.574	.012*

* $p < .05$

As shown in Table 3, covariance analysis was used to analyze the score of the scale of computational thinking perspective, and it was found that the overall score of the experimental group was higher than that of the control group ($F = 5.526$, $p = .021 < .05$). Further analysis of the three sub-dimensions measured by the computational thinking perspective questionnaire showed that the scores of the experimental group in expressive ability, connection ability and questioning ability were significantly higher than those of the control group (Ability to express, $F = 6.074$, $p = .015 < .05$; Ability to connect, $F = 4.017$, $p = .048 < .05$; Ability to question, $F = 4.869$, $p = .029 < .05$).

6 Discussions

This quasi-experimental study applied WPBL in a flipped undergraduate engineering course with the aim of integrating the computational thinking training and engineering content learning. The results showed that WPBL significantly improved engineering students' computational thinking knowledge performance, especially on the Abstraction and Algorithm Thinking dimensions. Although not significantly performed better on Decomposition, Evaluation and Generalization, the experimental group who learned via WPBL scored higher than the control group. In terms of computational thinking skills, the experimental group scored significantly better on Creativity and Algorithmic thinking, but not on Cooperativity, Critical thinking and Problem solving. In terms of computational thinking attitude, there were significant differences between the experimental group and the control group in expression ability, connection ability and questioning ability.

A key finding of this study was that the WPBL significantly enhanced students' overall computational thinking knowledge performance. Specifically, WPBL had a significantly positive impact on the Abstraction and Algorithm dimensions. This finding extended the previous research with put forward ideas that computational thinking and engineering problem solving were tightly related and suggested cultivating students' computational thinking in engineering learning [32]. Engineering education itself attaches great importance to practical operation and seeking the scientific principles behind the main factors [33]. WPBL in this study paid great importance on facilitating students to solve authentic problems in engineering industry with the practical actions and scientific principles. That could be explained why the experimental group performed significantly better on Abstraction and Algorithm Thinking. The development of inter discipline curriculum was not paid great importance on in current engineering education programs. Therefore, that was why the students in this study did not perform well in Decomposition, Evaluation and Generalization.

Another key finding of this study was that WPBL significantly improved students' overall performance of computational thinking skills. Specifically, WPBL had a significant positive effect on the dimensions of Creativity and Algorithmic Thinking. This finding was similar to previous research suggesting that the use of problem-based learning in engineering education could effectively promote students' creative and algorithmic thinking [34]. However, the previous study showed that the improvement of skills such as cooperation in PBL was difficult to be reflected in a course and students' learning performance was also affected by previous cooperation experience [35]. In this study, students were exposed to WPBL for the first time and they had very limited cooperation experience, this could explain why in this study students did not perform very well, such as Decomposition, Evaluation and Generalization. WPBL had a good effect on solving ill-structured problems [35], and critical thinking [36], but in this study, dues to the lack of experience, students' performance was not good.

In the aspect of computational thinking attitude, the results of CT perspective evaluation showed that students' expression, connection and questioning abilities have been significantly improved, which indicated that after students learned under the WPBL to improve engineering undergraduates' computational thinking performance in flipped classroom, students were more inclined to use computational thinking to express their views and more actively used the way of computational thinking to connect with real life. Moreover, Xiaoya, the intelligent learning platform, provided students an opportunity and tools to express, interact, and to integrate the learning resources. The intelligent learning platform also gave some timely feedback during the learning process, so they could reflect on their learning process in a timely way.

7 Implications

Based on the findings of this study, we proposed the following implications for researchers to further improve the development of computational thinking. First, the training of computational thinking could integrate into engineering knowledge learning. Second, the intelligence learning environment provided guarantees for the implementation of the integration, such as rich resources, convenient collaboration tools and cognitive tools, as well as intelligent monitoring of the learning process and real-time feedback.

8 Limitations and Future Research

There are two limitations of this study. First, the sample size was small. The participants were from the same university, so the experimental data might not be representative enough. Second, statistical analysis was used to explore whether students improve in several key elements after adding computational thinking. A more permanent inspection is required to make a more in-depth investigation on the development of computational thinking. Based on these shortcomings, future research intends to extend the size of the sample to obtain the patterns of the students with more diverse backgrounds. In addition, other data collection and analytical techniques, such as videos of their lessons while using computational thinking, could supplement to provide more support for the findings, and the time of this experiment can be extended appropriately.

9 Conclusion

In this study, Web problem-based learning (WPBL) was adopted in a flipped engineering undergraduate course, aiming at improving students' computational thinking ability through active learning of engineering content. Students in the experimental group who learned through WPBL performed significantly better than other students in the control group who learned through lecture-based method, which suggests that there is a close relationship between engineering education and computational thinking, and they influence each other to a certain extent. Training engineering students' computational thinking performance can be integrated with the study of engineering content.

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Cultivating Students' Creative Thinking Using Visual Narrative in an Agile Blended Learning Environment

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Abstract. The purpose of this study is to examine the effectiveness of a course design to foster students' creative thinking using visual narrative. This research examined a course called "Thinking about the Past, Present and Future of a Locality" at K University in Japan as a case study. Through the analysis of data from students' reflection reports and artifacts, the authors identified that students improved their imagination, narrative creation skill and expressive skill through Visual Narrative (VN) during the course, "Thinking about the Past, Present and Future of the Locality". Furthermore, students encountered five areas of difficulty in creating the VN diagrams. These were (1) selecting and choosing information when determining a theme or content to express to the audience in the VN diagrams, (2) pictorially expressing what they wanted to convey, (3) imaging a future world that does not exist, (4) structuring the VN diagrams with a narrative, and (5) communicating to the audience in an easy-to-understand manner. Diffusive thinking activities for inquiring new ideas, combination of ideas of other students, accumulation of experience in production and presentation, and collaboration in groups helped students overcome these difficulties.

Keywords: Creative thinking · Visual narrative · Instructional design · Social Constructivism · Blended learning environment · Projected-based learning

1 Introduction

To nurture more of the next generation of reformers in the future, the development of higher-order thinking, especially creative thinking, became a new and challenging educational goal in universities in Japan [1, 2]. Developing students' creative thinking differs depending on what is being concretely aimed for, the subject matter, and the specific social context. Thus, the instructional design and the effectiveness using new strategies based on the features of curriculum are required.

In Japan, universities have large, lecture-type classes where the instructor teaches more than 100 students in a lecture hall [3]. In such lecture-type classes, there is a problem of little interaction between the teacher and students, and teachers are limited in supporting students' critical thinking and creativity. To remedy this situation, project-based learning for developing higher-order thinking skills with small groups of university

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students has been promoted in some universities as an advanced approach. This study took a project-based learning course which focused on improving students' creative thinking using visual narrative strategy in Japan as a case study.

2 Related Work Review

2.1 Creativity in University Students and Two Aspects of Creative Thinking

According to Bloom's Taxonomy, the educational goals of schools can be categorized into six stages: memory, understanding, application, analysis, evaluation, and creativity [4, 5]. Creativity is the highest and most difficult level in the taxonomy. Thus, how to cultivate students' creative thinking becomes a major challenge in higher education.

Definitions of creative thinking vary [6], but according to Hokanson, creative thinking is the thinking ability to generate and express new and applicable ideas [7]. There are two aspects in creative thinking, generation, and expression.

To generate ideas, thinking about things in the process of diffusion is conducted effectively [8–10]. When students generate ideas, they form ideas through thought operations such as imitation, transformation, combination, conversion, and original creation of ideas [11].

To express ideas, there are a variety of ways, such as presentation using words, paint, music, metal, or clay and so on. Since each expression has features, choosing a suitable expressive method needs to be considered based on the instructional goals and concrete situation [9].

2.2 Learning Environment for Fostering Students' Creative Thinking

To foster students' creative thinking, constructing an appropriate learning environment is required. Firstly, a space that allows students to feel safe and free is crucial [12–14]. Secondly, it is also desirable for students to actively explore on their own while accessing a variety of resources [9, 12]. These resources included materials they use to think and work. Since the internet supplies large amount of information that make references easily available and using mobile phones are convenient, information on the internet through mobile learning is also an effective resource. Thirdly, physical activity allows for more diffused thinking [15–18]. Finally, human resources (students in the course) and interactions that occurred among students are good resources to trigger students thinking more creatively based on social constructivism [19].

In summary, it is crucial to create a blended learning environment that utilizes diverse resources to help students think freely.

2.3 Cultivating Creative Thinking Using Visual Narratives

How to express students' ideas? Ways that express ideas through drawing, artwork, and other artifact creation were identified as effective [7]. Visually presented ideas have the merit of conveying messages to the onlooker intuitively, whereby the looker can understand and interpret it by themselves without communication with the actors.

Another way that combines visual and storytelling, called Visual Narrative can be beneficial by triggering communication between the actors and the onlooker. Visual narrative (VN) is "a visual that essentially and explicitly narrates a story" [20]. VN has characteristic features such as presence of visual medium, a story, actors and visuals constructed with the idea of communicating a story to the onlooker [20]. Using VN, students tell stories concretely and communicate with other students after creating the visual with imagination. Images are most powerful when they are evoked by a story, rather than provided in isolation [18–22]. Therefore, the authors considered VN as having the potential to make the students' ideas be more concrete and to bring these ideas closer to a direction that can be applied to the real world. Thus, a design to foster students' creative thinking by using VN is needed.

However, while students participated in activities using VN, students were required to apply new and applicable ideas, express their ideas to visuals based on imagination, and design and storytelling skills. These skills were also indispensable [9, 22].

3 Research Objective

Based on the above, this study will identify the effectiveness of creative thinking lesson design using VN. The specific research questions driving this study are:

1) What aspects of creative thinking were enhanced through using VN?
2) What are the difficulties in representing students' ideas to VN diagrams and how did they overcome difficulties?

Through clarifying the lesson design using mobile phone in the blended learning environment, the authors tried to propose some suggestions to design more effective blended learning environments to support students to think more creatively.

4 Design and Research Method

4.1 A Design to Cultivate Creative Thinking Based on the First Principle of Instructional Design and Social Constructivism

This research examined an initial educational course called "Thinking about the Past, Present and Future of the Locality" which was a project-based learning course, at K University in Japan, to develop creative thinking for first year students. The goals of this course were (1) researching the past and present of the agreed upon local issues, finding and expressing the situation and problems; and (2) imagining the future of the locality and creating new ideas and solutions to local issues. The following are three features in the design.

Firstly, based on Mirrill's first principle of instructional design, guide students to think about the past, present, future in local issues. Mirrill's first principle of instructional design is characterized as supporting students learn autonomously to integrate their existing knowledge and experience to form new ideas and problem-solving [23]. Since students have rich life experiences about local issues around them, triggering their existing knowledge and experiences is necessary to direct them when solving local issues. (1)

Problem: Explore current and past issues in the local area. (2) Activation: Activate the knowledge that each student has and think about why these issues are so. (3) Demonstration: Sharing and explaining the issues and its causes within the group. (4) Application: Imaging the future issues and exploring how to solve the issues. (5) Integration: Creating VN diagrams to express the past, present, and future in local issues.

Secondly, based on social constructivism [19], different interactive activities were designed. (1) Treating cell phones as a resource to access information. Although college students have cell phones, as a rule, they are not allowed to use them in class at most universities in Japan. This course allowed students to freely research relevant information with their cell phones in class. (2) Students work together in a group. At the stage of demonstration, application and integration, students kept thinking, creating VN diagrams and doing presentations together.

Thirdly, students thought about and expressed local issues using VN. (1) The lecture briefly told the students about thinking strategy, such as storming (diffusive thinking), and summarizing information in categories (convergent thinking). (2) Students created VN diagrams based on their ideas and imagination (A VN diagram was expressed as a poster, A1 size). (3) Students did storytelling based on the VN diagrams and communicated with the other students. At the end of each class, students reflected on their experiences and completed a self-rubric evaluation form (Fig. 1).

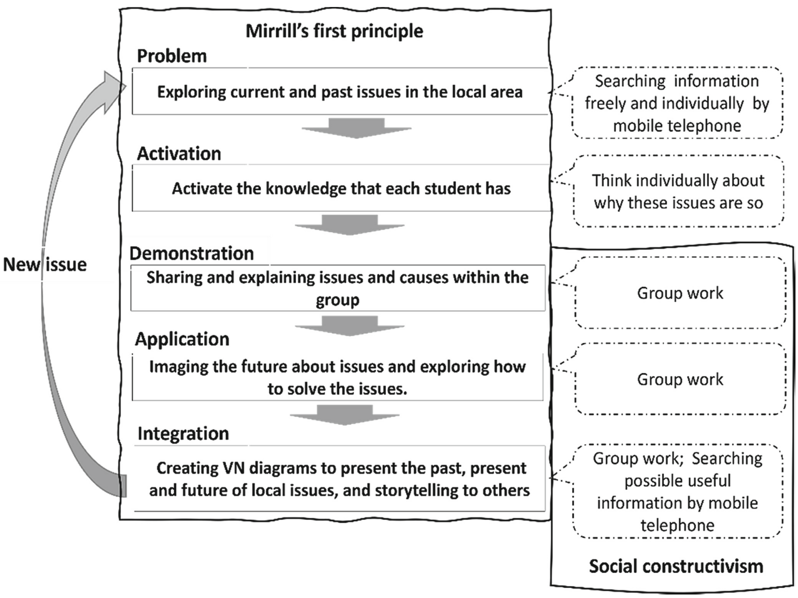

Fig. 1. Course design based on Mirrill's first principle of instructional design and social constructivism

This course included 15 lessons that were divided into seven components in a term. Each lesson was 90 min. Twenty-three undergraduates participated in this course during the spring term in 2022.

The components consisted of (1) Icebreaking and drawing life diagram to introduce students' past, present and future, in the first lesson, (2) Methods for identifying local issues and strategy for solving them, (3) Selecting a topic of interest from multiple themes and creating a past, present, and future poster with VN, (4) Creating a past, present, and future poster with visual narratives on the theme of home, (5) Creating past, present, and future VN diagrams on the theme topic, (6) Creating past, present, and future VN diagrams on any topic, and (7) Writing reflection reports.

4.2 Data Collection and Analysis

In this study, the authors administered a qualitative method to collect and analyze the data. To clarify how the students improved their creative thinking, twenty reflection reports and twenty VN diagrams that students drew at the last lesson were analyzed.

To analyze the reflection reports, the authors used the following procedure: (1) Divide the data based on meaning and attach focused codes; (2) Create and label axial codes based on the focused codes; and (3) Identify theoretical codes [24]. From the analysis, eleven axial codes were created. The authors indicated the theoretical codes in bold type and cited the reflection report data with italic type. VN diagrams were referenced as supplemental material.

5 Result and Discussion

5.1 Three Aspects of Creative Thinking Fostered in the Course

From the data, the authors identified that students improved their imagination, narrative creation skill and expressive skill through VN strategy during "Thinking about the Past, Present and Future of the Locality".

Imagination. In the course, students were required to finish the VN diagrams about the past, present, and future of the locality. Students reported that their imagination improved since they had to express issues and problem-solving in the future. For example, S21 said that creating a visual narrative diagram in the future required imaging a world that did not actually exist. She *began to "imagine her own ideal future after participating the activities in the course"* (cited from the reported by S21). As Saaty indicated, imagination through imagery plays an important role in the way people think and may prove useful in developing creativity [9]. The authors considered the creation activity of VN diagrams was helpful for students to think more creatively.

Narrative Creation Skill. Students created three patterns of narratives in VN diagrams (Figs. 2, 3 and 4). These patterns could be divided into: (1) Pattern 1 (Ten students): The past was good, but recently problems have emerged. Propose how to solve those problems in the future. (2) Pattern 2 (six students): There have been problems in the past, and recently those problems have become even worse. Propose how to solve that problem in the future. (3) Pattern 3 (four students): There were problems in the past, and some of them have been solved. However, some problems still exist. Suggest how to solve the remaining problems in the future.

Based on Yamada, narrative is the ability to link two events and has the advantage of making these events become impressive [20–22]. Half of students used Pattern 1. Three narrative patterns showed the diversity when students linked events. These discoveries may help the lecturer to guide students to link events using VN.

Expressive Skill Through Visual. Students tried to express their intentions to others by visuals. Since many students have not experienced drawing, they had a hard time adjusting to expressing messages in pictures or diagrams. However, many students began to express their ideas through visuals well. For example, S7 described problem-solving about ocean pollution in the future without words, only visuals. She drew a bird and fish laughing in the sky and blue sea to show the improvement of ocean pollution.

The observer can easily understand the changes in environment and improvement immediately. Expressive skill through visual is helpful to foster students' intuition of creativity [9].

Title: *Ocean Pollution*

Poster Description: *In recent years, many oceans have been polluted by human waste and wastewater….Marine pollution began in the 1920s and 1930s, when the chemical industry began to develop, and the pollution intensified during the period of rapid economic growth….To prevent marine pollution, it is necessary not only to take national measures, but also to do what everyone can do. The solutions are: (1) reducing the amount of leftover food and grease, (2) plastic should be sorted for recycling, and (3) companies can change the materials used for plastic products to paper and develop environmentally friendly shampoos and detergents.*

Fig. 2. A VN diagram of Pattern 1 (S7)

Title: *Unexpected? Secrets of Roadside Stations*
Description of Poster: *The background of the establishment of roadside stations is due to the increase in long-distance driving and the increase in the number of women and elderly drivers due to the spread of automobiles. 2022 has seen successful examples of roadside stations that have disaster prevention centers and use products from roadside stations to promote the region as a thank you for tax payments. On the other hand, there are also examples of failed roadside station management. The roadside station of the future that I envision is as follows. For example, there could be amusement parks or athletic facilities targeting families, or drive-in theaters where people can watch movies without leaving their cars in a vast parking lot, taking advantage of the difficulty of making a long trip due to the COVID-19 Pandemic.*

Fig. 3. VN diagram of Pattern 2 (S22)

Title: *Increasing Shuttered Towns and Future Shopping Street*s
Poster description: *In the Showa era, towns were bustling with people of all ages. Many people, young and old, visited fishmongers, grocers, boutiques, candy stores, and other stores.*

Due to the increasing number of shuttered towns, aging stores, aging customers, and the entry of major chains, traditional stores have been closing in droves now. In the future, we can establish shared offices, shared kitchens, and community spaces to eliminate the problem of vacant storefronts and create spaces where people can further interact with each other.

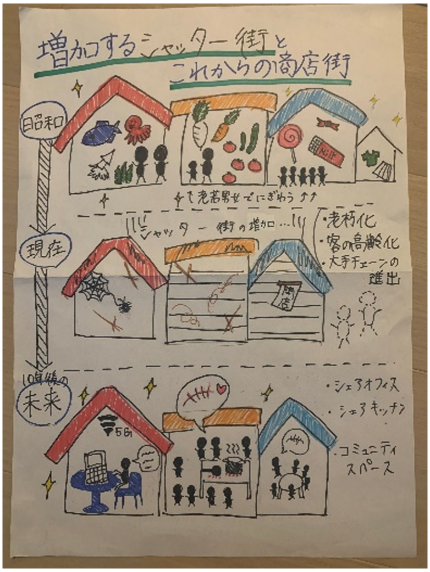

Fig. 4. VN diagram of Pattern 3 (S21)

5.2 Difficulties-Overcoming in Five Areas When Creating VN Diagrams

Based on the analysis of data, the students encountered five areas of difficulty in creating the VN diagrams. They were (1) **selecting and choosing information** when determining a theme or content to express to the audience in the VN diagrams. (2) **pictorially expressing** what they wanted to convey, (3) **imaging a future world** that does not exist, (4) **structuring the VN diagrams with a narrative**, and (5) **communicating to the audience in an easy-to-understand manner.**

These difficulties were overcome by the interaction of the following four factors. (1) **Diffusive thinking activities for purchasing new ideas**. With limited time in the course, students needed to sort out and express what they wanted to convey. They thought diffusively through storming, referring to the internet for information and imagining the future freely, which enabled them to generate new ideas. (2) **Accumulation of experience in production and presentation**. Students noticed areas for improvement on their VN diagrams in the process of production or after their presentations. Thus, they continued to explore new ideas and better expression due to positive feedback and increased motivation. (3) **Combination of ideas**. By referring to other classmates' presentations, students were able to design their own VN diagrams and incorporate other people's ideas into their own, forming ideas with originality. (4) **Collaboration in groups**. Students worked with the same group members all semester. In group work, members played different roles. To create better VN diagrams, the members checked each other's assignments and supported each other and finally formed relationship of mutual trust in collaboration.

In creating the VN diagrams, I thought it was important to clarify what I wanted to convey and to be aware of how I should draw it to convey what I intended, but this was *difficult. I overcame this difficulty as follows: I asked members in group to look at my drawings and ask them how they felt about them. If I could not come up with a new and nice idea, I searched the internet for reference photos and illustrations to find a way to express myself. (Reflection reports of S7)*

The difficulty in creating a visual narrative diagram is representing the future X years from now. Unlike the past and the present, it was necessary to express in pictures what does not actually exist, so I was able to overcome this difficulty by imagining what my ideal future would look like, listening to the group members' ideal futures, and incorporating and combining them into the visual narrative diagram. In addition, since it was difficult to express the ideas in pictures without using words as much as possible, I used my imagination to draw pictures that were easy to understand and devised ways to express them. (Reflection reports of S21)

This class was the first time for me to work on a visual narrative diagram. I struggled a lot to convey the details to the observer by only using illustrations. I had to draw pictures that were memorable at a glance according to the theme. It was also needed that somebody could easily understand the flow of the past, present, and future. (Report of S22)

From the difficulties students stated, creation of VN diagrams was a work filled with challenges. As S22 stated, this was the first time she worked on VN diagrams and wondered how to express ideas by pictures "that were memorable at a glance according to the theme." She "searched the internet for reference photos and illustrations to find a way" to express images that she did not have. This shows that using her mobile phone to access information freely at some work stages was effective.

S7 reported that she "asked members in group to look at her drawings and asked them how they felt about them" to check whether the audience understood her drawing or not. S21 succeeded in facing difficulty in imagining the future by listening to group members' ideal futures and incorporating and combining them into her VN diagrams. Most students had little educational experiences of participating in activities for improving drawing based on the intuition and imagination, since they are not art students. Since intuition and imagination are crucial for all university students [7, 11, 25], The authors considered that using VN strategy was effective for improving intuition and imagination in students.

A new discovery, in the analysis of the data, was that students' combined ideas by referring to other groups' VN diagrams to form new ideas. The design was aimed at students thinking diffusively by referring to their past knowledge and experiences and expressing their ideas on VN diagrams through collaboration in groups. Many students reported that their inspiration also came from other group's VN diagrams and presentations. This showed students easily analyze and combine ideas with each other when they received new and strong visual stimulations.

6 Conclusions, Practical and Theoretical Implications and Future Perspective

This study identified three aspects of creative thinking that were enhanced through using VN strategy in a designed, blended learning environment based on Mirrill's first principle of instructional design and social constructivism. Since the strategy of VN highlights pictorially expressing ideas based on intuition, imagination and diffusive thinking, students encountered difficulties when created VN diagrams. Four factors, diffusive thinking activities for creating new ideas, combination of ideas of other students, accumulation of experience in production and presentation, helped students overcome their difficulties in the course.

This study has significant practical implications for using VN strategy to foster students' creative thinking. As a case study, the analysis showed great potential to foster students' imagination, intuition and diffusive thinking of creativity [9, 25]. This course design can be introduced into other universities that are conducting educational reform and developing ways to cultivate students' creativity.

Two theoretical implications need to be stated here. The first theoretical contribution is the design linked to Mirrill's first principle of instructional design and social constructivism [19, 23]. The second theoretical contribution is developing new teaching strategy using VN strategy to foster students' creative thinking.

It should be noted that this study examined students' creative thinking using VN strategy in a blended learning environment based on the analysis of students' reflection reports. The features of creativity in VN diagrams that students created need further analysis through examination of their VN diagrams [22]. To help students to express pictorially and with images, a nonexistent future, AI-generated images can be utilized in the future when using VN. To this end, future studies are suggested to examine how AI-generated images help students' pictorially expressing and imagine a future world.

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Key Complexities Inhibiting Design and Implementation of Adaptive-Inclusive Learning Environments

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Abstract. We studied factors shaping polarization within the population of the United States in order to examine the complexity of building and evaluating adaptive-inclusive learning environments. Our approach evolved from prior research and used "Thought Experiments" and literature reviews of educational as well as cognitive, developmental, psychosocial, and social psychology research. The goal has been to understand critical barriers to inclusivity and adaptivity within blended and totally online learning environments. We analyzed the political and sociological diversity of the United States as a conceptual framework for delineating critical elements of AI designs that could result in truly adaptive and inclusive teaching-learning environments across grade levels from Kindergarten to graduate work but also essential to the emerging needs for life-long learning and adaptation to shifts in technology use by the American workforce. As the research that led to this paper unfolded, we studied promising AI applications such as ChatGBT, focusing on how elements of such applications could become part of an adaptive-inclusive learning environment as well as what adaptations would be needed for them to have inclusive and adaptive capacities that serve diverse learners.

Keywords: Adaptive Education · Inclusive Education · American Education · Adaptive-Inclusive AI · ChatGPT

1 Introduction

Many research teams have been designing and evaluating adaptive learning environments that are inclusive of a broad base of learners and, in an ideal design, have adaptivity coupled to inclusivity allowing any learner to develop knowledge and skills related to complex problems [1–5]. The SARS-CoV-2 virus and its multiple subvariants created a deadly and widespread viral pandemic of Covid-19 disease during 2020–2023. We researched healthcare-related portals for patients and providers and this pandemic provided opportunities for broadly-based case studies of important factors shaping adaptivity and inclusivity of learning environments designed for face-to-face, blended, and totally online delivery [6–12].

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The history of the United States has been fraught with antagonism among political as well as ethnocultural groups. However, patterns of disparate ideologies and behaviors became even more pronounced during 2016–2023 with increased political and sociological conflicts then emerging as Covid-19 disease spread across the country. We had anticipated this possibility based on studies of healthcare disparities within the American population since 1996 [1], and began to focus on how to address insidious biases and development of misconceptions among learners of all ages.

Our research explored the implications of how polarization among different groups of Americans impacted sensible design of adaptive-inclusive learning environments. For example, *Hidden Tribes: A study of America's Polarized Landscape*, presented data along what the authors described as five dimensions of individuals' "core beliefs" described as follows: (1) tribalism and group identification; (2) fear and perception of threat; (3) parenting styles and authoritarian disposition; (4) moral foundations; and (5) personal agency and responsibility (a complete copy of the report and its methods can be accessed at: https://hiddentribes.us/media/qfpekz4g/hidden_tribes_report.pdf).

Hidden Tribes led us to reconsider how we build adaptive AI engines in order to reach any member of any social group, especially when different groups have distinct suites of beliefs, worldviews, and attachment to or association with their respective groups. For example, the authors of *Hidden Tribes* described how and why an individual is shaped by and shapes other members' of their respective group's understanding of and perspectives about education, health, social, and political issues. The authors also noted that these group alignments predict perspectives about social and political issues "with greater accuracy than demographic factors like race, gender, or income" (see p. 5 of the Executive Summary). Of course, if we want to build a truly adaptive-inclusive teaching-learning environment, we have to understand how AI engines could be built to facilitate the adaptivity and inclusivity necessary for different learners, such as any learner from any of the seven "Tribes" delineated by the *Hidden Tribes* study: Progressive Activists, Traditional Liberals, Passive Liberals, Politically Disengaged, Moderates, Traditional Conservatives, and Devoted Conservatives.

Even if accommodation of learners from each "Tribe" could be accomplished, we still have additional complications in design of sensible learning environments, such as what theory of cognition and learning might we choose? We argued in earlier work [1] that we need to build learning environments that have layers of dashboard functionality allowing an instructor or administrator to choose a particular theory of cognition and learning as well as a theory of behavioral change. Even if we could choose an evidence-based theoretical framework, how would we create additional layering and interactivity of AI engines that allow assessment of learners' cognitive stage of development as well as their psychosocial stage of development?

For over 20 years, we built adaptive-inclusive learning environments designed for diverse learners, and here we use "diverse" in the sense of learners being unique combinations of a cognitive stage of development as well as their psychosocial stage of development [1]. We created teaching-learning activities that were sensitive to the language proficiency, culture, ethnicity, and individual preferences of end users. However, these efforts evolved prior to the time we understood the problems of how and why polarizations in a learner's framework could add additional layers of complexity to accommodate differences among individual learners in their willingness to engage in learning. We expanded our studies to understand how sociopolitical and socioreligious profiles shape willingness to engage in learning, especially in healthcare areas.

In this paper, we extend earlier studies of adaptive-inclusive teaching-learning environments for nursing education and analyze how to accommodate the types of “diversity” among individuals’ psychosocial and cognitive frameworks. More specifically, we reevaluated the learning environments we had developed then modeled how they would have to be modified to serve diverse age groups within the United States. Our approach focuses on how to help learners understand the complexity of SARS-CoV-2 mutations into different subvariants and why vaccination against the emerging variants is at least a partial strategic pathway to mitigate spread of Covid-19 disease. We begin by reviewing a psychological approach to designing adaptive-inclusive learning environments and then explore the results of three Thought Experiments that examine factors we identified as crucial to building adaptive-inclusive learning environments.

2 A Psychological Approach to Solving Complexities in Design of Adaptive-Inclusive Learning Environments

2.1 Human Cognition and Learning Nested Within Stages of Psychosocial Development

Within the research literature, there are multiple theories of cognition and learning as well as multiple theories of behavioral change based on what has been learned [1–3]. Design of adaptive-inclusive learning environments should be based on a theory of cognition and learning. However, there are several to choose from. Since different educational systems may favor one theory over another, we re-examined how and why to build an adaptive-inclusive learning environment with administrative dashboards allowing educators to select the particular theory of learning and cognition best fitting their theory and praxis of education by matching theories to the cognitive stage and instructors’ understanding of how their students learn as well as students’ dispositions to act on what they learned. In our early work, we focused on four theories of cognition and learning: Adaptive Character of Thought, Cognitive Load, Cognitive Flexibility, and Situated Learning theories [1]. Adaptive Character of Thought and Cognitive Load theories cluster into the more individualistic structured theories of learning while Cognitive Flexibility and Situated Learning theories fit within what many educators call a constructivist framework.

However, theories of learning must be coupled to theories of behavioral change to understand how individuals learn and then act or do not act on what they have learned. Just as there are multiple theories of cognition and learning, so too there are many theories about how individuals engage in behavioral change (as described in [1]).

2.2 Remediation of Misconceptions During Learning

Through an extensive literature review, Tashiro and colleagues [1] described gaps in our knowledge of the following: (1) how can an educational environment improve disposition to learn; (2) relationships of learning outcomes to the level of realism and relevance within an educational environment; (3) how to determine thresholds of learning experiences that lead to measurable outcomes; (4) how to assess learning to determine authentic learning outcomes; (5) delineation of cognitive processes and domains being instantiated and the stability of knowledge retained; (6) what processes improve disposition to act on knowledge gained; (7) what processes influence accurate knowledge transfer; (8) how learning outcomes are developed during the learning process (e.g., instantiating conceptual and performance competencies); (9) how misconceptions are developed during and sustained after working within an educational environment; and (10) how do educator-learner and learner-learner social networks or e-communities impact learning. None of these gaps have been bridged, because truly inclusive and adaptive educational environments have been hard to build and evaluate.

Since these 10 gaps were first described, we have increasingly focused on how misconceptions are formed. This focus is justified because the other gaps are related to how misconceptions form and how they shape the theory and praxis of education at all ages and developmental stages. Consequently, we concluded that understanding pathways of misconception development is key to building adaptive-inclusive learning environments. In brief, we argue the processes and outcomes of learning, especially when they are compared to experts in a field, must be built into adaptive-inclusive environments so we can help learners better develop processes minimizing misconception development while also helping develop these patterns of thinking and learning that approximate expert patterns.

3 What Does the American Population Know About Viruses and Evolution of a Virus into Subvariants

Consider the earlier mentioned study of polarization in the United States—*Hidden Tribes: A Study of America's Polarized Landscape*, which provides a framework for understanding polarizations within America subpopulations. We studied complex contagions [13] to explore how different "Tribes" might approach finding out about critical issues in healthcare related to the Covid-19 pandemic. Responses include: what are likely educational levels attained by different Tribe members, how might political or religious clusters within the different Tribes influence decisions about sensible responses to the pandemic, how does Tribe membership influence sociopolitical stances within everyday American life, and how might the profiles of members in different Tribes predict attitudes about responses to the Covid-19 pandemic's spread and healthcare responses to containing the pandemic as well as the options for vaccinations.

We then examined patterns of vaccination hesitancy or anti-vaccination sentiment. Specifically, how do members of each Tribe network and exchange information with others in the same Tribe or other Tribes. When we focused on the American population's response to the spread of Covid-19 disease, we wanted to know how to design research to help us study individuals' understanding of science and healthcare practices, political affiliation, strength of any particular political group's anti-vaccination and pandemic-related anti-healthcare rhetoric, and how interactions among group members' understanding of science and mathematics as well as other *ways of knowing* (e.g., political, religious, sociological) might dominate or overturn ideas of best practices in science and healthcare to mitigate evolving threats to public health during a pandemic.

Three questions emerged: (1) What is the general scientific literacy of the American population and how might adaptive-inclusive learning environments improve this literacy? (2) Where do Americans get their information and how might adaptive-inclusive learning environments improve accuracy of that information? (3) Can models of Chatbot AI improve certain types of engines within an adaptive-inclusive learning environment? We had already built and studied AI engines for an adaptive-inclusive learning environment to train American undergraduates in Healthcare fields: Nursing, Medical Assistants, Emergency Medical Technicians, and Paramedics. Our models of learning environments later were revised to accommodate an undergraduate Computer Information Technology curriculum at Northern Arizona University [4] and also within a prototype for a patient education teaching-learning environment. [1] We then designed three thought experiments that could explore the three questions listed above.

3.1 Thought Experiment 1: Americans' Level of Scientific Literacy to Use Information from the United States Center for Disease Control

The senior author (Tashiro) worked during 2021 as a vaccinator at several mass vaccination sites in Pima County, Arizona. He discovered how little people coming for vaccinations as well as healthcare providers giving vaccinations knew about viruses, evolution of viruses, how vaccinations prevent viral infections, and the pathophysiology of COVID-19 disease. He asked a simple question: What designs of adaptive-inclusive learning environments could help Americans learn about the behaviors and mitigations needed to control and reduce the pandemic's spread across America? We realized the CDC almost certainly was thinking along the same lines, so examined their websites, which allowed us to view information about Covid-19 during the pandemic:

https://www.cdc.gov/coronavirus/2019-ncov/Covid-data/Covidview/index.html

Using the "Wayback Machine" (accessed at: https://archive.org/web/), we sampled textual material on the CDC Weekly Review from dates already past and also followed the site to collect ongoing CDC posts. In both retrospective and active ongoing data collection, we sampled entries for Saturday—since updates were released each Friday. Our sample period began on April 11, 2020, and continued until June 27, 2022.

From samples of text on each day sampled, we conducted analyses of the Flesch Reading Ease and the Flesch-Kincaid Grade Level metrics (see: https://www.researchgate.net/publication/335630551_Examining_the_impact_of_text_style_and_epistemic_beliefs_on_conceptual_change). These metrics provide information about the level of education a reader would need to understand basic concepts in the CDC Weekly Report. The Flesch Reading Ease scale provides a measure of ease of reading, from 0 to 100: scores between 90–100 are generally considered understandable by 5th grade students in United States' schools; scores in the 60–70 range suggest material can be understood by 8th–9th graders; scores ranging from 0–30 are considered understandable by college graduates. Another way of interpreting the scores with this scale can be: 90–100—very easy reading, 80–89—easy, 70–79—fairly easy, 60–69—roughly the American literacy level, 50–59—somewhat difficult, 30–49—difficult, and 0–29—very difficult to read. In contrast, the Flesch-Kincaid Grade Level scale provides a measure of the likely grade level of written material: scores of 0–4 suggests material suitable for a beginning reader (grades 1–4); scores from 5–12 suggest material suitable for an average American reader or grades 5–12; scores between 13–18 suggest material suitable for a skilled reader, such as individuals late in their high school years through college.

We looked for evidence if the CDC Website was adapting Reading Ease and Grade Level of textual materials about Covid-19 as the pandemic unfolded in 2020–2022. This approach was driven by our interest in how and why to build an adaptive-inclusive engine that would assess learners' reading levels and automate text selection to match learners' levels of Reading Ease and Grade Level. Such automations could improve learning opportunities for a larger percentage of the American population.

Figure 1 summarizes our findings. When we look at the data from the CDC site covering information on Covid-19, the Reading Ease of CDC materials is initially 20–30 but increases to 30–50, a transition from very difficult to difficult for most Americans to read. Over the time period studied, the Grade Level data suggest a slight decrease from 15 to 12, indicating grade level accessibility from material suitable for a skilled reader in late high school and college to a level suitable for a reader in high school. However in 2023, 79% of U.S. adults were literate, but 21% of adults in the US were illiterate so would not be able to read the CDC Weekly Updates on Covid 19. About 54% of American adults have a literacy below 6th grade level so many would have difficulty reading the current types of CDC Covid-19 Weekly Reports.

The simple interpretation is that the CDC may have tried to make complex material a bit simpler for the American population using their COVID-19 website. However, in both Reading Ease and Grade Level figures you will notice increased variability in scores during the period of weeks 43–106. Such variability is consistent with increasing infection rates and difficulty handling the care of patients during spikes in Covid-19 infections. CDC also was urging the need for compliance during rollout of vaccines.

As builders and researchers focused on adaptive-inclusive learning environments, how would we have built and managed an information platform like the CDC Covid-19 information websites that provide, for the most part, textual information. If we look at the literacy level of Americans, we find over 130 million American adults have low literacy skills (data from a Gallup analysis as well as from the U.S. Department of Education). Another way to interpret the literacy rate is that more that 50% of America adults (ages 16–74) can only read at levels between 6–8 grade in the American school systems. See reports at:

> https://www.barbarabush.org/wp-content/uploads/2020/09/BBFoundation_GainsFromEradicatingIlliteracy_9_8.pdf as well as at https://www.apmresearchlab.org/10x-adult-literacy.

Governmental agencies like NIH, especially during national crises, could create adaptive and inclusive information outreach systems that allowed any American citizen to find the level of reading and comprehension that best met their educational levels. Such systems would have to assess each individual and create individually customized learning environments that could monitor every learner's progress through the information provided but also introduce learning assessments that did not drive the learner away but engaged them in ways they could improve comprehension, evaluation, and utilization of the information. We also hope learning environments would help learners think about and then plan shifts in their behaviors likely to improve their and their loved ones effective use of information provided.

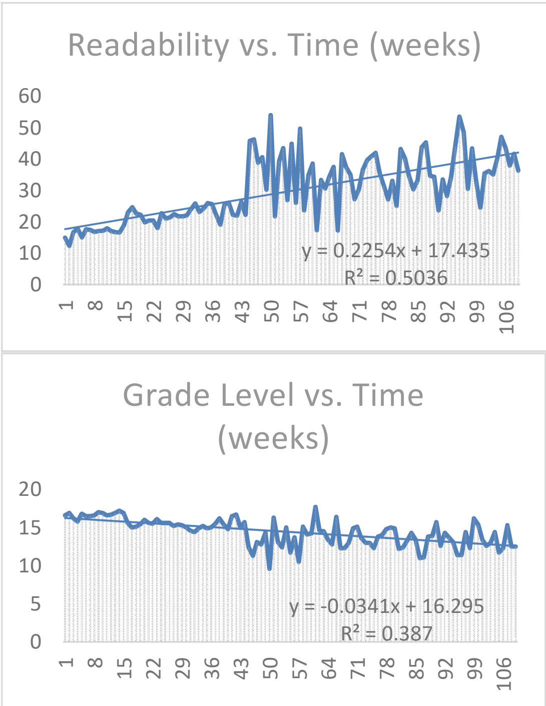

Fig. 1. Reading Ease and Grade Level Analyses of CDC Covid-19 Weekly Updates. Y-axis is Readability or Grade Level Score (Grades 1–20), while X axis is the Week number beginning April 11, 2020, and going through June 11, 2022.

3.2 Thought Experiment 2: Sources of Information About Covid-19 and Literacy Requirements from Popular American News Programs

Our second Thought Experiment focused on collection and analysis of news stories and followed a pattern similar to that conducted in Thought Experiment 1, but with certain modifications to accommodate accessibility of these stories. Again, we used "The Way Back Machine" but accessed videos and transcripts from news stories found in archives of MSNBC, CNN, and Fox News. Unlike data collection from the CDC, however, we selected 3 specific dates to analyze: 7/29/20, 12/31/20, and 9/1/21. These particular dates corresponded to peaks in American Covid-19 cases. We wanted to capture news coverage of those peak periods of infection. The archives for each collection of news videos and transcripts for MSNBC, CNN, and Fox News are respectively:

https://archive.org/details/TV-MSNBCW, https://archive.org/details/TV-CNNW, and https://archive.org/details/TV-FOXNEWSW

A single overlapping time slot was chosen for analysis—8:00 am to 9:00 am PDT for MSNBC and CNN but 6:00 am to 9:00 am PDT for Fox News (because the archives for Fox did not offer the same 8–9 am slot as the other two). We anticipated the selected time slots in the morning would offer a general summary of what each news channel believed to be most relevant for each given sampling day.

The selected date-time corresponded to a unique video and its transcript for each news channel. We searched for the first news story related to the Covid-19 virus, quarantine restrictions, the Covid-19 vaccine, hospitalization, or discussions that were relevant to the pandemic. For each news story, we copied the corresponding section of the transcript into a Microsoft Word document and used the "Editor" feature to calculate the document's "Flesch Reading Ease" and "Flesch-Kincaid Grade Level" metrics. News programs for all three networks had an anchor who presented information but then engaged one or more commentators or experts to discuss the news covered in that respective program. Since we were interested in a kind of *gestalt* for the news session, we combined the transcriptions retrieved from the news program anchor and all of the respondents during each sampled news segment.

Table 1 provides the Readability and Grade Level of MSNBC, CNN, and Fox News morning shows during the morning time interval of 6:00–9:00 AM on 7/29/20, 12/31/20, and 9/1/21. As mentioned, these particular dates corresponded to peaks in US Covid-19 cases.

We did not conduct statistical analyses of these data except to calculate Reading Ease and Grade Level for each of the news shows. Our logic for using minimal descriptive statistics was that the raw data came from news shows in which a lead anchor interacted with or interviewed reporters, experts, and politicians would create issues of heteroscedasticity within and across data sources. Our approach collapsed all of each channels' transcriptions of a particular day-news channel to provide what we believed is an overview of the complexity in the news provided by each news outlet about the COVID-19 pandemic. We justified this approach because of considerable evidence people comprehend more from reading than from listening to conversations, unless their reading skills are quite low. Consequently, transcript assessments may have provided higher estimates of comprehension than actually occurred when people listened to the news.

To capture the complexity of the conversations unfolding during news programs, we used transcriptions of the conversations and analyzed the entire conversation, which included multiple contributors discussing issues with a single person who was the program anchor. Again, the anchor generally selected topics of discussion and moderated the evolving discussions. Our intent was to capture how much viewers might understand based on analyses of Reading Ease and likely Grade Level that the viewers would require to interpret the information within the respective news program.

This second Thought Experiment also broadened our understanding of how to build better adaptive-inclusive learning environments. While there is ongoing debate about the effectiveness of reading versus listening, evidence suggests an individual can comprehend more through the reading than listening to the audio of the same information (unless the listeners are taking notes). Our choice of using transcripts in Thought Experiment 2 was informed by information we studied within the following website:

https://gotranscript.com/blog/reading_vs._listening_which_is_more_efficient_for_studying#:~:text=We've%20already%20discussed%20how,more%20efficiently%2C%20transcription%20is%20essential

The values for Flesch Reading Ease in Table 1 varied from 47.5–68.2, scores indicating the material is understandable by 8th–9th graders in American schools, so middle school into early high school—that is, slightly below a high school level. In terms of mean grade level, the transcripts of news varied from 7.2–11.6. Based on the Flesch-Kincaid Grade Level that would be between 8th–11th grade in the American school system. Of course, there is no meaningful "average" American level of literacy because of the heterogeneity in American citizens' literacy levels. Certainly within the evolving technologically-oriented American economy and evolving complexity of technology in routine use within this economy, many employers value higher levels of reading and listening comprehension skills.

Again taking the perspective of developers and researchers of adaptive-inclusive education systems, we want to make sure such systems contain diverse opportunities to learn from news, lectures, demonstrations, experiments, and readings so learners develop substantive skills in reading, writing, heuristic analysis, and general literacy in the discipline areas of a particular class or assignment. Table 1 reveals that at least some of the main news outlets in America may be reaching broad audiences. However, different learners would need different levels of sophistication in comprehending presentations of materials they are tasked to learn. In particular, training in sophisticated heuristic reasoning and debiasing will be important as the amount of unsubstantiated information is passed on by many news feeds and social media as *fact* or *truth*, often to the disadvantage of the general population.

3.3 Thought Experiment 3: Potential for Chatbot Models in Adaptive-Inclusive Educational Systems

Since first exploring Chatbots, we wondered if these types of AI could become an integral part of the adaptive-inclusive learning environments we have been building over the past 20 years. The publisher Elsevier Incorporated, which initially published our simulations for training healthcare students at the undergraduate level, integrated these simulation environments into their online course management system known as *Evolve*. Faculty members can choose their own approach to teaching and learning by using *Evolve* in conjunction with student excursions into the simulation environments and other learning resources available within *Evolve*.

Following the development of Chatbots and in particular ChatGPT, we began to see new ways of nesting elements of ChatGBT into extant educational systems such as

Table 1. Reading Ease and Grade Level of Newscast Transcripts from Dates of Peak Covid-19 Infections in the United States. In this article, we do not give the names of the news anchors, though if you are interested you can track down the specific shows news segments we have mentioned.

Date	News Show	Mean Reading Ease	Mean Grade Level
07.29.2020	MSNBC (8–9 am)	64.2	8.3
	CNN (8–9 am)	68.2	7.6
	Fox (6–9 am)	47.5	11.0
12.31.2020	MSNBC (8–9 am)	65.8	7.9
	CNN (8–9 am)	54.2	9.7
	Fox (6–9 am)	55.2	11.6
09.01.2021	MSNBC (8–9 am)	65.0	8.2
	CNN (8–9 am)	60.0	9.5
	Fox (6–9 am)	68.4	7.2

Evolve, but also more generally into blended and totally online environments for education. Of course, if you read the rapidly expanding literature related to ChatGBT (both in print and online) you also find considerable concern among scholars and educators about the values and disvalues of AI like ChatGBT. We will return to that issue at the end of this section.

However, in the context of our Thought Experiments 1 & 2, and also integrating what we were discovering in works like *Hidden Tribes*, we began to rethink how we design learning environments (in-person, blended, and totally online) to accommodate the diversity of different ways of thinking and learning. For example, unlike many countries, the United States does not have a nationalized curriculum for schools or universities. Curricular content for grades K-12 tends to evolve within states and municipalities so that within any single state as well as across states you can find diverse approaches to curricular structures and approved choices of educational materials—this includes proportions of face-to-face, blended, and totally online course offerings.

To integrate our approaches in Thought Experiments 1–3, we studied a variety of ChatGPT use cases, which you can find in the literature as well as on YouTube. For this paper, we explore a YouTube video entitled "Can ChatGPT Write Your Next Scientific Paper?" (see: https://www.youtube.com/watch?v=wnGPt030IG4). Moderator Karen L. McKee provides an exploration of some of ChatGPT's capacities that could aid scientific research and writing. First she notes the mixed attitudes of faculty about ChatGPT, and then in the video she tests various capacities of the system as she demonstrates how ChatGPT responded, exploring what McKee felt the system could and could not do with respect to effective scientific writing. If you are unfamiliar with ChatGPT you can find information from the developers at oepnai.com and explore ChatGPT functionality at chat.openai.com.

We will be brief in this paper, but if you want to know more about how ChatGPT works you might find this video an interesting starting point. McKee began her use case of ChatGPT by asking a question related to her own research—"What is the effect of sea level rise on coastal wetlands?" In her opinion, she got a pretty good answer. Then she tried to trick ChatGPT by asking a question that to her seemed nonsensical—"What is the effect of sea level rise on beagles?" Yet ChatGPT responded with a surprisingly sensible answer that the sea level rise would not likely have much impact on beagles because dogs may visit but are not normally inhabitants of coastal wetlands.

As we analyzed the YouTube video, several key points stood out to us: Sensible questions often resulted in sensible answers (from a scientific and general content perspectives) though without citations for sources of information. Giving the system a section of a scientific abstract, McKee asked the system to suggest several titles, and the system returned five titles, some of which were, in her judgement, at least partially relevant to the excerpt content. McKee then asked the system to write a short paper based on the abstract she had offered earlier to ChatGPT—she noted how the system took previous information she had given it but the resulting paper did not meet her standards. She asked for an expansion on the system's response, but in this case ChatGPT's response had accuracy problems. She posed additional questions about the accuracy of the system's response—the system responded with suggestions for corrections.

McKee concluded ChatGPT might improve some types of scientific writing and this capacity could be valuable to students who have limited experience writing technical language as well as students who speak-write English as a second or third language. McKee then asked ChatGPT for suggestions for future research and found the responses reasonable. A very interesting exchange occurred when she asked the system to rewrite a section of prose so it would be suitable for a 12-year-old. McKee found the response useful, for example to provide an excerpt for a newspaper or for presentation to the US Congress or members of state government.

We present a simplified summary of her perceptions about the value and disvalue of her experiences in the ChatGPT session. **Positives**: ChatGPT could be used (but with care) to summarize a draft of a paper or paper sections; provide support for choosing a title; assist with ideas for rewrites of sections of a paper; create various versions of an abstract for a paper; simplify or offer critiques of some of the scientific writing; summarize reference material entered into the system; and craft tweets or quick notes to media about research. **Negatives**: ChatGPT can sound authoritative but offer completely wrong responses; has little ability to provide references (although there are some workarounds for this issue); currently does not have content developed past 2021—so the information could be out of date (but this area seems to be changing as updates are added); cannot compare data or results unless provided with prior work; McKee also expressed concerns about responses being paraphrased or plagiarized as well as concerns about use of unauthorized or copyrighted sources of information.

A key question evolved for us—how might ChatGPT serve diverse learners of all ages wanting to learn science and mathematics, especially in times of crisis like a worldwide pandemic. There has been an enormous response from faculty at all grade levels about whether or not ChatGPT is a suitable tool for K-12 and undergraduate education. This is an emerging and complicated set of discussion areas and we will not address the complexity in this paper. However, interested readers may get a hint of the complexity by reading a variety of online summaries about various topics: don't ban ChatGPT—teach with it; abstracts from ChatGPT fool scientists, why writers argue ChatGPT is a bad idea, and some worries about odd and inappropriate responses from the system.

4 Discussion and Conclusion

Our simple descriptive Thought Experiments were designed to explore the complexities inhibiting ways and means to build learning environments that can adapt to the idiosyncrasies of each learner in inclusive ways. Our approach has been to create and evaluate evidence-based approaches suitable for the diverse American population, including students in K-12 levels, high schools, colleges and universities, but also in professional schools as well as the general adult American population. In this paper, we focused on the impact of polarization within the American adult population during the healthcare crises of the Covid-19 pandemic. The sustained crisis of the ongoing COVID-19 pandemic, and especially the vaccination hesitancy and antivaccination attitudes of many Americans, allowed us to explore how and why to create more inclusive models of articulated AI engines that could help create evidence-based adaptive-inclusive teaching and learning environments to educate Americans of all ages in ways that might overcome the crippling polarities within America's sociopolitical factions.

More specifically, our three Thought Experiments point to the need for more detailed studies of general as well as scientific literacy of the American population, the assessment of the veracity of information sources—including American news information, and the potential for AI like ChatGBT to provide more interactive learning opportunities that might help remediate low levels of literacy within the American population. Prior research with funding of over $10 million USD provided partial solutions for components of an Adaptive-Inclusive learning environment that we created to evaluate a sensible model for adaptive blended learning for health education serving families with a parent or child who had a medical problem. In that model (described in detail within [1]), we described three key, interlinked subsystems.

User Profile Triad of Three Subsystems: The User Profile Triad has a primary Inclusive Adaptive Interface (IAI) as an Administrative Dashboard that allows administrators or instructors to select a theory of cognition and learning as well as a theory of behavioral change, both of which shape the types of learning activities consistent with the respective theories. The IAI is coupled to a database system we called the Learner Profile (LP) that in turn feeds user data to an Electronic Learning Record (ELR). Together, the User Profile Triad Subsystems collect learner data and personal preferences through time and pass these data to the LP that updates the ELR.

End User Customization Dyad: The User Profile Triad feeds information to a linked pair of search and assembly subsystems—A Matchmaker (MM) that selects an Instructional Design Template (IDT) based on the Administrator's or instructors' choices of an evidence-based theory of cognition-learning as well as the selected theory of behavioral change. MM and IDT work together in ways that optimize learners' disposition to engage in learning but also in ways that improve disposition to act on knowledge gained.

Personalized Teaching-Learning-Assessment Triad: The MM-IDT engines connect to a triad of three linked subsystems—An Assembler Engine (AE) that reads data from the IDT and metadata streaming from MM then searches through and selects Learning Object Repositories (LOR) to create customized learning experiences for the user that is an individually personalized teaching-learning-assessment-diagnostic Educational Environment (EE).

Early versions of these interlinked subsystems were bult and evaluated with funding from the United States National Science Foundation and the United Sates National Institutes of Health, with additional research and development funding from the publishers Harcourt Health Sciences and Elsevier Incorporated. These versions became prototypes for more advanced systems designed to be both adaptive and evidence-based.

We mentioned in the Introduction how the study "Hidden Tribes" described distinct American population subgroups. Americans' responses to pandemic health mitigations and vaccinations against the SARS-CoV-2 virus and its subvariants revealed major polarizations within the American population that mapped to the five dimensions of individuals' core beliefs described within "Hidden tribes": tribalism and group identification, fear and perception of threat, parenting styles and authoritarian disposition, moral foundations, and personal agency and responsibility. These dimensions were the basis for the cluster analyses conducted by the researchers that led to their delineation of the seven "tribes" within the American population: Progressive Activists, Traditional Liberals, Passive Liberals, Politically Disengaged Individuals, Moderates, Traditional Conservatives, and Devoted Conservatives. These groups differed in age profiles, political affiliations, generalized income, patriotism, ethical and religious frameworks, and political party affiliations.

Close examination of these seven groups reveals that their different attributes require a more comprehensive understanding in order to modify our earlier approaches to creating the User Profile Triad of Three Subsystems, the End User Customization Dyad, and the Personalized Teaching-Learning-Assessment Triad. Such modifications have become our research foci for future work.

However, additional research will also focus on the literacy of Americans, especially in the areas of science and mathematics. Given the low literacy of Americans in these critical areas of modern societies, the general model of ChatGPT provides options for reaching a broader American audience if users can engage in interactive questioning with the AI. Despite such an interesting opportunity, Chatbots still have problems largely shaped by two factors: (1) the most critical is the sources of information—basically, we need structured and reviewed educational materials instead of frequency of small bits of text like the "tokens" used in systems like Chat GPT; and (2) the need for improving the collation and delivery pathways of the information within educationally sound frameworks. These two problems have been articulated in an interesting article. [8] More specifically, educational databases can be selected and reviewed, then structured within a Chatbot model that uses metadata to access appropriate educational materials for a particular learner—and here we use "appropriate" to mean those materials selected by an engine such as our User Profile Triad and End User Customization Dyad systems described above, with these systems shaping individualized content and learning activities within the Personalized Teaching-Learning-Assessment Triad.

In closing, *Hidden Tribes* data open new opportunities for research. In our experience, individuals within the Progressive Activists and Traditional Liberals have different ideas from Traditional Conservatives and Devoted Conservatives about the types of education they value for themselves and their family members. Specifically, Progressive Activists differ from Devoted Conservatives in their commitments to the current movements to ban books in American schools especially those covering woke culture, cancel culture, Critical Race Theory, scientific foundations of climate change, and scientific-medical rationales as well as responses to mandates for vaccination against COVID-19 disease. [8–16] We have begun translating our research designs into suitable models for blended as well as totally online systems that value and can unbiasedly educate all learners despite diverse issues that may divide them.

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Gamification and Interactive Learning Environment

Research on the Practice of VR Entering the Classroom–Taking City University Students of Macau as an Example

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Abstract. This paper constructs a comprehensive practical teaching system in colleges and universities with the goal of cultivating innovative practical ability, and puts forward new measures to implement innovative practical teaching in virtual reality classroom, which has contributed to the introduction of new technologies into the classroom. On the basis of literature review, this study uses a structural equation model to conduct theoretical research, and discusses the influence of new virtual reality technology on blended learning performance. In order to verify our conjecture, we collect data and do statistical analysis using SPSS 24.0 and PLS 3 software. The results show that the application of new technology can directly improve students' academic performance, and learning motivation plays an part of intermediary role in the development model of academic performance. On the contrary, learning strategies have not played an important role in this study.

Keywords: Self-efficacy · learning strategy · Learning motivation · Hybrid learning performance · Virtual reality

1 Introduction

In recent years, the education administrative department of the central government and universities in China have attached great importance to the cultivation of college students' practical innovation ability. The Ministry of Education regards practical teaching as one of the key indexes to evaluate the teaching level of colleges and In recent years, China's education administrative department and universities have attached great importance to cultivating college students' practical innovation ability. The Ministry of Education regards practical teaching as one of the key criteria for evaluating the teaching quality of colleges and universities. Colleges and universities have taken practical and effective

Achievements of Key Research Base of Humanities and Social Sciences in Shenzhen: Skilled Society Research Center of Shenzhen Institute of Technology.

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measures, actively carried out practical teaching reforms, and raised funds through multiple channels to increase investments in laboratory construction, which significantly improve experimental teaching conditions and have a positive impact on enhancing students' practical and innovative abilities.

The Smart Tourism Research Institute of City University of Macau was established in 2018, with a focus on the theme of "scientific and technological innovation in tourism and leisure". The Institute conducts related research with tourism big data analysis and virtual reality tourism as the main research directions. Among the 70 academic journal papers published by the Institute in 2021, 44 were published in SSCI-indexed journals, and 70% of the papers were published in Q1 and Q2 journals. These accomplishments in international core journals demonstrate the innovative ability and professional level of the Institute's research team. The Virtual Reality Laboratory was funded by the Macao government to purchase sufficient 360VR equipment for experimental research.

This study is based on the innovative teaching technology practice of VR equipment for graduate students majoring in international tourism and management at City University of Macau in 2020. Teachers distributed 360 VR devices to students, conducted outdoor VR exercises in groups, and opened three courses on the application of new VR technology in the tourism industry. Based on this VR practical course, this study analyzed, using professional structural equation model software, whether the new VR technology contributes to improving teaching skills among teachers, whether students accept the teaching of new technology, and whether they can make significant progress in learning performance.

2 Literature Review

2.1 Self-efficacy of VR Technology

Self-efficacy refers to the belief that an individual possesses the ability to tackle challenging or novel tasks and handle adversity in a harsh environment. Self-efficacy significantly impacts how people feel, think, and behave (Bandura, 1997) [1]. Individuals with high self-efficacy are more inclined to take on more challenging tasks, set higher goals for themselves, and persevere through setbacks. Through cognitive restructuring, high self-efficacy individuals increase their effort and maintain their motivation for a longer period compared to those with low self-efficacy. Moreover, a strong sense of self-efficacy enables individuals to choose demanding environments, explore new territories, and create new opportunities, reflecting a belief in their competence across various situations.

Although self-efficacy is often understood as field-specific or task-specific, researchers have proposed a broad sense of self-efficacy that refers to an individual's overall confidence in coping effectively with various demands or situations (Schwarzer and Jerusalem, 1995) [2]. A broad sense of self-efficacy aims to establish a robust and stable sense of personal ability to cope with a variety of stressful circumstances, reflecting a generalization across multiple domains of functioning. While the author believes that self-efficacy should play a role in specific situations, this paper combines the application of virtual reality technology with students' self-efficacy to study and design the independent variables of this paper.

2.2 Learning Motivation

Motivation refers to the inner force that drives individuals to take action to meet their needs (Armstrong, 2001) [3]. The purpose of education is to help students acquire knowledge and skills while encouraging them to have a desire for success. These two goals are interrelated with motivation theory. Learning Motivation is a complex concept that is influenced by a series of psychological and social factors which exist not only within the learner but also in their social and natural environments. The American Psychological Associations (1997) [4] Learner-Centered Principles emphasize internal factors under the control of the learner, as well as external factors that interact with those internal factors.

In describing the key determinants of learning motivation, McCombs and Whisler (1997) [5] identify self-awareness and beliefs in personal control, ability, clarity, and prominence of personal values, interests, and goals, personal expectations and influence on success or failure, emotion, and general psychological states as core factors. These are related to the concept of "learning identity," learners' beliefs, values, and attitudes towards themselves, which impact their goal orientation and are also related to their sense of efficacy as a learner. A person's perceptions of the causes of success and failure are central to the development of motivation for learning.

According to Johnston (1996) [6], "willingness to learn" is at the core of the learning process, which is closely related to the concept of motivation. She believes that the will to learn comes from a person's sense of deep meaning or purpose and can be described as the energy to take action on meaningful things. The level of willingness to learn is related to the degree to which the learner is prepared to invest, which engages their motivation to process, perform, and develop as a learner over time.

2.3 Learning Strategy

Learning strategies can be categorized into cognitive strategies, metacognitive strategies, and resource management strategies. Cognitive and metacognitive strategies are further divided into metacognitive self-regulated learning and peer learning (Pintrich, 1999) [7]. Learning strategies manifest in students' behavior and thoughts, which impact their learning goals and motivation. The analysis indicates that learners' proficiency affects the use of learning strategies, and the learning environment plays a role in determining how learners learn and what strategies they adopt to improve their learning outcomes. There appears to be a circular relationship between strategy use and beliefs, where more positive beliefs lead to greater learning success. Similarly, motivation and the use of strategies are interrelated, and an increase in motivation levels results in a higher level of learning success and better use of strategies. Having an understanding of learning styles is critical to the use of strategies, given that learners have diverse learning styles. Recognizing learners' styles will undoubtedly assist teachers in planning instruction accordingly.

2.4 Hybrid Learning Performance

Blended learning is considered a hybrid teaching mode that formally combines traditional face-to-face teaching with pure online learning. Both Sinterberg, Fassler, and Bauer-Messer have used these two terms interchangeably, but they have also defined blended learning differently. They define blended learning as a distance education method that utilizes technology combined with traditional education. On the other hand, blended learning is described as a combination of new and old teaching methods, such as using online tutorials or other teaching technology.

In the context of performance, only achievements can be used to evaluate work behavior (Gilbert, 2013) [8]. Nickols, an American training consultant, asserts that performance is the outcome of behavior, and behavior is an individual's activity. The implementation of activities changes the environment to varying degrees, and the degree of change is the result of behavior. Bernardine believes that learning performance should be defined as the result of learning, as this outcome is most closely related to learning objectives, learner satisfaction and investment. Meanwhile, Murphy maintains that learning performance is a set of behaviors related to the learners' goals (Jensen & Murphy, 1990) [9].

This paper discusses blended learning performance from three perspectives: learning ability, academic achievement, and learning outcome, including both process and results. The term "learning" used in this paper refers to the mixed teaching mode of virtual reality learning and distance learning based on face-to-face learning. The combination of virtual and real technologies promotes the learning process.

2.5 Research Hypothesis

According to the variable relationships presented in the literature review, we have proposed the following research assumptions:

H1: Self-efficacy in using VR technology has a positive impact on hybrid learning performance.
H2: Self-efficacy in using VR technology has a positive impact on learning strategies.
H3: Self-efficacy in using VR technology has a positive impact on learning motivation.
H4: Learning strategies has a positive impact on hybrid learning performance.
H5: Learning motivation has a positive impact on hybrid learning performance.
H6: Learning strategies serve as an intermediary between self-efficacy in using VR technology and hybrid learning performance.
H7: Learning motivation acts as an intermediary between self-efficacy in using VR technology and hybrid learning performance.

Based on the literature review on the relationship between the application of VR technology, learning strategy, learning style, and blended learning performance, Fig. 1 illustrates the hypothetical relationship between the theoretical model and the various constructs (VR technology application, learning strategy, learning motivation, and blended learning performance) of all the indicators tested in our research.

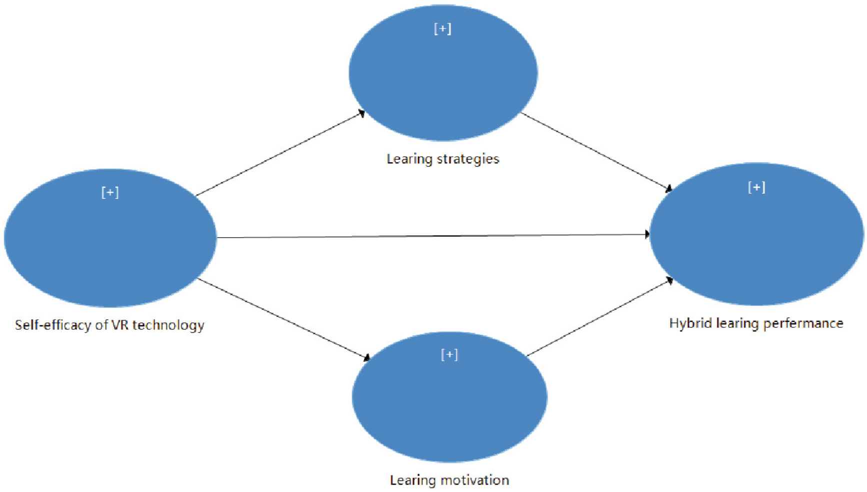

Fig. 1. Research Model

3 Methodology

3.1 Suitable Subjects

This research aims to collect and analyze data from tourism students who completed the VR new technology application course in 2020. During the course, the teacher explained the principles of VR technology, taught the steps for using the head-mounted 360VR device, assigned on-site VR shooting tasks of tourist attractions, and required the shooting team to give reports on their tasks. Over the course of six months, students gained a certain understanding of the application of VR technology, the use of 360 head-mounted devices, and video data editing and production. This aligns with the research background and purpose of our study: identifying what kinds of learning strategies and motivations need to be maintained in the classroom to improve their learning performance.

3.2 Data Collection and Sample Characteristics

This study is based on 80 graduate students majoring in international tourism and management at the City University of Macau in 2020. The students come from a diverse range of genders and ages. We conducted a detailed investigation using a scale and divided the responses into five levels from "strongly disagree" to "strongly agree." The Likert 5-Point Scale was fully applied in the questionnaire. We analyzed the data using SPSS 24.0 and PLS 3. The questionnaires were collected online through Tencent Questionnaires during the students' holiday period from January 1, 2023, to January 5, 2023.

3.3 Measurements

The scale used to measure the various components of the proposed model - self-efficacy in VR technology, learning strategies, learning motivation, and hybrid learning performance - is based on measurement standards extracted from literature. Learning motivation was measured using six items from Duncan, T.G. & McKeachie, W.J. (2005) [10]; learning strategies were measured using five items from the same source; and hybrid learning performance was measured using seven items. The self-efficacy scale used in this paper was adapted from Schwarzer (2005) [11], with four items deleted and the remaining five items were used.

3.4 Data Analysis

PLS-SEM analysis was used instead of traditional covariance-based structural equation models (CB-SEM) due to the complexity of the model - with a large number of constructs and indicators - relative to the sample size (N = 200). Using CB-SEM would have caused the model to be empirically under-identified. Additionally, the use of PLS-SEM can help to overcome deviations from normality in data sets (Chin, 1998) [12]. PLS-SEM is considered effective in generating stable and robust results with small sample sizes (around 100 observations; Valle & Assaker, 2016 [13]) and non-normally distributed data, making it suitable for this study.

The SEM-PLS test is an analytical method that is not based on many assumptions. It can be used with data that may not be normally distributed and that have nominal, ordinal, or interval-to-ratio scales. SEM-PLS can confirm theories and explain the presence or absence of relationships between latent variables. The processing of SEM-PLS using SmartPLS 3 involves two stages: (1) testing the outer model and (2) testing the inner model. In the second stage, the aim is to determine the influence between variables.

4 Result

We used SPSS 24.0 and PLS 3 to analyze the reliability and validity of the descriptive statistical data and scales. Firstly this study distributed 80 questionnaires and successfully recovered all 80, resulting in a recovery rate of 100%. The effectiveness rate of the questionnaires was also 100%. Based on the analysis of the descriptive information from the responses, it was found that 68% of the respondents were female students and 76% were between the ages of 20 and 25. Additionally, all the researchers involved in the test had postgraduate degrees. The questionnaires used a 5-point Likert scale. Then we confirmed the structural reliability by combining the reliability (CR) and Cronbach's α values. For example, the CR of all factors was found to be far above 0.7, and the Cronbach's α values were all above 0.7 as well. We also found that the intercorrelation between the factors exceeded the threshold of 0.5 (ranging from 0.505 to 0.723) (Hayes, 2013) [14]. These results indicated high discriminant validity and demonstrated acceptable levels of internal consistency reliability and convergent validity, as shown in Table 1.

After obtaining the reliability and validity of the model, we analyzed the internal relations of the model. (Table 2) shows that there is a significant positive correlation

Table 1. Average Variance Extracted (AVE), Composite Reliability, and Cronbach's Alpha

Dimension	Cronbach's alpha	Combinatorial reliability(CR)	Average variance extracted(AVE)
Self-efficacy of VR technology	0.905	0.929	0.723
Learning motivation	0.796	0.856	0.505
Learning strategies	0.788	0.853	0.538
Hybrid Learning performance	0.934	0.947	0.719

among self-efficacy of VR technology and learning motivation ($\gamma = 0.620$, $P < 0.001$), learning strategies ($\gamma = 0.638$, $P < 0.001$), and hybrid learning performance ($\gamma = 0.168$, $P < 0.05$). Additionally, learning motivation was found to be positively correlated with hybrid learning performance ($\gamma = 0.700$, $P < 0.001$). These results provide initial support for our proposed hypotheses.

Table 2. Variable Correlations Analysis

Dimension	Self-efficacy of VR technology	Learning motivation	Learning strategies	Hybrid Learning performance
Self-efficacy of VR technology	1	0.620***	0.638***	0.168**
Learning motivation		1		0.700***
Learning strategies			1	0.010
Hybrid Learning performance				1

Note: *P<0.1, ** P<0.05, ***P<0.01

Based on the suggestion of Edwards and Lambert (2007) [15], we utilized bias-corrected confidence intervals and generated 5000 bootstrapped samples using the Process macro in PLS 3. As shown in (Table 3), the results indicated that self-efficacy of VR technology had a significantly positive effect on hybrid learning performance ($\gamma = 0.166$, $t = 2.418$, $P < 0.05$), supporting H1. Self-efficacy of VR technology also had a significantly positive effect on either learning strategies ($\gamma = 0.648$, $t = 9.070$, $P < 0.001$) or learning motivation ($\gamma = 0.625$, $t = 8.162$, $P < 0.001$), supporting H2 and H3. Furthermore, learning motivation was found to have a significantly positive effect on hybrid learning performance ($\gamma = 0.702$, $t = 7.202$, $P < 0.001$), supporting H4. However, learning strategies had no effect on hybrid learning performance as it was not statistically significant ($P = 0.918 > 0.1$), leading us to reject H5.

Table 3. The Results of SmartPLS Analysis

Model and Structure	Beta Value	T Value	P Value	
Self-efficacy of VR technology→ Hybrid Learning performance	0.166	2.418	0.016	**H1 Accepted**
Self-efficacy of VR technology→ Learning strategies	0.648	9.070	0.000	**H2 Accepted**
Self-efficacy of VR technology→ Learning motivation	0.625	8.162	0.000	**H3 Accepted**
Learning motivation→ Hybrid Learning performance	0.702	7.202	0.000	**H4 Accepted**
Learning strategies → Hybrid Learning performance	0.016	0.103	0.918	**H5 Rejected**
Self-efficacy of VR technology→ Learning strategies→ Hybrid Learning performance	0.009	0.097	0.923	**H6 Rejected**
Self-efficacy of VR technology→ Learning motivation→ Hybrid Learning performance	0.438	5.761	0.000	**H7 Accepted**

Next, we analyzed the relationship between variables and their indirect influences. To examine the potential mediation of learning strategies and learning motivation, we utilized the bootstrapping method (Zhao et al., 2010) [16] in the Process tool with a confidence level of 95% and 5000 bootstrap samples, as well as Hayes and the indirect effect measurement method (Hayes and Preacher, 2014; Montoya and Hayes, 2017) [17, 18] (Table 3). Our results revealed that learning strategies cannot act as a mediator between self-efficacy of VR technology and hybrid learning performance ($\gamma = 0.009$, $t = 0.097$, $P = 0.923 > 0.1$), leading us to reject H6 for direct-only non-mediation. However, learning motivation had a significantly positive influence between self-efficacy of VR technology and hybrid learning performance ($\gamma = 0.438$, $t = 5.761$, $P < 0.001$), supporting H7. This suggests that learning motivation plays an intermediate role between self-efficacy of VR technology and hybrid learning performance. Further analysis is required to determine whether the intermediate role of H7 in the research hypothesis is a complete or partial intermediary, which can be judged by calculating the value of VAF in PLS 3.

(Table 4) displays data for two mediation reactions. We found that the P-value of the mediation reaction represented by H6, as assumed in the research, is greater than 0.1, indicating that it is not statistically significant and therefore has no mediation effect. While the P-value in the mediation represented by H7 is less than 0.01, indicating that it is statistically significant. We then utilized the tool to measure the VAF value for analysis, which revealed an indirect effect of 0.44 and a total effect of 0.609.

Table 4. Intermediary effect test

	Indirect effect	Total effect	VAF	P value
Self-efficacy of VR technology→ Learning strategies→ Hybrid Learning performance	0.007	0.609	1.1%	0.923
Self-efficacy of VR technology→ Learning motivation→ Hybrid Learning performance	0.440	0.609	72%	0.000

Upon calculating the VAF, we found that the indirect effect (0.44) divided by the total effect (0.609) equaled 0.72 or 72%, which is less than the threshold of 80%. Therefore, learning motivation plays a partial intermediary role between self-efficacy of VR technology and hybrid learning performance, supporting H7.

Upon verifying the research hypothesis, we organized and analyzed the obtained data using the PLS 3 software and improved our structural model accordingly, as shown in (Fig. 2), which displays the structural result of our model.

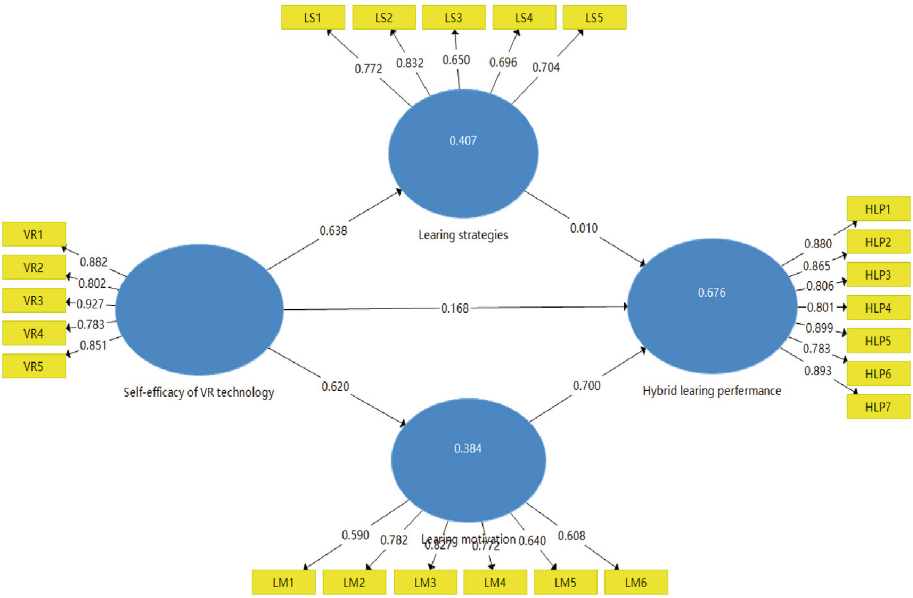

Fig. 2. Results of PLS-SEM analysis

5 Discussion and Conclusion

Our aim is to investigate whether the incorporation of VR technology in the classroom can enhance students' learning abilities, cultivate their awareness of autonomous learning, and diversify teaching methods, and to examine the relationship between learning strategies, learning motivation, and performance in the academic application of new technology. From the 80 research samples in this study, we found that learning motivation, as always, positively affects students' academic performance, and it also plays a role in the relationship between VR new technology application and academic performance. The role of partial mediation effects. Previous literature also affirms that self-efficacy and motivation significantly impact blended learning performance, aligning with our research findings.

For the significance of this study, it uses SmartPLS data analysis software to study the effect of college students using VR technology on learning. The research results show that learning to use VR technology can help improve academic performance, while maintaining a high degree of learning motivation for new technologies will also improve academic performance. These may be the unique temperament of the new generation of young people in the Z generation who dare to try and actively experience new things. However, in this research analysis, it is also found that formulating definite learning strategies for young people in Generation Z does not help them significantly improve their performance, which is inconsistent with the findings in our literature. The idea is no longer to complete the study plan step by step, and no longer devote energy to complete the learning tasks. I think this is the next research direction for educators. We need to know enough about the people of the new era in the world before we can provide them with more educational resources that are more suitable for them.

Due to the limitations of the study, these results may not be suitable for drawing general conclusions based on the current research environment due to the small number of subjects in this study, and the educational phenomenon is different from other parts of the world. Future research is recommended to test research models of Generation Z youth in other countries.

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How Can Teachers Facilitate Computer-Supported Collaborative Learning? A Literature Review of Teacher Intervention in CSCL

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Abstract. Computer-supported collaborative learning (CSCL) has evolved rapidly in the last three decades, and teacher interventions have regained attention. Based on 106 articles in *The International Journal of Computer-Supported Collaborative Learning*, the study focuses on teacher intervention in CSCL, summarizing three significant issues regarding their definition, mechanism, and theoretical foundation. The definition includes the definition of teacher and intervention in CSCL. The mechanism of teacher intervention consists of six aspects of intervention content, intervention level, intervention timing, intervention method, technical tools of intervention, and influencing factors. The theoretical foundation includes Knowledge Building Theory, Script Theory, Social Cognitive Theory, and Instrumental Genesis Theory. Finally, this paper proposes a framework for teacher intervention in CSCL, aiming to provide theoretical and practical references for CSCL-related teachers and researchers, enhancing teachers' literacy of learning sciences.

Keywords: Teacher Intervention · CSCL · Learning Sciences · Literature Review

1 Introduction

In the past three decades, Computer Supported Collaborative Learning (CSCL) has flourished since its birth and has become one of the essential fields of Learning Sciences [1]. CSCL is a learner-centered learning approach in which a learning community constructs meaning, communicates emotions, and exercises collaborative skills in learning activities with computer technology support, such as network technology [1]. However, any learner-centered learning approach, including computer-supported collaborative learning, does not automatically guarantee excellent and expected learning outcomes after initiating learning, so teacher intervention is essential [1]. For teacher development, teachers' understanding and mastery of modern information technology and its appropriate application to guide and intervene in students' learning routes and strategies has

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also become a hallmark of modernizing teacher education. The limited relevant research also still calls for continued attention to teacher interventions that guide teachers to intervene in students' collaborative processes [2].

The International Journal of Computer-Supported Collaborative Learning (*ijCSCL*) is the official journal established by the International Society for the Sciences of Learning in 2006. This journal is dedicated to the field of CSCL, reflecting the evolutions of CSCL. Besides, a wide range of keywords are studied in the field of CSCL, and it is better to dig deeper into ijCSCL than to search generally. Therefore, the *ijCSCL* was selected as the primary literature source for this study. In the advanced search function of the Web of Science database, combined with wildcards, we identified topic = "teacher intervention*," topic = "teacher*," topic = " facilitator*" AND journal source = " International Journal of Computer-Supported Collaborative Learning" and the time frame was set between January 1, 2006, and December 31, 2021, the first 15 years of *ijCSCL*. At the same time, this paper considers other important literature in the Web of Science core collection and CNKI databases in a snowball approach to systematically sort out the definition, mechanism, and theoretical foundation of teacher intervention in CSCL.

2 Definition of Teacher Intervention in CSCL

The term "teacher" refers to both the social role of teaching and the person who holds that role. The role varies with learning activities. In contrast to didactic learning, the teacher in collaborative learning is not only the instructor of knowledge but also the guide and learning partner of students. They need to design collaborative tasks and rhythms appropriate to the level of the learners [3].

For CSCL, computers enrich the resources and environment in the process but separate people, time, and space [4], placing higher demands on the teacher's role and behavior. As shown in Table 1, teachers need to perform appropriate behaviors to influence

Table 1. Teacher connotations in CSCL: teacher roles and behaviors.

Roles	Definitions of the role	Behaviors
Designer	Design of learning resources, collaborative processes [6]	Design of meaningful tasks
Developer	Concrete implementation of the design [6]	Development of collaborative resources and scripts
Manager	Management of learning resources and collaborative learning process [6, 7]	Coordination of collaborative progress, learner collaboration status
Supporter	Support in all aspects of technology, resources, knowledge, and emotions [4, 6, 7]	Answering learners' questions, caring for learners' emotions
Evaluator	Evaluating collaborative learning [8]	Evaluate the effectiveness of collaborative learning

the process from five aspects: designer, developer, manager, supporter, and evaluator, i.e., observing collaborative status, managing the collaborative process, and supporting collaboration by "asking questions, hinting, encouraging, and guiding" [5].

3 Mechanisms of Teacher Intervention in CSCL

3.1 Content of Teacher Intervention

Collaborative Role. Collaborative role refers to the behavioral pattern of learners in the collaboration process, and good role classification is an essential guarantee for effective collaborative learning. There are two main ways to classify collaborative roles: one is scripts role, in which roles are predetermined before the collaboration, such as assigning group leaders in advance; the other is emergent leadership, which means that without setting leaders and collaborative roles in advance, the group will automatically assign roles and emerging leaders during the collaboration process [9]. Gressick et al. adopted emergent leadership in an online asynchronous discussion activity with future teachers. It was found that emergent leadership was highly present among group members, with all members having appropriate collaborative roles and working together to advance the collaborative learning process. Teachers involved in group activities were usually contributors to topic control and argument development [10]. Based on this, Mercier et al. further refined the emergent leadership roles-intellectual leadership and organizational leadership [11]. Intellectual leadership refers to controlling the direction of topics and ideas during the collaborative process, such as bringing back the discussion that has gone off-topic. Organizational leadership refers to participants who plan, organize, manage, and confirm the group's collaborative process, such as organizing the division of labor among members and setting time points. The higher the number of intellectual leadership behaviors, the more successfully the task was completed.

Knowledge Building. Knowledge building (KB) actively constructs knowledge and continuously improves collective wisdom through communication and negotiation [12]. Krange et al. [13] organized students to solve biological problems using computer-supported three-dimensional models. During the collaboration, they found that learners encountered challenges in knowledge building and required significant teacher support to bridge the gap between experimental fundamentals (conceptual knowledge) and procedural understanding (procedural knowledge) [1]. There are two points that teachers can focus on. The first is to focus on students' improvisational representations. For example, Steier et al. [14] observed that learners in CSCL used a variety of improvisational representations, such as words, gestures, numbers, and body movements to describe map transformations. They found that improvisational representations extended collaborative meaning-making beyond verbal dialogue. The second concerns knowledge building [15]. Scardamalia proposed twelve principles of knowledge building to organize the collaborative learning process [16], which teachers can flexibly apply to involve learners in knowledge construction activities such as the production of artifacts and social practices, like Tao et al. had students ask questions of interest around the human body system, jointly developed a "big question" chart. Students continuously reflected on and modified the list of questions with the teacher's support, engaging in dynamic knowledge building [12].

Social Emotion. The Behavior and Interaction of Group Members Determine Social Emotion. It is a multiple entity of cognitive, sensory, emotional, and physiological responses, cognitive processes, and action tendencies, as well as one of the internal conditions and outcomes of collaborative learning [17]. Previous studies have found that anxious members may lead to poor group collaboration outcomes, which can further lead to anxiety, entering a vicious cycle [18]. Positive affect can enhance the gains of learners in CSCL as well as their competitiveness in competitive games [19]. Teachers can intervene by setting questions and organizing positive discussions and conversations. For example, Naykki et al. found that positive discussions in each step stimulated socioemotional support [20].

3.2 Levels of Teacher Intervention

The level of teacher intervention depends on the level of collaborative learning, which varies from individual, group, class, or community, or even cross-community collaboration, covering individual learners to learning communities [21]. Researchers have found that different levels of collaborative learning have different learning effects, such as cross-community partnership enabling students to construct a better understanding of the subject [21].

Studies have also focused on the transitions and connections between levels of collaboration from a systems perspective, giving some insight into teacher interventions. For example, by tracing the life cycle of a topic through the different levels of individuals, groups, and communities (from topic generation to topic closure), Vogler et al. reveal that the collaborative system evolves through learners' continuous responses that teachers can intervene during the topic life cycle [22]. Borge et al. found that teacher encouragement could make collaborative learners at the margins become collaborative learners at the center, playing a critical role in student collaboration [23].

3.3 Timing of Teacher Intervention

The timing of teacher intervention refers to the stage of teacher intervention in the collaborative process, and different timing of intervention has separate focus and effect in implementing teacher intervention. For example, Strauss et al. intervened by providing visual information, such as the contribution of learners to collaboration. They found that groups that intervened at the beginning tended to have more even participation and higher satisfaction [24]. Then how can teachers determine the timing of interventions? Schwarz et al. suggested that students' discussions can be observed and analyzed to grasp their needs for technical support and topic focus [25]. Ligorio et al. proposed that the rhythm of learners' collaborative learning depends on the tools used, the purpose of the activity, and the functions learners use to achieve their goals. Therefore, the timing and content of teacher interventions can be determined from the planned learner's learning rhythm through a unified software tool [26].

3.4 Strategies for Teacher Intervention

There are different criteria for classifying teacher interventions: direct and indirect interventions according to whether teachers have direct contact with learners; one-to-one and one-to-many interventions according to the number of learners in connection; individual interventions, group interventions, and group interventions according to the level of interventions. This study extracted the following four intervention strategies from a practical perspective by combining specific CSCL studies.

Build a Collaborative Environment for Learners. The collaborative environment is essential for learners to carry out joint activities and obtain collective resources. We can use games or game elements to build a gamified collaborative environment for learners [27], as game content can be used for collaborative learning. For example, Silseth et al. developed a computer game and used the game to record data from learners' interactive conversations. It was found that the content in a computer game can be an essential learning resource for collaborative learners [28]. Hamalainen et al. conducted vocational education instruction in 3D games. They found that when games mediated teacher-student interactions, teachers spontaneously developed new methods to support collaborative learning processes [29]. For example, Bielaczyc et al. conceptualized the knowledge forum as a collaborative space for "playing epistemic multiplayer games," allowing learners to participate more effectively in a community of knowledge building through the action of games [30]. Brom et al. integrated competitive elements into team games by having learners play social role-playing. They found that learners were generally positive and quickly entered a state of mind-flow [19].

Improve Learners' Group Awareness. Group awareness (GA) refers to the mutual perception of learners triggered by technical support that provides information about their peers' perceptions, social attributes, and collaborative learning behaviors [31]. Different classifications and effects of group awareness depend on the perceived information and the level of perception [31, 32]. Ollesch et al. provided learners with a wiki-based collaborative writing environment and designed a 2x2 experiment to explore the effects of cognitive awareness information, behavioral awareness information, and in combination, and found that both alone and in combination had positive effects on cognition and behavior. Still, only combining the two enhanced the quality of writing outcomes [32].

Provide Learners with Task and Process Prompts. Harney et al. set up two groups in a CSCL course, one with only task prompts and the other with task prompts and more specific process prompts. Learners in both groups were required to discuss the negative consequences of online social media use. It was found that learners in the group given task and process prompts showed higher collaborative learning efficacy and produced more argumentative discourse [33].

Guide Learners to Reflect. Allowing learners to reflect refers to reflecting on the collaborative process. For example, Johansson et al. recorded videos of students' collaborative learning. When debriefing, they asked learners to talk about their own peer's collective behaviors from a third-person perspective, which helped learners to reconceptualize their collaborative learning performance with others and improve their collaborative awareness [34]. Further, Yang et al. had previously low-performing learners reflect on their performance. They found their focus on knowledge construction goals increased significantly, as did their subsequent discursive influence on knowledge construction in collaborative learning [35].

3.5 Technical Tools for Teacher Intervention

The potential separation of person, time, and space in CSCL challenges teachers to keep track of learners' collaborative progress and provide timely instruction. Using the necessary technologies and tools to support teacher interventions, such as learning analytics and learning analytics dashboards [37] is essential. Learning analytics technologies can use learning-related data to reveal learning patterns, predict factors that impede learning, and provide timely interventions [36]. For example, it can help teachers optimize online discussions and pair learning partners by analyzing the content of student discussions [27], or it can help teachers control collaborative progress by graphically and visually showing the progress of group collaboration [37, 38].

Learning analytics dashboards are the most typical manifestation of learning analytics technology that can help teachers to intervene effectively [37]. Schwarz et al. designed and developed a learning analytics dashboard that alerts teachers when students encounter difficulties (e.g., off-topic discussions, technical problems, etc.). The results showed that teachers who received warnings could successfully coordinate the progress of multiple groups, answer or resolve complex student problems, and control the progress of group collaboration compared to teachers who did not have dashboard alerts [38].

3.6 Influencing Factors of Teacher Intervention

Teacher interventions are teacher-initiated behaviors that ultimately act on learners. Thus, teacher interventions are influenced by the teacher, the learner, and the relationship between the two parties. Regarding teachers' beliefs, Song et al. examined two examples of teachers teaching math fractions. They found that each of the two teachers held two beliefs, an innovation-oriented belief that students learn better in a computer-supported learning environment. The other was a teacher-centered conception that students can only learn well if they understand the concepts under the teacher's guidance. The study found that in practice guided by innovation-oriented beliefs, students demonstrated the birth of the idea of "division." In contrast, in approaches recommended by teacher-centered thinking, students' inquiry processes are highly homogenized [39]. Learners' beliefs affect the effectiveness of teachers' interventions. Rourke et al. studied students' argumentation and reasoning in the forum and found that critical argumentation was rare [40]. Interviews revealed that students perceived criticism as a personal attack and needed to establish a proper perception of the course content. Teachers need to give students further examples of "critical speaking" practices. In terms of teacher-student relationships, Madaio et al. conducted a study on the impact of the closeness of the relationship on teacher-student interventions. They found that the higher the intimacy of the relationship, the more direct the expression of the tutor's intervention and the more problems the learner solved [41].

4 Theoretical Foundation of Teacher Intervention in CSCL

A review of research on teacher intervention mechanisms reveals that teacher intervention in CSCL relates to many theories, such as Knowledge Building Theory, Scripting Theory, Social Cognitive Theory, and Instrumental Genesis Theory. The previous research cases explicitly mentioned knowledge construction theory and scripting theory. In contrast, although social cognitive theory and instrumental origins theory were not expressly mentioned earlier, both can support teacher interventions from macro and micro perspectives.

4.1 Knowledge Building Theory

In contrast to constructivist theory, Knowledge Building Theory (KBT) focuses more on deep knowledge building, i.e., learners' involvement in problem-solving, community construction, and understanding complex concepts [42]. This theory emphasizes that learning is the process of building knowledge and can rely on tools such as Knowledge Forum [12]. As for teacher intervention, Scardamalia, one of the founders of the theory, proposed twelve pedagogical principles to support teachers in CSCL, such as taking practical and authentic problems as a starting point, respecting students as active subjects of construction, and so on [16]. There have been empirical studies that have demonstrated the validity of KBT. For example, Tao et al. point out the validity of involving students in the construction of knowledge in a dynamic "body system" with the support of the teacher [12].

4.2 Scripting Theory

Scripting Theory is a classic approach to facilitating learning and developing collaborative skills in CSCL [43]. "Scripts are pedagogical scaffolds for learners to co-construct group knowledge in a collaborative learning process. There are two types of scripts: internal and external scripts [44]. The former are the patterns in learners' minds that help them build cognitive structures. The latter are representations of external resources the teacher or instructional designer predetermined, such as a sequence of tasks for making artifacts [45]. As for teacher intervention, teachers often encounter many problems in developing scripts regarding design, evaluation, and implementation [46]. Many researchers have conducted related explorations, such as Zheng et al., who worked on improving collaborative scripts and summarized three indicators that teachers can refer to the range of knowledge activated, the degree of knowledge construction, and the degree of interaction of collaborative methods [47].

4.3 Socio-cognitive Theory

Socio-cognitive theory (SCT) assumes that an individual's behavior is related to themself and the social environment they live [48]. The core of the approach is Triadic Reciprocal Determinism [48], meaning that when learners are in a learning environment, three factors, environment, behavior, and personal factors, interact with each other. Among them, environmental factors refer to the school, classroom, teacher, peers, and learning materials, which Lu et al. refined into student cohesion, teacher support, engagement, equity, cooperation, task orientation, and investigation, as well as computer use, differentiation, and learner's mental temperament. Behavioral factors refer to the actual behavior of learners and include preparatory behavior (preparing learning materials), classroom learning behavior (participating in collaborative activities), and post-learning behavior (completing assignments) [49]. Personal factors include psychological, emotional, and physical factors, such as the learner's perception of the environment [23, 50]. Teacher interventions guided by SCT in CSCL can revolve around three factors, for example, building a gamified learning environment [30].

4.4 Instrumental Genesis Theory

Instrumental Genesis Theory (ITT) connects society and technology through tools. Tools are defined as a hybrid entity consisting of two parts: artifacts (technology) and usage solutions (society). The tools are also different if the artifacts are the same but used differently. Instrumental Genesis Theory in CSCL is mainly used to explain how artifacts are generated through learner-teacher interactions in classroom activities [45]. In addition to its use in classroom activities for an explanation, Carvalho et al. tracked how artifacts were designed before collaborative learning began to inform subsequent teacher design [51]. Lonchamp et al. also found that tools mediate CSCL collaborative tasks and discussion activities and can bring new ideas and support to teachers when utilizing artifacts [52].

5 Conclusion and Future Work

Based on the above analysis, this study proposes a framework for teacher intervention in CSCL to provide an overview of this field, as shown in Fig. 1. Regarding theoretical foundation, Knowledge Building Theory can indicate the content and principles of interventions for teachers, Scripting Theory can help teachers develop collaborative roles and design collaborative processes, Socio-Cognitive Theory can give teachers interventions, and Instrumental Genesis Theory gives teachers an understanding of "artifacts and tools."

In terms of the content of the intervention, teachers can help learners identify collaborative roles through scripts and emergent leadership. While focusing on learner behavior, teachers can focus on establishing intellectual leadership roles and learner improvisation [53]. Regarding the level, teachers can raise the level of collaborative learning of learners from individual to learning community to give learners a higher sense of collectivity. Regarding the timing, there are different intervention priorities for pre- and post-collaboration. In terms of strategies, gamified collaborative environments, group perceptions, task process prompts, and reflection are all measures that can be directly drawn upon. Regarding technology and tools, learning analytics and learning analytics dashboards can inform the timing and content of teacher interventions. Regarding influencing factors, teachers' beliefs, learners' perceptions, and teacher-student relationships all affect the effectiveness of interventions. Attention should be paid to teachers' creativity and openness and building good teacher-student relationships.

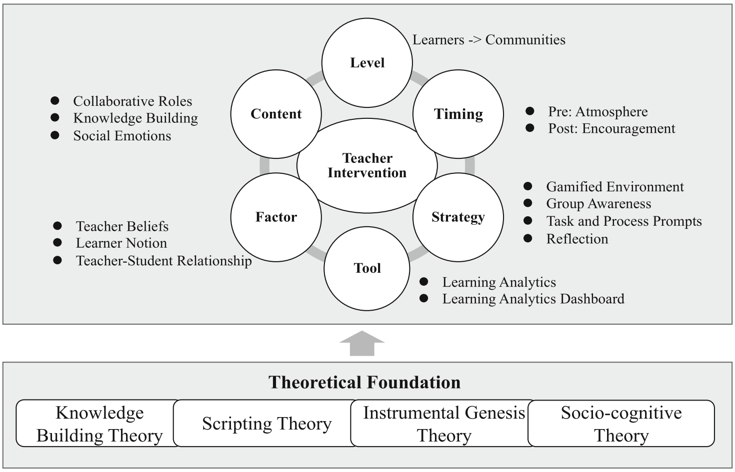

Fig. 1. Framework for teacher intervention in CSCL

CSCL is a learner-based learning approach that plays an increasingly important role in developing learners' 21st-century skills. Future research and practice on teacher interventions in CSCL could focus first on the impact of teacher understanding on instructional design and the integrity of learners' collaborative learning diversity and inquiry ideas [39]. Second, the role of learning analytics in teacher interventions should be emphasized. Data should be recorded and analyzed throughout the design and implementation process to help teachers develop adaptive collaborative scripts. Finally, the role of different types of social-emotional production and how teachers should begin interventions deserve further attention and research.

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Assessing Secondary Students' Digital Literacy Using an Evidence-Centered Game Design Approach

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Abstract. This study measured secondary students' digital literacy using a digital, game-based assessment system that was designed and developed based on the Evidence-Centered Game Design (ECGD) approach. A total of 188 valid secondary student samples were included in this study. Fine-grained behavioral data generated from students' gameplay processes were collected and recorded with the assessment system. The Delphi method was employed to determine the feature variables extracted from the process data that were related to digital literacy, and the Analytic Hierarchy Process (AHP) method was used to construct the measurement model. The assessment results of the ECGD-based assessment had a high correlation with the standardized test scores, which have been shown to be reliable and valid in previous large-scale assessment studies.

Keywords: digital literacy · digital game-based assessment · ECGD · assessment model

1 Introduction

With the wide application and rapid development of the Internet, artificial intelligence, and big data in social life, the digital transformation of all walks of life is accelerating. Digital literacy is the comprehensive ability to use information technology to access and communicate information, create digital content, and comply with online ethics in order to adapt to the requirements of digital society [1]. China has attached great importance to digital literacy and has issued relevant policies for promoting it. In November 2021, the Office of the Central Cyberspace Affairs Commission of China released "Action Guideline for Enhancing Digital Literacy and Skills for All", which clearly articulates the need to enhance digital literacy and skills for all people [2]. In April 2022, China's Ministry of Education released the Information Technology Curriculum Standards for Compulsory Education, which explicitly set digital literacy cultivation as the central goal of the curriculum [3].

Digital literacy assessment is necessary for accurately grasping students' digital literacy development level, and it is the basic premise of the promotion of students'

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digital literacy. Currently, digital literacy assessment has mainly adopted the "question-answer" test design paradigm, with self-reported scales and standardized tests as the main assessment tools [4]. However, these fail to accurately reflect students' digital literacy in real-world scenarios. For example, Nguyen and Habók found that the assessment results of self-reported scales have a low correlation with students' digital literacy performance in real-life situations [5].

To address the limitations of existing studies, this study used the ECGD approach to evaluate students' digital literacy. ECGD is an evaluation paradigm driven by theory and data. In terms of theory, ECGD-based assessment emphasizes the design of gamification tasks based on evaluation indicators to induce relevant performance from students and thereby obtain fine-grained process data [6]. With respect to data, ECGD-based assessment advocates extracting evidence that reflects students' ability and literacy from complex process data, namely characteristic variables, to achieve evidence-based reasoning [7].

This study proposes a new assessment method for students' digital literacy, which could provide more abundant and reliable evidence for evaluating students' digital literacy levels.

2 Literature Review

2.1 Digital Literacy

The concept of digital literacy was first proposed in 1997 by Yoram Eshe-Alkalai, who viewed digital literacy as a necessary survival skill in the digital age. It includes the ability to use software or operate digital devices, a large variety of complex cognitive, motor, sociological, and emotional skills used in a digital environment, and the ability to perform tasks and solve complex problems in a digital environment [8]. With the real advent of the digital age, digital literacy is generally regarded as a comprehensive ability for individuals to learn, work, and develop in the digital society. However, the interpretation of its specific definition is slightly different. There are three typical views of the conceptual definition of digital literacy. The first view emphasizes the aspect of digital skills. For example, Calvani (2009) proposed that digital literacy is the ability to flexibly explore and confront new technological situations, to analyze, select, and critically evaluate data and information, to explore the potential of technology, and to effectively articulate and solve problems [9]. The second view emphasizes digital practices and creativity. For example, the American Library Association defined digital literacy as the ability to use information and communication technologies to discover, evaluate, create, and communicate information [10]. The third view addresses the aspects of digital security and ethics. For example, the Office of the Central Cyberspace Affairs Commission of China proposed that digital literacy is a collection of qualities and abilities that citizens in a digital society should possess in their learning and working lives, such as digital access, production, use, assessment, interaction, sharing, innovation, safety and security, ethics, etc. [2].

Based on the above points of view, our research team posits that digital literacy is a typical embodiment of information literacy in the digital age, comprising the awareness, ability, and literacy of individuals to properly use information technology to acquire, integrate, manage, and evaluate information; understand, construct, and create new knowledge; and to discover, analyze, and solve problems. Digital literacy comprises four dimensions: information awareness and attitude (IAA), information knowledge and skills (IKS), information thinking and behavior (ITB), and information social responsibility (ISR) [1].

2.2 Game-Based Assessment of Digital Literacy Based on ECGD

ECGD is a theory derived from ECD that integrates gamification tasks with assessment design [11]. ECD theory emphasizes the construction of complex task situations, obtaining multiple types of procedural data, and achieving evidence-based reasoning. The conceptual assessment framework of ECD comprises three core models: the student model, evidence model, and task model. The student model defines the knowledge, skills, and abilities (KSAs) to be measured. The evidence model describes how to update the information for student variables in the task model based on the test-takers' performance in the task. Task models describe how to structure different kinds of situations to evoke student performance to obtain data. ECGD extends this framework by integrating gamified tasks into the ECD assessment paradigm. ECGD-based assessment approach emphasized creating complex, realistic tasks to evoke student performance on KSAs, which are conducive to reflect students' digital literacy in real-life scenarios. Students' gameplay processes can also generate rich and complex process data, which can provide abundant evidence to reflect students' KSAs.

Many researchers have used ECGD to assess higher-order thinking skills. For example, Chu et al. (2018) developed a digital game-based assessment tool based on ECGD to measure scientific knowledge and skills. The results showed that students' mastery of the overall skill could be well predicted by task-related behavioral features [12]. Bley (2017) developed a digital game that used the ECGD approach to measure intrapreneurial competencies; the results showed that learners' intrapreneurial competencies can be accurately measured in this fashion, as can their cognitive performance during the task. However, few empirical studies have been conducted yet on digital literacy assessment [13]. Although our research team has previously developed a digital game for assessing students' digital literacy based on ECGD, our research only proposed a conceptual framework and designed a tool, which has not yet been validated with empirical measurement data [14].

3 Methods

3.1 Participants

The participants were 210 seventh-grade students randomly selected from five classes at a middle school in Wuhan, including 114 boys and 96 girls. All participants were informed of the research purpose and were required to sign formal consent forms to participate in the study.

3.2 Instruments

Digital Game-Based System for Assessing Students' Digital Literacy

This study utilized the narrative game "Guogan's Journey to A Mysterious Planet", previously developed by our research team [14], to assess students' digital literacy. The game comprises 13 tasks involving the four dimensions of digital literacy. Students are given two chances to complete each task. When a student finishes a task incorrectly twice, the system presents a Pass card and begins the next task. During gameplay, students gain different gold coins according to their task performance. Students can choose whether to click a "help" button during the gameplay process; doing so costs them coins. They can also click a "return" button to return to the previous page to confirm information.

Table 1 shows the details of the gamification tasks, including the task type, the corresponding dimension, and the observed variables. The observed variables include: completion time (the time period elapsed from when the player starts answering to when the task is completed); thinking time (the total time the mouse stayed in different areas of the interface during the students' answering process); correctness (whether the task was completed correctly or not); answer times (whether students completed the task successfully the first time); help times (number of times the "help" button was clicked); return times (number of times the "return" button was clicked); similarity (the similarity of the action sequence with the reference sequence) efficiency (the efficiency of the action sequence).

Table 1. Description of the gamification tasks

<table>
<tr><th>Task</th><th>Task Type</th><th>Dimension</th><th>Observed variables</th></tr>
<tr><td>Tasks 1,3,6,10,11</td><td rowspan="4">Multiple-choice question</td><td>IAA</td><td rowspan="4">completion time, thinking time, correctness, answer times, help times, return times</td></tr>
<tr><td>Tasks 2,13</td><td>ITB</td></tr>
<tr><td>Task 7</td><td>ISR</td></tr>
<tr><td>Task 8</td><td>IKS</td></tr>
<tr><td>Task 4</td><td>The maze</td><td>IKS</td><td rowspan="4">completion time, thinking time, correctness, answer times, help times, return times, similarity, efficiency</td></tr>
<tr><td>Task 5</td><td>Dragging question</td><td>IKS</td></tr>
<tr><td>Task 9</td><td>Matching question</td><td>IKS</td></tr>
<tr><td>Task 12</td><td>Sorting question</td><td>ISR</td></tr>
</table>

Standardized Test

In order to verify the results of the digital game assessment, this study used a standardized test of digital literacy, comprising 30 multiple-choice items, designed in our previous study [1], which has been proven to be a reliable instrument for measuring secondary students' digital literacy.

3.3 Data Collection and Storage

With the help of the school administrators, the digital literacy assessment was conducted in the middle school's computer lab. Students were required to complete the digital game and the standardized test within 40 min. The digital game assessment system used the xAPI-based statement to record the data generated during the gameplay process. The xAPI-based statement describes students' behavioral process with the following elements: Actors (students), Task (the game task to be completed), and Context (the game context). There are four elements describing the behavioral process related to a task: Verb (actors' behavior in a task), Object (the object operated on by actors), Tool (the tool employed by actors), and Timestamp (behavior occurrence time). The xAPI-based process data was stored in the JSON format in the database of the assessment system.

3.4 Data Pre-processing and Analysis

After matching the xAPI-based process data and the standardized test data, a total of 210 students' data were collected. The data were then pre-processed in the following steps: 1) processing of missing data. A total of 10 student samples were excluded, in which the majority of the tasks were not finished. For student samples with a few missing data items, mean values were used to replace the missing values; 2) processing of abnormal data. A total of 12 pieces of data were eliminated due to repeated submitted answers. The remaining 188 student samples were used for data analysis in this study.

The Delphi method was employed in this study to determine the feature variables for constructing the assessment model of students' digital literacy. Specifically, an "expert advisory group" was established, composed of 14 scholars, teachers, and researchers in the field of digital literacy assessment. They were invited to complete a survey, in which they were required to determine the feature variables of each task related to students' digital literacy performance, and sort these feature variables according to their importance. Then, the AHP method was used to determine the weight of the feature variables. Specifically, the analysis steps were: 1) construction of a judgment matrix by pairwise comparison of the importance of feature variables; 2) calculation of the weights of the feature variables for each task; and 3) verification of the consistency of the judgement matrix [15].

4 Results

4.1 Construction of the Assessment Model for Digital Literacy

Determination of the Feature Variables

Through the analysis of the questionnaires submitted by the experts, the applicable feature variables for each task were identified, as shown in Table 2. According to Table 2, return times were regarded as an inapplicable feature variable for all tasks, while completion time, thinking time, and correctness were identified as feature variables for Tasks 1, 2, 3, 11, and 13. With respect to Tasks 5, 9, and 12, the feature variables except for return times were regarded as useful variables for evaluating students' digital literacy.

Table 2. The feature variables of each task as identified by experts

Task	Feature variables							
	CT	TT	CO	HT	AT	EF	SI	RT
Task 1	√	√	√	×	×	×	×	×
Task 2	√	√	√	×	×	×	×	×
Task 3	√	√	√	×	×	×	×	×
Task 4	√	√	×	√	×	√	√	×
Task 5	√	√	√	√	√	√	√	×
Task 6	√	√	√	√	√	×	×	×
Task 7	√	√	√	√	√	×	×	×
Task 8	√	√	√	×	√	×	×	×
Task 9	√	√	√	√	√	√	√	×
Task 10	√	√	√	√	√	×	×	×
Task 11	√	√	√	×	×	×	×	×
Task 12	√	√	√	√	√	√	√	×
Task 13	√	√	√	×	×	×	×	×

NOTE: CT: completion time; TT: thinking time; CO: correctness; HT: help times; AT: answer times; EF: efficiency; SI: similarity; RT: return times

Calculation of the Weight of Feature Variables

The AHP method was then applied to the data. First, the weights of the feature variables of each task were calculated; the values of the average random consistency index RI ranged from 0 to 1.59. Table 3 shows the calculation results of the weights of the feature variables for each task.

Table 3. Calculation results of the weights of the feature variable for each task.

Task	Feature variables						
	CT	TT	CO	HT	AT	EF	SI
Task 1	0.254	0.114	0.632	/	/	/	/
Task 2	0.263	0.119	0.618	/	/	/	/
Task 3	0.276	0.118	0.606	/	/	/	/
Task 4	0.162	0.130	/	0.266	/	0.291	0.151
Task 5	0.138	0.112	0.220	0.089	0.106	0.168	0.167
Task 6	0.104	0.069	0.422	0.173	0.232	/	/

(*continued*)

Table 3. (*continued*)

Task	Feature variables						
	CT	TT	CO	HT	AT	EF	SI
Task 7	0.110	0.071	0.432	0.181	0.206	/	/
Task 8	0.215	0.131	0.441	/	0.213	/	/
Task 9	0.131	0.106	0.242	0.103	0.113	0.149	0.156
Task 10	0.139	0.074	0.427	0.190	0.170	/	/
Task 11	0.241	0.118	0.641	/	/	/	/
Task 12	0.101	0.109	0.262	0.094	0.114	0.168	0.152
Task 13	0.237	0.126	0.637	/	/	/	/

Construction of the Assessment Model
Based upon the weights of the digital literacy evaluation indicators for primary and secondary students as obtained in our previous study [1], and also upon the weighting results of the above analysis, the linear mathematical expression of the digital game-based digital literacy assessment model is as follows:

$$Y = 0.295 * Y1 + 0.170 * Y2 + 0.289 * Y3 + 0.246 * Y4 \tag{1}$$

wherein,

$$\begin{aligned} Y1 = {} & 0.20 * (B1 * 0.114 + B2 * 0.254 + B3 * 0.632) + 0.20 * (B1 * 0.069 + B2 * 0.1 \\ & 04 + B3 * 0.422 + B4 * 0.173 + B5 * 0.232) + 0.20 * (B1 * 0.119 + B2 * 0.263 + B \\ & 3 * 0.618) + 0.20 * (B1 * 0.131 + B2 * 0.215 + B3 * 0.441 + B4 * 0.213) + 0.20 * (B \\ & 1 * 0.106 + B2 * 0.131 + B3 * 0.242 + B4 * 0.103 + B5 * 0.113 + B6 * 0.149 + B7 \\ & *0.156) \end{aligned} \tag{2}$$

$$\begin{aligned} Y2 = {} & 0.5 * (B1 * 0.126 + B2 * 0.237 + B3 * 0.637) + 0.5 * (B1 * 0.071 + B2 * 0.11 \\ & 0 + B3 * 0.432 + B4 * 0.181 + B5 * 0.206) \end{aligned} \tag{3}$$

$$\begin{aligned} Y3 = {} & 0.25 * (B1 * 0.074 + B2 * 0.139 + B3 * 0.427 + B4 * 0.190 + B5 * 0.170)+ \\ & 0.25 * (B1 * 0.118 + B2 * 0.241 + B3 * 0.641) + 0.25 * (B1 * 0.130 + B2 + 0.162 \\ & +B4 * 0.266 + B6 * 0.291 + B7 * 0.151) + 0.25 * (B1 * 0.112 + B2 * 0.138 + B3 \\ & *0.220 + B4 * 0.089 + B5 * 0.106 + B6 * 0.168 + B7 * 0.167) \end{aligned} \tag{4}$$

$$\begin{aligned} Y4 = {} & 0.5 * (B1 * 0.118 + B2 * 0.276 + B3 * 0.606) + 0.5 * (B1 * 0.109 + B2 * 0.1 \\ & 01 + B3 * 0.262 + B4 * 0.049 + B5 * 0.114 + B6 * 0.168 + B7 * 0.152) \end{aligned} \tag{5}$$

In the above expressions, Y1, Y2, Y3, and Y4 represent the four dimensions of digital literacy, namely IAA, IKS, ITB, and ISR; B1-B7 represents the values of the seven feature variables, namely thinking time, completion time, correctness, help times, answer times, similarity, and efficiency.

Among these, the values for thinking time and completion time needed to be processed and then weighted. According to the experts' suggestions, the data in terms of thinking time and completion time were processed as follows: 1) reasonable time ranges of students' thinking time and answering time were determined based on the corresponding time distributions; 2) the duration of thinking time and completion time were divided within reasonable time intervals into four parts (10%, 40%, 70%, and 100% of the duration); 3) values were assigned to different durations, with the principle that the longer the duration, the lower the score. For example, if a student's thinking time fell with the top 10% of the reasonable time range, then a value of 1 was assigned; if a student's thinking time fell with 100% of the reasonable time range, then a value of ¼ was assigned. Additionally, a value of 1 or 0 was assigned to the variable of correctness depending on whether the student answered correctly or incorrectly; a value of 1 was assigned to the variable of help only if the students did not click the "Help" button, otherwise 0 was assigned; a value of 1 was assigned to the variable of answer times only if the student answered correctly the first time. The values of similarity and efficiency were calculated using the Levenshtein distance.

4.2 Description Analysis of the Digital Game-Based Assessment Results

Based on the above assessment model, the mean scores of the students' digital literacy and the four dimensions were calculated, as shown in Fig. 1. The students were found to have demonstrated moderate level of digital literacy, with an average score of 70.14. With regard to the four dimensions, the average score for ISR was 21.53, and the average score rate was 87.5%, indicating that students showed high level of information social responsibility; the average score for ITB was 13.36, with an average score rate of 78.6%; the average score for IAA was 21.12, with an average score rate of 71.6%; and the average score for IKS was 14.13, with an average score rate of 48.9%, indicating that the students lacked information science knowledge and technical skills.

4.3 Verification of the Digital Game-Based Assessment Results

The results of Pearson correlation analysis show that the correlation coefficient of the standardized test score and the game-based assessment score was 0.914. This indicates that the results of the game-based assessment for digital literacy were reliable and valid.

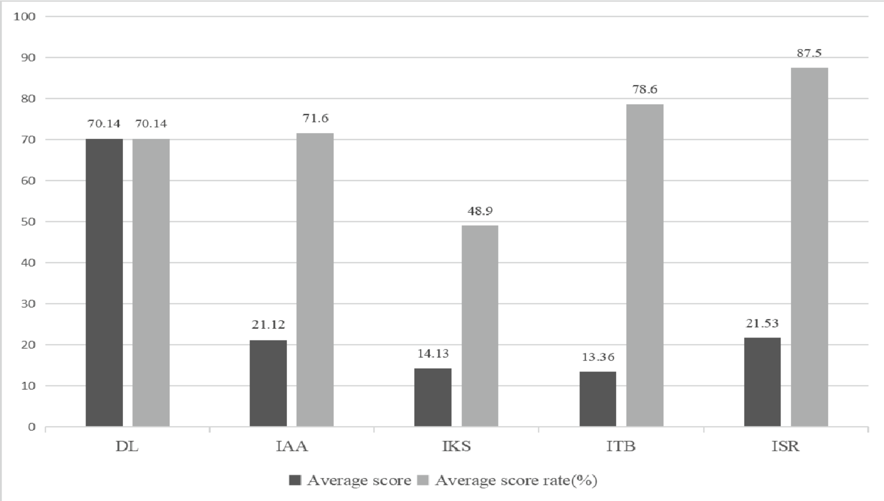

Fig. 1. Results of the digital game-based assessment of the students

5 Discussion and Conclusions

This study adopted the ECGD approach to conduct digital literacy assessment on secondary students. Specifically, we followed four steps to assess students' digital literacy, including using gamification tasks to evoke students' performance related to digital literacy with the digital game-based assessment system we developed in our previous study, extracting feature variables from process data generated from students' gameplay processes, and constructing an assessment model with the Delphi method and the AHP method to measure students' digital literacy. Pearson correlation analysis showed that the digital game-based assessment results were consistent with the standardized test score, indicating that the ECGD-based digital literacy assessment appears to be reliable and valid, when compared with the standardized test. The ECGD-based digital literacy assessment can collect abundant evidence for digital literacy, which is neglected by such traditional assessment methods as standardized testing. For example, by analyzing the similarity and efficiency of students' action sequences, we could analyze the hidden problem-solving processes behind the consistent answer results, thus obtaining more objective and richer insight into students' performance.Therefore, we believe that the ECGD-based assessment method is particularly suitable for evaluating such complex and implicit competencies as digital literacy.

It should be noted that this study has several limitations that point to directions for future research. First, the sample size of this study was relatively small, and future studies should be conducted with many more participants, in order to verify the validity of the ECGD-based digital literacy assessment approach with more convincing data. Secondly, although this study compared the game-based assessment results with standardized test score via Pearson correlation analysis, the ECGD-based assessment approach should be further verified in future research with psychological measurement model, such as cognitive diagnosis model.

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Museum Blended Learning Through Digital Learning Platform: The Case of Smithsonian Learning Lab

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Abstract. The COVID-19 pandemic has brought unprecedented challenges to public cultural institutions, including museums. The museums gradually recognize the significant potential of digital technology in assisting museums to enhance their accessibility. Accordingly, the necessity and urgency of digital change is becoming increasingly prominent. How to ensure that the collection starts a new life cycle after entering the digital museum space and stimulates the educational potential of the collection. This has become one of the key issues that need to be explored in the post-pandemic era when museums utilize digital learning platforms to carry out blended education and expand their educational functions. As a forerunner, the Smithsonian Institution has created an interactive museum digital learning platform named *Smithsonian Learning Lab*, which has carried out pioneering exploration in three aspects, including digital educational resources, interactive digital tools, and learning outputs. It has constructed a new model of museum blended learning in the digital ecosystem, which provides significant enlightenment and a reference for Chinese museums to develop digital learning platforms and expand their educational functions in the future.

Keywords: Museum Blended Learning · Digital Learning Platform · Digital Curation · Digital Narrative

1 Introduction

The outbreak of COVID-19 pandemic has brought unprecedented challenges to public cultural institutions, including museums. Increasingly, museums are recognizing the need and urgency for digital transformation, due to the significant potential of digital technology in assisting museums to enhance their accessibility and increase public participation. How to ensure that the collection starts a new life cycle after entering the digital museum space, as well as making good use of the dynamic and reusable characteristics of digital collections [1]. This has become one of the key issues that needs to be explored in the post-pandemic era when museums utilize digital learning platforms to carry out blended education and expand their educational functions.

Although museums in China have also begun to explore digital practices in recent years, the practices mainly confine to transporting material collections and on-site exhibitions into virtual space. For example, a three-dimensional panoramic scan of the on-site

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exhibition is presented on the museum website in the form of virtual exhibition tour, and digital scans of the artefacts are shown as high-definition pictures in digital showcases. However, audiences online often end up with aimless wandering in virtual exhibition halls due to insufficient instructions. Moreover, owing to the lack of diversified and effective application of museum cultural resources on the digital platform, the digitization of museum collections has not brought in innovative expression and diversified interpretation, and the online audience has not yet transformed from passive visitors to active learners [2].

In comparison, there are some innovative digital practices of museums internationally that are worthy of research and reference. For instance, the Smithsonian Institution, currently the largest museum, education, and research complex in the world, established the Smithsonian Office of Educational Technology (OET) in 1976 to serve public education by bringing Smithsonian collections and expertise into the nation's classrooms. OET created the Smithsonian Learning Lab in 2016, which is an interactive museum learning platform that not only displays its vast collections digitally, but more importantly provides users with interactive tools to customize their learning or instructional activities, aiming to inspire the innovative use of its rich digital materials and the sharing of knowledge on a global scale.

This paper analyzes the Smithsonian Learning Lab as an interactive digital learning platform from three aspects (see Fig. 1), including the digital resources and collections, interactive tools and features, as well as learning outputs and outcomes. The paper highlights the most conspicuous features and advantages of the Smithsonian Learning Lab, and discusses how it constructs a new model of museum blended learning in the digital ecosystem, aiming to provide enlightenment and a reference for the future development and construction of museum digital learning platform in China.

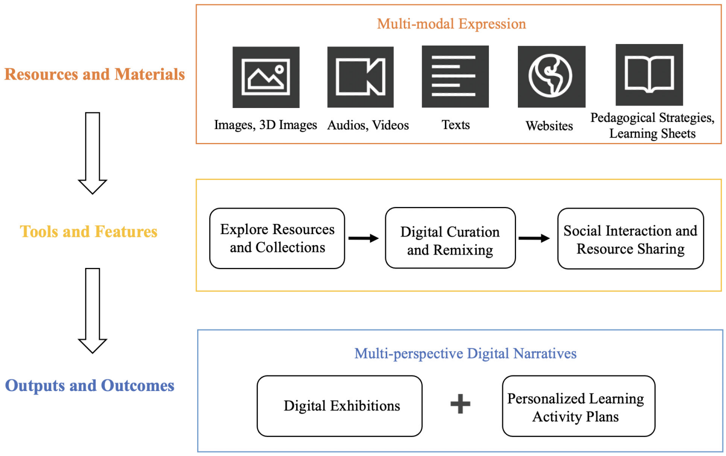

Fig. 1. Structure of Smithsonian Learning Lab

2 Learning Resources and Materials: Multi-modal Expression

Since the 1990s, the museums have been exploring the digital preservation, management and presentation of their collections. While there may be a variety of approaches to using digital museum resources for blended learning, the core idea of these pedagogical practices is that it is not limited to translating an in-person museum experience [3], but rather establish a connection between online and on-site museum learning experience [4].

Traditionally, museum education is a kind of object-based learning that takes place in a physical environment. The audience constructs meanings through in-depth observation and active exploration of the exhibits selected, organized, and designed by museum professionals according to a certain logic and format [5, 6]. Whereas, in online museums, although learners cannot physically see the collections, digital contexts can still connect learners to museum objects through their unique multi-modal expressions. As digital technologies enrich the diversity of information expression, online learning platforms allow museums to provide media and other technological resources that are underutilized in offline venues or may not be appropriate for physical museums [7]. These multi-modal learning "toolkits", composed of digital resources, offer limitless possibilities for online learning and communication, supporting online learners to build multi-dimensional, multi-sensory digital learning experiences [8–10].

Specifically, the Smithsonian Learning Lab has taken full advantage of digital technology, presenting the vast museum resources through multi-modal knowledge expression, which also forms the foundation of blended learning via the Learning Lab - digital resources. Currently, there are more than 6.17 million digital resources that are live on the Learning Lab platform, and this number is still being updated. Some of the most prominent digital resource modes include images, 3D artefacts, videos, audio recordings, websites, lesson plans, and many others.

Users can zoom in and out of digital images freely, allowing exquisite details such as texture, brush strokes, and patterns to be clearly presented. For example, users can zoom in on a character scene painted on blue and white porcelain. Details such as a person's facial expressions, clothing, and musical instruments are all brought to life (see Fig. 2). These delicate details are not easily captured by viewers in a physical exhibition. While it is often these details that highlight the ingenuity and craftsmanship of an artwork, as well as the artistic, historical, social, and scientific values behind it.

Fig. 2. Example of image zooming feature

In addition to 2D images, the Learning Lab now provides users with 3D images of approximately 1,000 pieces from the collection. For example, users can rotate and zoom in 360 degrees to see the body shape and bone structure of a tortoise (see Fig. 3), resulting in a more complete and comprehensive knowledge construction of the creature.

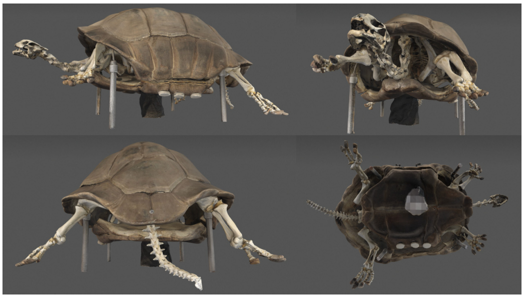

Fig. 3. Example of 3D image rotation feature

Additionally, video resource, as expression that integrate visual and auditory sensory experiences, is also an important type of learning resource within the Smithsonian Learning Lab. The platform publishes over 20,000 online video resources so far, including lesson recordings, academic webinars, interviews, documentaries, performing arts, and many others. As multi-sensory expressions, these videos are better suited to digital contexts than physical spaces. Not only can they present images, sounds, and texts at the same time, and create connections between these symbols, but they can also provide users with multi-dimensional interpretations of the collections in order to better serve the needs of various learners.

The Smithsonian Learning Lab also provides users with more than 2,600 museum learning resources from external websites, including digital exhibitions curated by Google Arts & Culture, online art history tutorials from the Smarthistory, and Project Zero Visible Thinking Routines, a teaching strategy developed specifically for museum resources by the Harvard Graduate School of Education. These external resources provide users with digital learning materials developed by other platforms based on the Smithsonian's collections. By participating in relevant online exhibitions and courses, learners construct their knowledge of the Smithsonian's collections and establish connections with other museum collections. Educators can apply museum pedagogical strategies directly to object-based instructional activities, encouraging meticulous observation and critical reflection on cultural and artistic works.

Furthermore, just as collections in physical museums require panels and labels to illustrate and interpret the exhibits, multi-modal digital resources also need to be complemented by textual information. Therefore, every digital resource contains information about object type, source, medium, dimensions, topics, copyright, etc. (see Fig. 4). The information covered appears to be similar to that in a physical museum, yet the hyperlink gives it more possibilities. For example, learners can explore other artefacts under the same topic by clicking on the keywords associated with the resource, or learn more about other artworks created by the same artist. The hyperlink structure supports multi-modal content expression in digital space, creating connections and logic between resources, and providing the audiences with a learning experience that is difficult to realize in physical space.

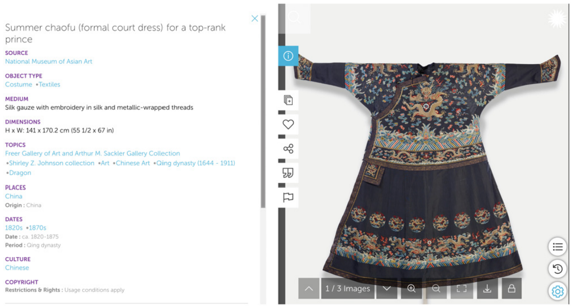

Fig. 4. Example of digital resource information

3 Learning Tools and Features

The immediate availability of digital resources can lead to a more flexible, and creative approach to museum education [11, 12]. Combined with a set of learning tools unique to the digital space, learners can make their own choices about what resources to access, who provides them, how to organize them, and how to personalize the dissemination and sharing of resources.

3.1 Exploration of Resources and Collections

With the spread of constructivism in education since the late 1980s, museum educators have gradually shifted from a collection-centered approach to a learner-centered approach, aiming to create a highly customized learning experience for audiences by focusing on their individual needs [7, 13, 14]. Visitors to museums do not come as blank slates, but with expectations and motivations as well as a wealth of prior knowledge, interests, skills, beliefs, attitudes, and experiences. All of these individual backgrounds combine not only to affect why people visit museums but also their learning experiences, and what meaning they make of such experiences [5, 15, 16].

However, constrained by the limitations of exhibition space and the uniqueness of material artefacts, it is difficult for physical museums to customize exhibition design according to every visitor's previously acquired knowledge, personal experiences, and interests. In addition, from curators drafting exhibition outlines, selecting exhibits, and interpreting artefacts, to designers working on exhibition formats, to education departments planning and implementing educational activities based on exhibitions, the entire process is led by the museum. Instead of participating in the process and contributing their own ideas and perspectives, visitors can only passively accept the official exhibitions and educational activities. Historical exhibitions, for example, are usually arranged in chronological order, which requires a basic knowledge and understanding of the historical timeline. However, for some audiences, especially children, the insufficiency of knowledge can affect their learning experience to some extent. What is more, it is often difficult for visitors without extensive museum experience to quickly locate exhibits that match with their own interests and knowledge level in a physical museum. Some visitors may even lose their direction in the oversized exhibition hall space.

Therefore, based on a constructivist perspective, the key to constructing a high-quality digital museum learning experience is to arouse the audience's interest and to connect the learning resources to their prior knowledge and personal experience [17]. The Learning Lab provides users with a tool to explore resources based on their knowledge, experience, and interests. It takes full advantage of the non-linear content structure of the Internet, as well as the replicability and reusability of digital materials, to build a robust system that maximizes the need for self-discovery.

The discovery feature of Smithsonian Learning Lab allows users to search for resources or collections by using keywords. Due to the sheer volume of Smithsonian's resources, search results typically contain tens of thousands of resources. For example, using *Chinese* as a keyword will result in 23,192 resources and 99 resource collections (see Fig. 5). To assist users in finding the resources or collections that best meet their individual needs, the platform provides a *refine research* feature that allows users to filter search results by the *metadata tags* of the resources, which includes filtering digital resources by media type (image, video, audio, text, learning resource, 3D image, etc.), subject (social studies, art, science, language, etc.), creator of the collection (Smithsonian Institution, individual user), and many others.

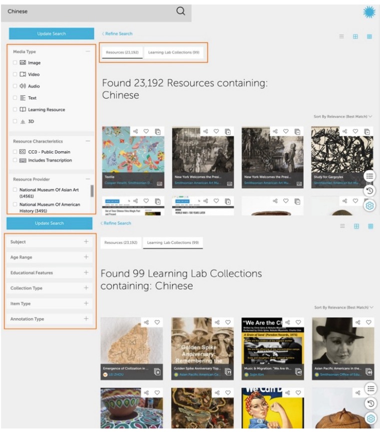

Fig. 5. Search results for keyword *Chinese*

Instead of searching for resources in a haystack, the Smithsonian Learning Lab's research refining feature provides users with great autonomy, enabling them to use metadata to filter resources in order to find the most accurate learning resources that align with their knowledge and interests. This non-linear and multi-perspective content organization structure provides users with diverse pathways than offline museums, which could cater for the blended learning requirements of different users.

3.2 Digital Curation and Remixing

Exhibition narratives in physical museums are usually official, authoritative, and linear in their presentation and interpretation of the exhibits. After entering the digital context, the objects and resources still need to be reorganized and curated in some ways. Compared to physical museums, digital museums can increase learners' engagement in curating and interpreting collections [7, 18]. The openness of digital content, as well as the multi-modal expression of knowledge encourage learners to create, edit, refine, and share their ideas in a digital space, allowing them to easily participate in the process of content construction and dissemination. This process of creation and contribution is an essential aspect of a learner-centered, constructivist style of learning [3].

Therefore, how to encourage the effective organization of museum digital resources depends on the support of new digital curatorial tools. The Smithsonian Learning Lab provides users with a *digital curation* tool that facilitates them creating connections and stories between individual resources by designing their own *digital collections*.

The term *curation* has its roots in museology, and originally referred to the selection and interpretation of exhibits to be displayed in a museum or gallery setting. Today, the role of a curator is increasingly multi-faceted, blending diverse identities including exhibition curator, educator, manager, and organizer. At the same time, curators may be responsible for writing panels, exhibition articles, and other related works [19]. With the development of digital technology and multi-modal expression, the meaning of curation has expanded from curating exhibitions in physical spaces to reorganizing digital content such as documents, music, or internet information in cyberspace. The Smithsonian Learning Lab provides a digital curation platform open to the public worldwide, breaking the curatorial authority of museums and empowering each user to experience the role of a curator.

Another key concept applied to the digital curation tools is *remixing*, which originally refers to the act of editing music by adding, deleting, and modifying. The digital ecosystem also extends its connotation, as remixing can also refer to "the digital creation of new content through the modification of multi-modal resources online" [20]. The Learning Lab incorporates the concept of remixing into its digital curation tools, allowing users to filter, edit, and reorganize digital resources to create personalized digital collections and learning materials. Users can also make adaptations of existing collections for their own needs, which allows for a customized, reusable, and iterative museum pedagogical design.

The digital curation tools serve the needs of the platform's diverse user community, including school teachers, curriculum developers, museum educators, media professionals, parents, and museum amateurs around the world. Every user could remix and curate the digital resources according to different needs, instructional objectives, and personal interests, which reflects each creator's unofficial and tailored narrative.

At the same time, in order to ensure the consistency of the platform content and facilitate its subsequent use, users need to include the following basic information when creating a digital collection: its title, author, keywords, resource description, learning objectives, etc. (see Fig. 6). These metadata are just like *tags* added to the resources, making it possible to organize a large amount of data in digital context. Instead of manually classifying the collections, as in the case of physical museums, the platform automatically assigns the resources to the corresponding categories according to their *tags*. On one hand, the *metadata tagging* facilitates the search for resources; on the other, it provides a scalable structure for this vast and continually updated content [20].

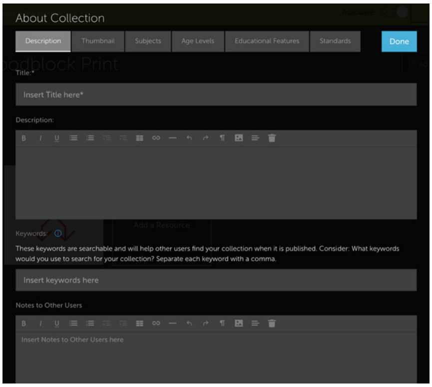

Fig. 6. Basic information editing interface of digital collection

3.3 Personalized Social Interaction and Resource Sharing

Based on the theory of social constructivism, the museum is a place of *social bonding* and *social learning* where learning occurs not only through dialogue and interactive experiences between visitors and exhibits, but also through interactions and conversations between visitors and others [21]. The vast majority of visitors go to museums as part of social groups, including family groups, school groups, etc. All members within a social group utilize each other as vehicles to decipher information, reinforce shared beliefs, and make meaning. Museums create milieus that are unique for such collaborative learning [5].

In physical museums, social interactions consist of questions and discussions that arise from viewing exhibits and reading panels, primarily in the form of face-to-face conversations [11]. These exhibits are referred to as *social objects* [22], which trigger interactions and communication among visitors. By interpreting the stories behind the exhibits or placing them in different contexts, physical museums attempt to connect visitors to the collections and generate dialogue within the social group. In order to facilitate the social mediation function of exhibits in the digital museum context, learning platforms should provide online audiences with tools that support dialogue, discussion, and sharing.

The tools provided by the Smithsonian Learning Lab allow learners to personalize social interaction and resource sharing in several ways: (1) Users can share the digital collections they created on a small scale by providing URLs to others prior to publication, which may be applied to sharing resources with specific groups and soliciting comments on new collections; (2) After publishing a collection, it becomes an open, searchable resource on the Learning Lab platform and other search engines as well; (3) Users can copy the code of a collection so that an interactive version of the collection can be embedded directly into other websites; (4) The tools of downloading allow users to export collections in PDF, Word, or brochure formats, making it convenient for offline learning contexts. These different ways of sharing resources take the advantages of digital technology, overcoming the limitation of physical space, and enabling digital resources to spread across platforms or media.

4 Learning Outputs and Outcomes: Multi-perspective Digital Narratives

Based on the Smithsonian Learning Lab's vast multi-modal digital resources and a variety of interactive digital tools, individual and institutional users have produced over 10,000 digital collections open to the global community, which encompass multiple forms of digital narratives. Varying from exhibitions containing a range of thematic digital artefacts, to comprehensive educational programs that meet curriculum standards, the open interactive learning platform provides unlimited possibilities for creative use of digital resources.

The openness and reusability of digital resources give every artefact richer possibilities for interpretation. Unlike physical museums, where the same exhibit can only appear in one exhibition narrative at a given time, the same digital artefact can simultaneously play different roles within different narratives, serving as a point of connection or convergence between different interpretations [23]. The Learning Lab makes good use of this feature of digital resources, allowing the same digital resource to be added to multiple collections telling different stories. This non-linear narrative structure enables learners to draw inspiration from other users' creations and learn how to apply resources to diverse learning scenarios.

For example, an exhibit from the National Museum of Asian Art, Summer Chaofu (formal court dress) for a top-rank prince of the Qing Dynasty, is now part of five different narratives. The collection *A Close Look at the Chinese Imperial Garment -The Symbolism of the Power and Privilege* (see Fig. 7), provides materials to develop an understanding of the ruling class's visual language system for maintaining absolute authority over the reign. By exploring the meanings and design concepts of the traditional symbols, viewers will be able to describe how culture and belief influence the symbols, as well as how symbols reflect the Chinese conception of the cosmos.

In another collection created by the National Museum of Asian Art, *Animals and Nature in the Arts of Asia* (see Fig. 8), this imperial garment is selected along with other artworks containing animal or natural elements, attempting to explore how artists illustrate the perception and relationships between humans and nature. Multi-perspective digital storytelling enables a resource to be interpreted from a variety of perspectives by platform users, an innovative way of audience engagement in digital curation.

Furthermore, different user groups are allowed to personalize the outputs according to their own needs. Specifically, elementary and secondary school teachers can add

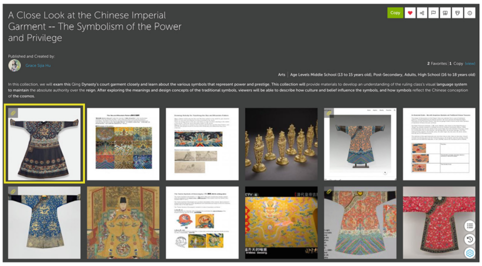

Fig. 7. Digital Collection: *A Close Look at the Chinese Imperial Garment -The Symbolism of the Power and Privilege*

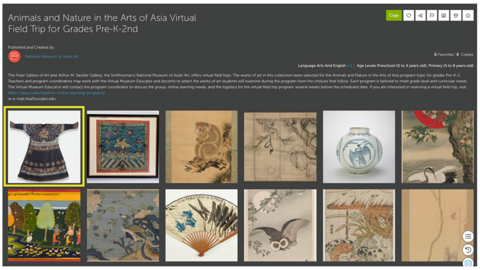

Fig. 8. Digital Collection: *Animals and Nature in the Arts of Asia*

authoritative and adaptable learning activities and thematic collections to their teaching toolkit, combining the Smithsonian's resources with their own to create personalized lessons and activities suitable for any subject or grade. As for course developers, they can hyperlink customized digital collections into a district's standards-based curriculum and instructional guides, providing more options for blended learning experiences. With regards to museum educators, the Learning Lab allows them to connect their own collections with the national collections to tell a richer, more complete story. Moreover, media specialists could utilize the platform to teach digital literacy and encourage digital citizenship with built-in tools for creating appropriate citations. Last but not least, the Lab provides students with access to millions of museum resources, allowing them to explore their interests in art, history, nature, and science, and using the interactive tools for inquiry-based research and projects.

5 Conclusion and Future

As a new interactive digital museum learning platform, the Smithsonian Learning Lab replaces the object-based knowledge expression in physical museums with multi-modal digital resources. Learners and educators utilize the resources and interactive learning tools to customize reusable digital content. The official and authoritative linear narrative has been substituted with personalized, multi-perspective, and non-linear digital narratives.

The Learning Lab has reconstructed a museum blended learning model in the digital ecosystem by combining various digital tools such as curation, remixing, and sharing, which has important implications for Chinese museums. In the future, the use of digital museum learning platform for blended learning in China should focus on the following three aspects for enhancement.

Firstly, organically integrating collections, exhibitions and education. The vast majority of China's museum websites divide them into three separate sections. The collection section mainly displays high-definition images of the exhibits, supported by a brief description of the artefact; The exhibition part covers the introduction of the exhibition, photographs of the key exhibits and panoramic scans of the exhibition; Whereas the education section is mainly concerned with publicizing on-site educational activities, including guided tours, lectures and courses. The unique advantages of digital space have not been fully exploited, including multi-modality, reusability and non-linear content organization of digital resources. In the future, Chinese museums should further develop blended learning activities based on its digital collections and exhibitions, as well as educational materials including syllabuses and learning sheets that can be directly used. By breaking the barriers between collections, exhibitions and education, museums can fully activate the vitality of their digital collections to support a rich variety of learning scenarios and educational programs, thus better fulfilling their educational mission.

Secondly, constructing learner-centered learning experiences. According to Lynda Kelly, an Australian museum education scholar, museums can support audiences in controlling their personalized museum learning experiences by providing multiple pathways and interpretive experiences appropriate for different groups [2]. In terms of existing practices in China's digital museums, most platforms only showcase official and authoritative narratives and rarely place the audiences in an active position where they can participate in the reorganization and creation of museum's digital content. "Everyone is a curator", an online curatorial project published by the Hangzhou Museum in 2021, allowed users to construct their own digital exhibition narratives by selecting 10 digital artefacts from the museum's online collection. As one of the few public curatorial platforms, this project is a pioneering attempt worth learning from and popularizing. In the future, the digital museum learning platforms in China should focus on designing interactive tools that support learners' free exploration, digital curation, and resource sharing.

Finally, strengthening the cooperation between formal and informal education. In September 2020, the Ministry of Education and National Cultural Heritage Administration of China jointly issued the "Opinions on the Use of Museum Resources for Education in Primary and Secondary Schools", proposing to strengthen the development of museum resources and their utilization in schools. Compared with the long-term and in-depth cooperation in the West, the current museum-school cooperation in China is still in its infancy, which takes school groups visiting museums as the main form. How to invite museums into the classrooms requires the support of digital learning platforms. In the future, efforts should be made to gradually establish long-term cooperation and a common mission between museums and schools. Educational resources need to be designed together based on museums' vast digital resources and national or regional curriculum standards. At the same time, primary and secondary school teachers are encouraged to guide students in safe and ethical digital practices and develop digital literacy necessary for them to be competent digital citizens.

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Learning Analytics and Big Data in Education

Research on Dynamic Learning Intervention Driven by Data

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Abstract. With the rapid development of the Internet and mobile information technology, the traditional learning environment has undergone great changes and gradually formed a hybrid learning environment that integrates virtual digital environment and real physical environment. In order to optimize the effect of blended learning in primary and secondary schools and improve the comprehensive literacy of students, the following practical problems need to be solved: How to build a dynamic diagnostic and intervention system based on the education cloud environment and serve primary and secondary schools to carry out IT-supported blended learning? This study proposes a "framework for the analysis and design of data-driven dynamic learning intervention models" based on Parsons' "AGIL" model and constructs a data-driven dynamic learning intervention model in an educational cloud environment based on the results of questionnaires surveys and expert interviews. It is used in teaching practice activities in middle school to diagnose learners full of personality differences, and implement targeted learning intervention activities according to the diagnosis results to improve students' academic level. It is found that the data-driven dynamic learning intervention model built in the education cloud environment can be well applied to the blended learning model in secondary schools, which effectively improves students' learning performance and realizes data-based decision-making and implementation of the learning process.

Keywords: learning intervention · learning behavior · learning analytics · blended learning

1 Background

Data-driven learning analytics is gradually becoming an important need for people. Human beings have been learning to understand the world since birth and learning as a way to acquire knowledge and communicate emotions has become an important part of people's daily life. With the introduction of a big data mindset, the concept and way of processing and problem solving based on big data have a wide impact on society. The emergence of learning analytics, cloud computing, big data-based processing, data mining, model building and other technologies provide significant opportunities to achieve educational problem-solving and promote reform and development in the field

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of education [1]. Data-based learning analytics technologies are dedicated to collecting, measuring, diagnosing, analyzing, and visually presenting data about learners and their contexts so that researchers can keep track of learners' learning status and optimize the learning process and learning environment [2]. With the advancement of related research, learning analytics has become more focused on analyzing and interpreting the big data generated by learners in the e-Learning environment, assessing the learning process of learners, predicting future learning performance, and identifying possible problems in the learning process [3]. At present, we are faced with great opportunities and challenges. The emergence of learning platforms, such as Khan Academy and Coursera, has led to the gradual spread of online learning and its integration with traditional school teaching, with more and more people becoming familiar and accustomed to this new way of learning and leaving a large amount of learning data in the Learning Management System (LMS) [4]. From logging into the learning platform to retrieving and downloading online resources, from reading learning materials to online tests, from online communication and discussion between teachers and students to learning evaluation, the LMS completely records learners' online learning behavior data, which solved the problem to collect learning behavior data difficult.

Research has demonstrated the importance of learning analytics for all stakeholders in the education sector. First, for learners, learning analytics can help learners use the information interpreted by the data to quickly and accurately understand their own learning performance in the learning process and use it as a basis to optimize their learning. The educational cloud environment can use these data to recommend reasonable learning paths for learners to carry out Auto learning and personalized learning by using learning analytics [5]. Second, for education researchers, education decision-makers and education implementors, learning analytics can be used to evaluate curricula and institutions, transform the traditional evaluation and assessment mechanisms, and support schools and educational institutions to implement dynamic and procedural evaluation. At the same time, for teachers, learning analytics technology can provide more accurate and deeper teaching analysis, help teachers to design and make teaching decisions based on the results of data analysis in the teaching process, thus providing more accurate and timely teaching interventions for students [6].

2 Determination of Factors Influencing Learning Performance in Blended Learning Environment

Learning is a very complex activity, and many factors interweave together to affect a person's learning. If we can understand which factors have an important impact on the learning effect, it can play a good effect in the learning intervention.

Learning interventions are targeted at learners of all kinds in learning activities. As the subject of learning activities, learners' motivation, cognitive ability, and learning level will have an impact on the learning process of individuals. The purpose of learning intervention is to hope that the intervention strategies and methods can match the characteristics of learners in learning activities. Therefore, whether the design of a learning intervention can meet the needs of learners in the learning process, and whether the learning intervention strategies and methods can match the learning characteristics of different learners is an important reference point to measure the excellence of a learning intervention design. In order to design good learning intervention programs, it is important to understand the characteristics of learners. However, education and teaching are extremely complex social activities, in which human being, as the subject, is itself a complex. It is difficult to consider all characteristics of learners in concrete practice with the existing technical means and theoretical basis. In the intervention design process, it is important to conduct a feasibility analysis to identify which characteristics of individual learners can be interfered with and which characteristics cannot be interfered with so that those characteristics that have an important impact on individual learning and are observable and interfere can be explored. The findings of this literature review suggest that the analysis of learner characteristics includes both intellectual and non-intellectual factors. Learning behavior, as an important component of the learning process, can also be used to analyze learner characteristics. The intellectual factors of learners usually refer to the knowledge base, cognitive ability, and cognitive structure of individual learners, while the non-intellectual characteristics of learners mainly consist of motivation and attitude, learning style, interest, emotion, will, and personality.

Through literature review, researchers and cooperative subject teachers designed the core content of the pre-test questionnaire, which was divided into seven dimensions of "learning motivation", "self-efficacy", "online learning behavior", "learning interest", "cognitive ability", "learning resources" and "online learning effect" were formed. A total of 45 questions were developed to measure the factors influencing learning performance in a blended learning environment, forming initial design of the questions to measure the factors influencing learning performance in a blended learning environment. The designed items were sent to subject experts through two rounds of Delphi questionnaires, and subject experts were invited to rate the importance of each item. At the end of each round, the unqualified items were excluded according to the screening criteria. And the final online learning performance impact factor questionnaire was formed after two rounds, measuring 30 items. Through the reliability and validity test and correlation analysis, we finally concluded that for online learning environment in the blended learning environment, the important factors affecting students' learning performance are cognitive ability, self-efficacy, learning motivation, online learning behavior, learning interest, learning resources, among which learning resources do not have a significant influence on learning performance.

3 Design of Data-Driven Dynamic Learning Intervention Models

In order to design the data-driven dynamic learning intervention model more accurately and to understand the content and structure of the learning intervention, the researcher conducted interviews and surveys with relevant experts and doctors in the field to improve the theoretical depth of the content and structure of the data-driven dynamic learning intervention and to provide a basis for the design and construction of the subsequent intervention model. On this basis, the researcher used Parsons' AGIL model as a basis to examine the construction of the data-driven dynamic learning intervention model system. And the four basic functions of the AGIL model were used to guide the construction of the data-driven dynamic learning intervention model. As shown in Fig. 1, a "data-driven dynamic learning intervention model analysis and design framework" is established.

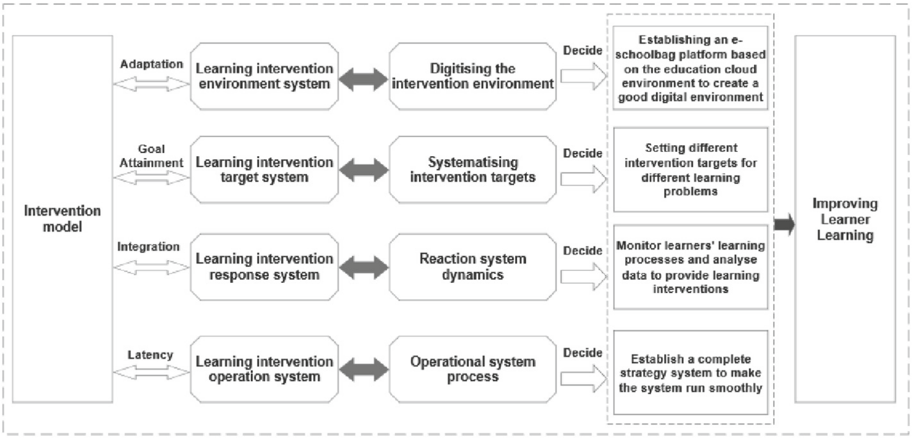

Fig. 1. Design framework of "data-driven learning intervention model "based on AGIL.

The framework first considers the data-driven dynamic learning intervention model as a system, and the improvement of learners' learning levels is the ultimate goal of the system. According to the "AGIL" model, the data-driven dynamic learning intervention model system consists of the learning intervention environment system, the learning intervention goal system, the learning intervention response system, and the learning intervention operation system, which respectively undertake the functions of adaptation, goal achievement, integration, and maintenance. In order to achieve the systemic goal of improving learners' learning, each system must be adapted. The learning intervention environment system should perform the function of adaptation under the digitalized goal, and achieve the structural requirement of digitalized intervention environment; the learning intervention target system should perform the function of goal achievement, and achieve the structural requirement of the systematized intervention goal; the learning intervention response system should perform the function of integration, and achieve the structural requirement of dynamic response system; the learning intervention operation system should perform the function of maintenance, and achieve the structural requirement of the operational system. The learning intervention operation system should perform the maintenance function and achieve the structural function of the operating system. Only when these functional demands are satisfied, can the goal of improving learners' learning level be realized.

Based on the analysis of the factors affecting students' learning performance, a data-driven dynamic learning intervention model was constructed based on the model design framework constructed by AGIL theory. The model was optimized by consulting experts several times, mainly including the composition of functional layers; the linear relationship between structures; the logical architecture of the model. Based on the consultation results, the model was revised, and a data-driven dynamic learning intervention model system was formed, as shown in Fig. 2.

After integrating the results of the questionnaire survey and experts' opinions, the researcher established the functional layers of the model based on the four basic functions of AGIL theory: "adaptation", "goal achieved ", "integration", and "maintenance".

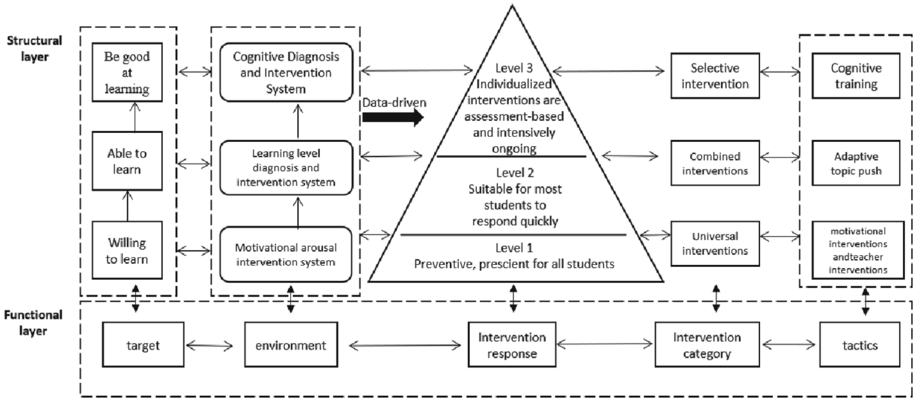

Fig. 2. Data-driven dynamic learning intervention model

The functional layers of the model were established in the underlying architecture, consisting of the learning intervention goal system, the learning intervention environment system, the learning intervention response system, and the learning intervention operation system. According to the composition of the functional layer, the structure system of "target", "environment", "intervention response", "intervention category" and "strategy" are constructed correspondingly.

The target system of the "Data-driven Dynamic Learning Intervention" model consists of three sub-goals: "willing to learn", "able to learn", and "good at learning". "The three subgoals are hierarchical in their logical relationship, which determines that the "data-driven dynamic learning intervention" model must be a hierarchical and progressive process in the process of goal achievement. By achieving the goals of each subsystem at different levels to achieve the overall goal of the system. This also satisfies the structural requirement of "systematization of intervention goals" as proposed in the design framework.

In the data-driven dynamic learning intervention system, the Learning Intervention Environment System mainly consists of the e-schoolbag system in the education cloud environment, the Motivation Arousal Intervention Subsystem, the Learning Level Diagnosis and Intervention Subsystem, and the Cognitive Ability Diagnosis and Intervention Subsystem. The three subsystems operate on the e-schoolbag learning platform in the education cloud environment. The "learning intervention environment system" retains a large amount of student learning data. These generated and retained data can ensure the normal operation of the entire dynamic learning intervention model so that student learning intervention needs can be analyzed based on the data, and interventions for student learning can be implemented digitally based on the education cloud environment, which satisfies the structural requirements for the digitalization of the learning intervention environment system in the design framework.

The learning intervention response system in the data-driven dynamic learning intervention model corresponds to the "intervention response" function in the functional layer. The main function is to coordinate the flow of data between subsystems so that all parts of the system can be coordinated into a effective whole. There are multiple subsystems in the data-driven dynamic learning intervention system, and the "target system" of the model is a bottom-up hierarchy, so the "intervention response" subsystem must be able to carry and coordinate the other subsystems in the system from the bottom up.

In the data-driven dynamic learning intervention model, the learning intervention operation system corresponds to the functional layer of "Intervention Categories" and "Strategies". The clarification of intervention categories and the formulation of strategies enable the system to operate according to certain norms. Intervention categories and strategies are also developed and built around the three-level intervention goal system, and the entire learning intervention system consists of three bottom-up levels: primary intervention, secondary intervention, and tertiary intervention. The intervention categories and intervention strategies corresponding to each level ensure that the whole intervention system is regulated and reasonably operated according to the corresponding operation process, which satisfies the structural requirements of the operating system process proposed in the design framework.

4 Intervention Implementation and Effect Verification

To construct a meaningful learning intervention model, it must be designed in the context of students' actual learning activities. And students' learning performance should be measured in a way that is appropriate to their learning activities when verifying the validity of the model and the effectiveness of the intervention. This study constructs a relevant model system and conducts continuous research activities in experimental schools. The design of this study was based on actual teaching. In the daily teaching environment of schools, through the use of cloud-based e-schoolbag for one semester, researcher have collected a large amount of data related to the learning process, including data of learners learning behavior, learning performance, and relevant scale data filled in by students. This study mainly adopted quantitative methods to verify the validity of the model and the intervention effect. The researcher conducted continuous research with teachers of relevant subjects in the project school. Research process used methods of big data analysis, scale surveys, and quasi-experimental research to quantitatively analyze the intervention effect of different intervention stages of the model, to explore whether the students' learning performance in each stage meets the requirements. Sorting out and analyzing these data can verify the implementation effect of the model. Taking the implementation and effect verification of the motivation arousal intervention as an example.

4.1 Research Sample Selection

The experimental school selected in this study is a senior high school in Guiyang. School L is a relatively well-equipped senior high school in Guiyang. It ranked among the top in the region in terms of size, with more than 10 classes in each grade, class sizes ranging from 40 to 50 students, and about 700 to 800 students in each grade. At present, L School vigorously promotes the reform of subject teaching supported by technology and information technology environment. The school has implemented flipped classroom teaching based on e-bookbag for more than two years. All the teachers have experience in teaching and organizing teaching under information environment, and the students are familiar with the corresponding teaching environment and learning mode. In this study, we conducted a motivational arousal intervention experiment with all students in 14 first-year high school classes, with 718 participants. Taking the physics class of 14 classes as the actual teaching scene, the relevant quasi-experiments and data collection work were completed through cooperation with 7 physics teachers.

4.2 Intervention Implementation

This study takes "practice and test" as the main line to carry out related research activities. Firstly, based on the actual teaching environment in schools, teachers and students use the e-schoolbag education cloud platform to conduct classroom and off-class teaching activities. The study integrated the intervention strategies of the motivational arousal intervention subsystem model in the "data-driven dynamic learning intervention" system with school teaching activities, so that the motivational arousal and intervention methods based on the e-schoolbag platform are organically organized together with in-class and out-of-class learning and become a part of teaching activities.

The intervention strategies constructed in the Motivational Arousal Intervention System are closely linked to the teaching process, both online and offline. However, the execution and implementation of various intervention strategies are inseparable from the teacher's organization and cooperation. Teachers needs to invest energy and time in setting the content of various intervention strategies. Such as reminding students to complete tasks in time. Teachers needs to set the corresponding reminder content on the tablet in advance, and the information will be pushed to the students' tablet automatically.

At the same time, teachers also need to design various strategies in their teaching activities. For example, they need to actively organize students to explore in the discussion forum. And they need to design various inquiry topics to trigger students to discuss, and praise and praise students who perform positively and excellent. Teachers organized students to learn and discuss by designing corresponding learning discussion topics, encourage students to reflect, and encourage students to mutual learning. Students' motivation is greatly enhanced by these learning interventions ways provided by the teacher and the system.

4.3 Validation of Intervention Effects

Duration of the Study

In this study, to further validate the effectiveness of the motivational arousal intervention subsystem model, the researcher worked collaboratively with several physics teachers to implement teaching activities using the e-schoolbag education cloud platform. Based on the intervention strategies and framework constructed by the motivational arousal intervention subsystem a four-week teaching activity was implemented.

Research Tools and Materials
SPSS statistical analysis software, AMS Achievement Motivation Scale.

Research Implementation
The AMS Achievement Motivation Scale (AMS) was used to measure the achievement motivation of 718 students who participated in the experiment. The AMS Achievement Motivation Scale has 30 questions, which are divided into the "motivation to succeed" subscale (questions 1–15) – M_S and the "motivation to avoid failure" subscale (questions 16–30) – M_{AF}. Each item of the scale was scored on a 4-point scale, ranging from a maximum of 4 points for "very consistent" to a minimum of 1 point for "not at all consistent". Achievement motivation $M = M_S - M_{AF}$, with higher scores on M indicating stronger achievement motivation. The scale has a reliability of 0. 77 ($p < 0.01$) and a validity of 0. 58 ($p < 0.01$). At the beginning of this phase of the experiment, the researchers sent the scale to 718 subjects to obtain the pre-test data of their achievement motivation. The scale data were collected again one week after the end of the intervention, and the two data collection intervals were 5 weeks. The scale was handed out by the researcher and each class teacher on the spot and filled in immediately. The researcher gave the scale filling guidance on the spot to ensure the accuracy and effectiveness of data. The researchers used SPSS statistical software and paired sample T-test to analyze the pre - and post-test data of 718 subjects, and then explained the relevant results in detail.

Data Analysis
Through the collection of scale data and statistical results with SPSS, and it was found that the overall motivation level of the subject sample increased significantly through a period of motivational arousal intervention. As can be seen from Table 1, before the intervention, the mean value of the overall achievement motivation M of the subjects was 0.1894, while after the intervention, the mean value of the overall achievement motivation M rose to 5.4903.

Table 1. Achievement motivation paired sample statistics.

		Mean (E)	Digital	Standard deviation	Standard error mean
Pairing 1	M-Posttest	5.4903	718	7.84770	.29287
	M-Pre-test	0.1894	718	7.15540	.26704

As shown in Table 2 by analyzing the results of paired sample t-test of achievement motivation of 718 subjects, it is found that the sig of the post-test and pre-test of achievement motivation M was 0.000, which was less than 0.05, indicating that there was a significant difference between the post-test value of achievement motivation M and the pre-test value of M. Comparing with the mean results in Table 1, it can be found that the level of students' achievement motivation has significantly improved after a period of intervention, and $M > 0$, which means that the subject students as a whole have the desire to pursue success. And are also willing to accept challenging tasks in the learning process, In the learning process they were willing to set certain goals for themselves and study hard to accomplish the goals.

Table 2. Paired samples t-test of achievement motivation

		Pairing Difference					t	Freedom	Sig.Tail
		Mean	Std. Error	Std. Error Mean	95% of the difference	confidence interval			
					Lower	Upper			
P-1	M-Post-test M-Pro-test	5.30084	10.73823	.40075	4.51406	6.08761	13.227	717	.000

Further explore the scale data to analyze the students' "motivation to pursue success" M_S and "motivation to avoid failure" M_{AF}. Table 3 shows that the mean value of "motivation to succeed" M_S of the subject group was 39.8036 before the intervention and 42.9290 after the intervention. "The mean value of "motivation to avoid failure" M_{AF} was 39.6142 before the intervention and 37.4387 after the intervention. In terms of the mean values, there was a certain degree of change in the motivation levels of both groups. For further analysis, a paired sample t-test was conducted on the motivation levels of the subjects in these two aspects, and the results are shown in Table 4.

Table 3. Paired sample statistics of M_S and M_{AF}

		Mean (E)	Digital	Standard deviation	Standard error mean
Pairing 1	Ms Post-test	42.9290	718	6.48734	.24211
	Ms Pre-test	39.8036	718	9.40691	.35106
Pairing 2	M_{AF} post-test	37.4387	718	4.24967	.15860
	M_{AF} post-test	39.6142	718	8.86802	.33095

As shown in Table 4, the paired sample t-test on the "motivation to succeed" M_S and "motivation to avoid failure" M_{AF} values of the subject showed that the significance of both were 0.000, which was less than 0.05. Indicating there was a significant difference between the pre-test and post-test results of "motivation to pursue success" M_S and the pre-test and post-test results of "motivation to avoid failure" M_{AF}. According to Table 3, the mean values of the two types of data before and after the intervention, showed that the "motivation for success" M_S increased significantly after the intervention, while the "motivation to avoid failure" M_{AF} decreased significantly after the intervention.

Table 4. Paired samples t-test of M_S and M_{AF}

		Pairing Difference					t	Freedom	Sig.Tail
		Mean	Std. Error	Std.Error Mean	95% of the difference	confidence interval			
					Lower	Upper			
P-1	M_S Post-test M_S Pro-test	3.12535	11.27102	.42063	2.29953	3.95116	7.430	717	.000
P-2	M_{AF} Post-test M_{AF} Por-test	-2.17549	9.97695	.37234	-2.90649	-1.44449	-5.843	717	.000

5 Conclusion

This study validated the implementation effect of an intervention model in a data-driven dynamic learning intervention environment. In the study, the intervention was implemented through a motivational arousal system and a related quasi-experimental validation session was designed to collect and organize data and validate the effectiveness of the intervention activities. It is found that the implementation of intervention has a significant effect on the change of learners' behavior in the education cloud platform. Through the AMS achievement motivation Scale before and after the test of the analysis and verification, and paired sample t test method to analyze the 718 subjects before and after the test data. The results showed that after a period of intervention, student's achievement motivation level increased significantly. The overall achievement motivation value of the subjects was positive, indicating that the subjects had the desire to pursue success on the whole, but also willing to accept challenging tasks in the learning process. They were willing to set certain goals for themselves in the learning process and to study hard in order to accomplish them. Further analysis of the scale data on M_S and M_{AF} revealed that the values of the two dimensions showed significant differences after the paired-sample t-test. The mean values of the two types of data pre- and post-test showed that the "motivation to pursue success" M_S of the subjects increased significantly after the intervention, while the "motivation to avoid failure" M_{AF} of the subjects decreased significantly after the intervention.

Through the verification of the intervention effects on motivational arousal, learning level and cognitive ability, it is found that the intervention model system constructed in this study can achieve better intervention effects. And the data indicators of the subjects after the intervention are significantly improved compared with before the intervention. The whole intervention system can work well in the high school physics teaching system and become a powerful learning support and service tool in the traditional school learning environment.

Learning is a complex and huge process. Due to the huge research system, each research process has a stage. In view of the heavy learning tasks of high school students, the duration of this study is only one semester and can only use students' physics classes and self-study sessions every day to carry out intervention activities, so the time is slightly rushed. If the experimental environment into the middle school or elementary school, for a long time, with the accumulation of data, the results of the study will be more accurate.

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Predictive Analytics for University Student Admission: A Literature Review

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Abstract. This paper presents a literature review on the use of learning analytics to support prediction in university student admission. The review covers four areas: types of research issues examined, types of data, analytical techniques, and performance metrics used. A total of 59 research articles published between 2013 and 2022 in relation to the use of predictive learning analytics for student admission were collected from Scopus for analysis. The findings show the major types of research issues including admission outcome, academic performance, admission yield, chance of admission, and suitable major/field of study. The types of data frequently used include academic performance, educational background, socio-demographic data, admission-related data, and application-related data. The findings also show that logistic regression, decision tree, random forest, support vector machine, and neural network are the most commonly adopted analytical techniques, whereas accuracy, recall, precision, F-measure, and R-squared are the most frequently used performance metrics. The results contribute to identifying the features and patterns of predictive learning analytics with respect to university student admission.

Keywords: learning analytics · predictive analytics · machine learning · student admission · university education

1 Introduction

Learning analytics has been increasingly applied in various areas of higher education. It refers to "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [1] (p. 34). Examples of its use include enhancement of student academic performance, increase of student retention rate, and improvement of student learning experience [2–5]. Besides teaching and learning purposes, applications of learning analytics have also been expanded to other areas of university education such as student admission.

Student admission involves recruiting suitable students for study in university programmes. However, there are challenges for prospective students to estimate their chance of being admitted to their preferred institutions or programmes because of the uncertainty about whether their academic profiles match the requirements of institutions. University administrators would also find it difficult to make reliable predictions about student

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enrolment for a programme because not all students eventually accept the admission offers from institutions.

In order to facilitate university student admission, a broad range of research has been conducted on generating useful predictions based on learning analytics. Roth et al. [6], for example, created a model to predict student matriculation using admission data. They identified various factors influencing university admission, such as students' SAT Math scores and ACT English scores, as well as the size and rank of high schools. Slim et al. [7] constructed a predictive model with factors related to student and university characteristics such as gender, ethnicity, institutional and federal money, and university financial aid, which are correlated to students' admission decisions. Other relevant studies include but are not limited to Stanley [8], Nurnberg et al. [9], Lux et al. [10], and Jamison [11] which focused primarily on the development of predictive models to identify factors that affect the likelihood of student admission.

Despite much research on the application of learning analytics to make predictions about student admission, scant attention has been paid to the systematic analysis and synthesis of relevant work. This paper addresses the literature gap by examining the use of learning analytics for making predictions to facilitate university student admission. In particular, it covers the following research questions:

1) What are the research issues examined in related studies?
2) What are the types of data adopted for predicting student admission?
3) What are the types of analytical techniques and performance metrics used for the predictions?

2 Related Work

The past decade has seen a surge in reviews on learning analytics. Relevant reviews have covered various areas such as the overall development of learning analytics in higher education [3–5] as well as its application for learning personalisation [2], learning intervention [12], and educational devices [13].

Reviews of learning analytics have been also carried out on predictions about student learning. Sekeroglu et al. [14], for example, analysed publications on prediction of student performance in terms of the research issues addressed, the models developed, as well as the datasets, evaluation metrics, and validation strategies applied. They found a growing importance for studies focusing on deep learning. Alwarthan et al. [15] examined the commonly used techniques and influential features for predicting student academic performance. They found that random forest and ensemble model are overall the most accurate models as reported in literature, whereas the issue of whether admission requirements have a strong connection with student achievements remains unresolved. Wilcox and Lawson [16] reviewed related literature to identify whether academic and pre-professional admission measures were effective predictors of student academic performance. Their findings show that using holistic evaluation of applicants and combination of didactic and non-didactic admission measures are helpful in recruiting students who are more likely to succeed.

Another area commonly addressed in reviews of learning analytics lies in student success. For example, Al-Alawi et al. [17] examined predictors of student success in baccalaureate programmes to identify the pre-admission variables and selection criteria for student admission which are able to predict student success in the programmes. They observed prominent cognitive predictors of student success such as students' GPA in former studies and aptitude-based entrance exams, whereas the predictive effects of non-cognitive variables such as age, gender and ethnicity of students are not clearly shown. They found that no single variable is the best predictor of student success, suggesting a combination of variables to obtain reliable predictions. Kuncel and Hezlett [18] analysed and synthesised studies on standardised tests to find out whether these tests are effective in predicting the success of graduate students. They found that the tests are useful in predicting students' academic outcomes and most measures of their success.

However, there has been scant attention given to the use of learning analytics for facilitating student admission. The only relevant review study by de Boer and Van Rijnsoever [19] focused on selection of student candidates. de Boer and Van Rijnsoever summarised the selection criteria based on students' non-cognitive skills, including personality tests, conscientiousness, person-organisation-fit, core-self-evaluations and polychronicity, which have been shown to be relevant to students' success in study. They argued that higher education institutions should understand students' relevant skills and knowledge for their success in the study programme and align these skills and knowledge the selection criteria.

To address the literature gap, this paper provides a comprehensive review of publications with respect to the use of predictive learning analytics for student admission in higher education.

3 Research Methodology

3.1 Data Collection

For this review study, related research articles were collected from Scopus. This publication database was selected for its broad coverage of peer-reviewed literature and extensive use in systematic literature reviews [20–22]. The keywords used for the literature search include: (learning AND analytics AND admission). The publication period of the articles was set between the years 2013 and 2022. An initial search yielded a total of 186 results, which were further screened based on the following selection criteria: (i) the article reports a study in relation to student admission in higher education institutions by using learning analytics for prediction; (ii) the article was written in the English language; (iii) the article is available in full text. Publications that failed to meet any of these criteria were eliminated from the present study. A total of 59 articles were eventually selected for review and analysis.

3.2 Data Analysis

The 59 articles were analysed through a content analysis approach. Relevant information in the articles was identified in relation to the types of research issues examined (research question 1), the types of data used for prediction (research question 2), and the types of analytical techniques and performance metrics used for prediction (research question

3). The coding was first performed by a researcher and checked by another researcher. Differences in the coding tasks between the two coders were discussed until agreement was reached.

Based on the information identified from the articles, the patterns and features of the use of learning analytics for prediction tasks in student admission are reported in the following section.

4 Results

4.1 Number of Publications

Figure 1 presents the number of publications along the years. The results show an overall raising trend in the number of publications. The number remained at a low frequency count in early years, but began to rise in 2019 and reached a peak with a frequency count of 14 in 2020. There was a slight drop in the number after 2020, with 12 publications in 2021 and 10 publications in 2022 respectively. These results imply that the use of learning analytics for prediction purposes in student admission has gained momentum in higher education in recent years.

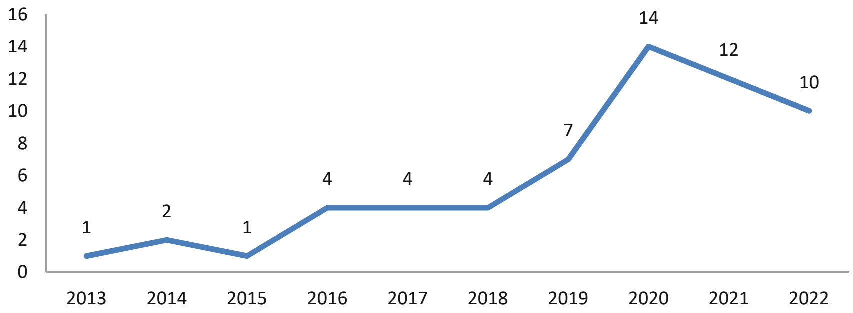

Fig. 1. Number of publications related to the use of learning analytics for prediction in university student admission.

4.2 Types of Research Issues Examined

Figure 2 shows the types of research issues examined in the studies. The top 5 most frequently examined issues are admission outcome (N = 17), academic performance (N = 14), admission yield (N = 13), chance of admission (N = 12), and suitable major/field of study (N = 12). It is worth noting that admission outcome, admission yield, and chance of admission, though being similar in a literal sense, have different focuses in predictions. The studies on admission outcome focused on prediction about whether students end up being admitted to their target institutions or not. Those on admission yield addressed the chances that students have of being admitted to their preferred institutions. Those on chance of admission examined the rate at which accepted students decide to enrol at a given institution. Overall these results reveal a strong scholarly interest in exploring the potential of learning analytics to support student admission.

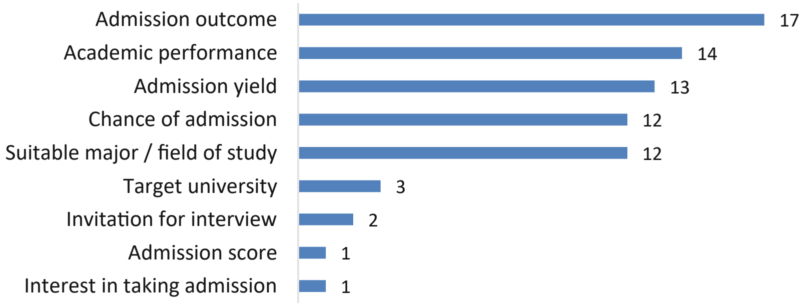

Fig. 2. Types of research issues examined in the studies.

4.3 Types of Data Used for Prediction

Figure 3 shows the types of data used for admission prediction in the studies. The most frequently used data is those relating to students' prior academic achievements (N = 56), followed by their educational background (N = 44), socio-demographic data (N = 38), application-related data (e.g. reference letters) (N = 27), and admission-related data (e.g. admission test and interview scores) (N = 20). The results indicate the importance of students' academic data particularly their previous academic performance to predict their university admission.

Fig. 3. Types of data used in the studies.

4.4 Types of Analytical Techniques Used

Figure 4 reports the types of analytical techniques used for university admission prediction in the studies. Among the various techniques, the top five most frequently used ones are logistic regression (N = 30), decision tree (N = 29), random forest (N = 29), support vector machine (N = 25), and neural network (N = 19). These results suggest the preferences for certain analytical techniques for university admission prediction in the studies.

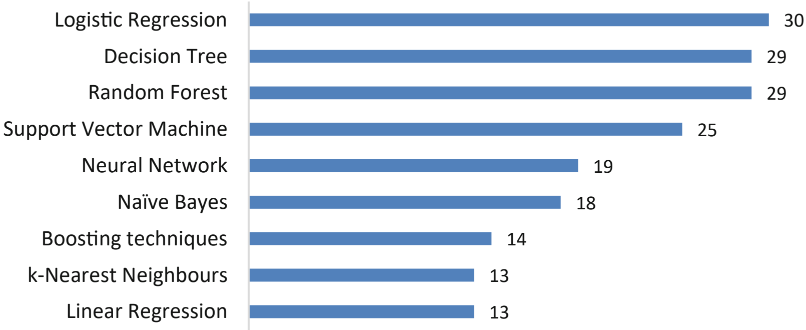

Fig. 4. Types of analytical techniques used in the studies.

4.5 Types of Performance Metrics Used

Figure 5 presents the types of performance metrics used for student admission prediction in the studies. A total of 11 performance metrics were applied, with the top 5 being accuracy (N = 41), recall (N = 22), precision (N = 19), F-measure (N = 17), and R-squared (N = 13). These results are related to the types of analytical techniques adopted. The frequent use of metrics such as accuracy would be resulting from the common use of classification-based techniques such as logistic regression.

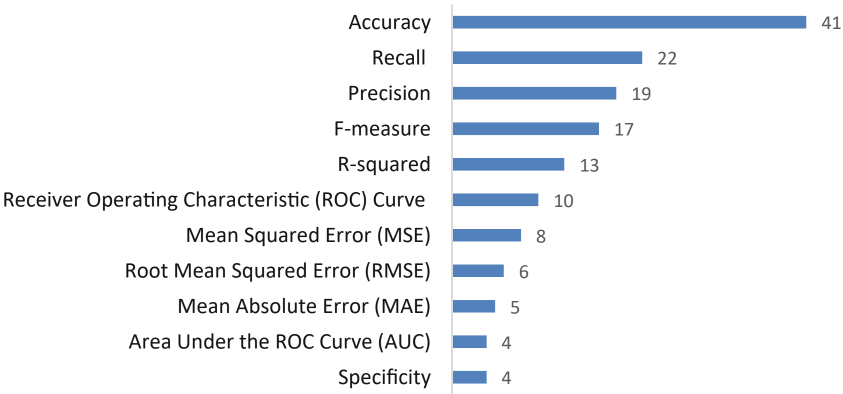

Fig. 5. Types of performance metrics used in the studies.

5 Discussion

The findings reveal the patterns and features of predictive learning analytics for student admission. Regarding the types of research issues examined in the studies, the results reveal that the issues mainly concern two aspects of university admission—one from the perspective of students and another from the perspective of institutions. Studies in relation to the former one tended to examine predictive models to forecast students' admission outcomes in order to help them find the best possible institutions that fit their personal profiles [23–25]. Studies related to the latter one tended to focus on model development for academic performance prediction so as to assist institutions in enrolling students who have the capability to succeed and in turn reduce non-completion rates [26, 27].

As regards the types of data used for prediction, academic achievement such as scores of standardised tests like GRE and TOEFL are found to be one of the most frequently used in the studies. This finding suggests the importance of prior academic achievement as a key factor for predicting student admission outcomes [28, 29]. In addition, data related to educational background such as the types and ratings of students' high schools and the courses previously taken by students are commonly used in the studies. This result shows the usefulness of such data in helping university administrators to better understand the type and quality of education that students have received and the type of subject knowledge that they have possessed [30–32].

Concerning the types of analytical techniques used, classification techniques such as logistic regression and decision tree were frequently used in the studies. These techniques have been often used in the form of binary classification or binary logistic regression [33] and represented in the form of a hierarchical structure [34]. Their common application in the studies may be explained by their simplicity in terms of the requirements for data preparation [35]. Also, these use patterns of analytical techniques are shown to be related to the types of performance metrics used. The popularity of metrics such as accuracy and recall reflects their wide applicability that allows seeking out various types of information points of interest in a dataset [36].

The study reveals the potential of learning analytics for enhancing the performance of a university in various aspects. While previous reviews have shown the use of learning analytics in higher education mainly in areas related to teaching and learning such as learning support [3], learning intervention [12], personalised learning [2] and in-class activities [13], this study illustrates its use also in student admission. The results suggest future work on examining the relationships between the analytical studies in various areas, such as the effects of recruiting suitable students for a programme on its student retention, and the types of learning support required for students with diverse backgrounds when they enrol in a programme.

6 Conclusion

The study presented in this paper examines prior research into the use of a learning analytics approach to prediction of university student admission in terms of the types of research issues examined as well as the types of data, analytical techniques and performance metrics used. The findings identify common types of research issues covering admission outcome, academic performance, admission yield, chance of admission, and suitable major/field of study, as well as popular types of data including academic performance, educational background, socio-demographic data, admission-related data, and application-related data. They also reveal the analytical techniques frequently applied such as logistic regression, decision tree, random forest, support vector machine, and neural network, as well as the metrics most frequently used such as accuracy, recall, precision, and F-measure. These findings contribute to highlighting the features and patterns of predictive learning analytics with respect to university student admission and summarising the common types of learning analytics techniques that could be used in making predictions about student admission.

There are limitations to the present study. Only research articles in the past decade were examined which limit the generalisability of the findings. Future reviews could cover a longer period of time to study relevant trends in this area. Besides, only publications pertaining to the use of learning analytics in university admission were analysed in the study. Future work could include a broader range of related techniques such as data mining and artificial intelligence to examine their potential use together with learning analytics to support student admission.

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Construction and Implementation of the Data-Driven Flexible Teaching Model of University Courses

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Abstract. Leading the construction of high-quality education system in universities with digital transformation, deepening the integration of data elements and courses teaching are important directions for the current and future teaching reform and innovation of universities. Facing the urgent needs of innovative talent development in China, this study explored the data-driven flexible teaching model of university courses based on the reform of university courses teaching as well as combines with the dynamic changes of students' learning needs and the objective reality of epidemic opening. This study adopted literature research method and design-based research method. Guided by *Curriculum and Pedagogy*, the connotation, key elements, and their relationship structure of flexible teaching in university courses were clarified firstly. Then, this study explored the driving mechanism and functions of data on the flexible teaching of university courses, and the data-driven flexible teaching model of university courses is constructed. Finally, this study through the implementation of the courses, the teaching model is continuously iteratively improved. At the same time, the teaching effect of the courses is detected and analyzed to verify the effectiveness of the flexible teaching model.

Keywords: University courses · Flexible teaching · Data-driven · Model construction · Teaching implementation

1 Introduction

At present, deepening the integrated development of digital technology and education, actively promoting the digital transformation of education has become an international consensus and an inevitable trend [1]. In the context of deepening the digital transformation of education, the cultivation of high-quality digital innovative talents has become a crucial part. As an important link to actively connect with the major strategic needs of the country and connect schools and society, universities play a vital strategic role in realizing the new journey of Chinese-style modernization and cultivating high-quality digital innovative talents that meet the development of the era and urgent needs. However, there is a growing conflict between the rapidly changing digital society and

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the inherent talent cultivation model of universities. The traditional university courses teaching cannot keep up with the changing needs of students and the dynamic updating of knowledge. Differently, the flexible teaching emphasizes active, flexible, ubiquitous, student-centered teaching and learning, which can free students from the shackles of the established courses teaching system and reshape their self-subjectivity. Based on this, this study aims at the urgent needs of innovative talent cultivation in China, explores the data-driven flexible teaching model of university courses based on the reform of university courses teaching as well as combines with the dynamic changes of students' learning needs and the objective reality of epidemic opening.

2 Literature Review

2.1 Current Research Status of Courses Teaching Reform in Universities

For a long time, scholars have accumulated lots of experience in exploring the direction of courses teaching reform, innovating courses teaching reform methods, carrying out courses teaching reform practice, and evaluating the effectiveness of courses teaching reform. For example, Jiangang Cheng stated that direction of digital transformation should be courses teaching in colleges and universities [2]. Youru Xie et al. proposed the construction method of *golden courses* from the aspects of course objectives, course contents, technology application, course mode and course evaluation [3]. Cates S.V. et al. proposed a competency-based course design model for online education programs [4]. Yuan Zou et al. designed a *six-in-one* university course teaching quality evaluation system guided by scientific teaching quality standards [5]. It can be seen that at present, scholars have done some theoretical and practical research of the course teaching reform in colleges and universities. But how to further clarify the direction of university courses teaching reform in the new era and explore the operability model of university courses teaching reform is still a problem worth exploring.

2.2 Current Research Status of Flexible Teaching

As a new teaching method, flexible teaching has been continuously enriched in related research, including theoretical explanation, essential connotation, influencing factors and design application. Ronghuai Huang discussed the super-large-scale online teaching practice characterized by flexible teaching and active learning during the epidemic period. He also proposed that the combination of flexible teaching and active learning will become a new form of education in the future [6]. Wade believes that flexible teaching is a method of university education provided for students, which can make students more responsible for their studies, more engaged in learning activities, and can meet their individual learning needs [7]. Veletsianos G et al. found that time investment and learning efficiency are important factors affecting flexible teaching [8]. Eradze M. et al. designed a hybrid flexible teaching framework for COVID-19 educational emergencies [9]. In summary, flexible teaching methods have been adopted many times to deal with emergencies in basic education. But how to effectively combine the current situation of course teaching reform in China's colleges and universities, give full play to the role of new production factors of data, and effectively innovate the large-scale flexible teaching model is still a problem to be resolved.

2.3 Current Research Status of Data-Driven Teaching

With the rapid development and wide application of the new generation of information technology, data has gradually become a significant indicator for promoting industry transformation and driving social innovation, and has also become the strategic asset and scientific force to change education and teaching. Karst K et al. analyzed the effectiveness of data-based differentiated teaching interventions in solving the learning gains of students at different learning levels [10]. Liming Guo et al. designed a data-driven five-dimensional support service framework for precision teaching, and selected 51 schools for 2-year teaching practice [11]. Suhkyung Shin et al. designed and verified the conceptual model of personalized flipped learning based on data in higher education environment [12]. It can be seen that the educational concept of data-driven teaching has become the consensus of scholars. But how to grasp the essence of university course teaching, find the fit between data elements and flexible teaching, and enhance the value of data still needs further exploration.

3 The Construction of Data-Driven Flexible Teaching Model of University Courses

3.1 Theoretical Basis

The essence of data-driven flexible teaching in colleges and universities is to confirm the subject status of students, and give students more learning options and equal quality adjustments based on data evidence. Humanistic learning theory, cognitive flexibility theory, evidence-based education theory, and constructivist learning theory will become the important theoretical basis for constructing mode. Humanistic learning theory emphasizes that in flexible teaching, we should attach importance to student-centered teaching, promote the integration of knowledge in teaching and promote meaningful learning. Cognitive flexibility theory emphasizes that it is necessary to promote the multiple representations of knowledge, pay attention to the multiple access of teaching, and pay attention to the non-linear link of resources in flexible teaching. Evidence-based education theory emphasizes that in flexible teaching, we should take full advantages of intelligent technology, find out educational practice problems, and play the role of data. Constructivist learning theory emphasizes that in flexible teaching, we should create a reasonable teaching context, focus on collaboration and communication in teaching, and promote students to construct meaning.

3.2 The Characteristics and Elements of Flexible Teaching of University Courses

The Definition and Characteristics of Flexible Teaching of University Courses
Flexibility refers to the stretchability and variability of something within a certain range. Flexible teaching is the migration of scalability and variability to the field of education. It can provide students with flexible and open teaching time and space, support dynamically adjusted teaching contents, teaching resources, teaching activities to meet students' personalized learning needs. The flexible teaching of university courses is a

teaching method based on the flexible and open teaching time and space, which makes dynamic adjustment and integration innovation on the objectives, contents, implementation, and evaluation of the courses. In this way, it is easier to adapt to the individualized learning needs of students on a large scale and achieve the objectives of courses teaching. The flexible teaching of university courses has the characteristics of equivalence and optionality, flexibility and adaptation, and integration and innovation.

Equivalence and Optionality. The flexible teaching of university courses emphasizes student-centeredness and provides students with multiple forms of learning engagement, learning activities, and learning resources of equal quality. At the same time, students are given the right to make their own choices within certain limits to ensure that all students can generate equivalent learning outcomes.

Flexibility and Adaptation. The flexible teaching of university courses emphasizes defining a dynamic developmental, bottom-not-ceiling learning limit for students. At the same time, it fully anticipates the different paths of student choice and the random problems that will arise in teaching, and makes flexible and natural adaptations in the teaching process based on dynamic feedback.

Integration and Innovation. The flexible teaching of university courses emphasizes the integration and innovation of traditional and new teaching environment, teaching methods, teaching activities, and resource tools based on class scale teaching goals and students' individualized learning needs. Then, it injects momentous vitality into flexible teaching and realizes effective integration of scaled teaching and personalized training.

The Elements and Relationships of Flexible Teaching of University Courses

Guided by *Curriculum and Pedagogy*, this study clarifies the elements of flexible teaching and their relationship based on the essence of courses teaching in colleges and universities through literature analysis and theoretical deduction, as shown in Fig. 1. It shows that it mainly includes seven elements: Core teaching subjects, appropriate teaching objectives, reconstructed teaching content, flexible forms of participation, multidimensional teaching activities, multiple teaching evaluation and flexible teaching environment.

The core teaching subjects include teachers and students, which not only highlight the leading role of teachers, but also show the main role of students. The appropriate teaching objectives emphasize respect for students' diverse needs and differing chemical situations, giving them the power and limits of their own choices. The reconstructed teaching contents emphasizes that teachers revitalize the organization, digital form and presentation of teaching content based on the requirements of the curriculum, the teaching time and space, and the cognitive rules of students. Teachers should give students the power and limits to independently deploy. The flexible forms of participation provides students with a choice of learning time and space, within certain limits for students to switch flexibly. Multidimensional teaching activities takes real problems as the entry point for students' cognitive transformation, students can participate independently and actively explore, and teachers can dynamically analyze and adjust flexibly. The multiple teaching evaluations emphasizes the macro-regulation by teachers and micro-regulation by students of their learning based on multiple assessment results. The flexible teaching environment supports students to identify and independently select the tools and

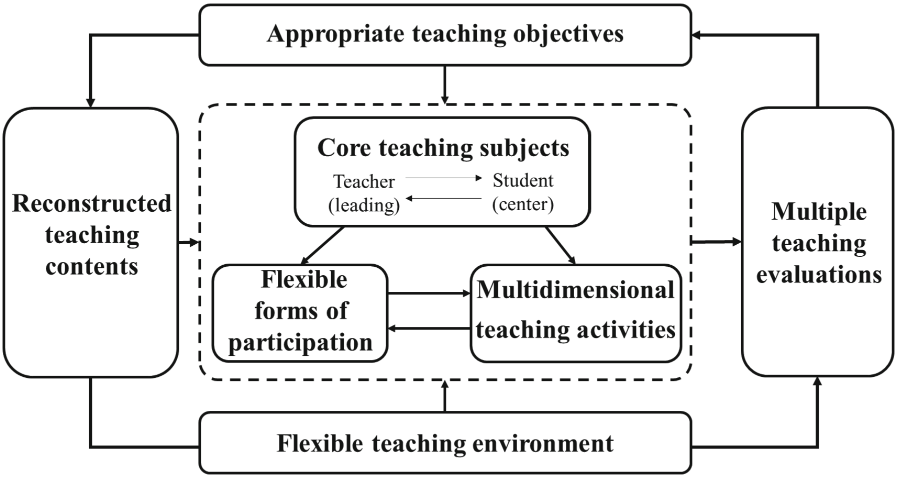


Fig. 1. The elements and relationships of flexible teaching of university courses

resources that meet their learning needs, and providing strong support for the smooth implementation of flexible teaching. These seven elements run through the whole process of flexible teaching, influence and interact with each other, and contribute to the occurrence and evolution of flexible teaching.

3.3 The Logic Path of Data-Driven Flexible Teaching of University Courses

Driving Mechanism of Data on Flexible Teaching of University Courses
To implement data-driven flexible teaching of university courses, it is necessary to clarify the driving mechanism of data on flexible teaching of university courses, as shown in Fig. 2.

The driving mechanism takes the teaching data of university courses as the central driving factor, and drives the key elements to interact multilaterally, which together form a complex and active feedback loop system.

The teaching data of university courses is multi-modal data, including explicit behavior data, implicit physiological data, cognitive emotion data and scene situation data and so on[13]. Intelligent platforms and tools are responsible for collecting relevant teaching data and transforming teaching behaviors. Digital resources and learning support are preserved and presented digitally in intelligent platforms and tools. In the process of flexible teaching implementation, teachers and students accurately target teaching objectives based on data connection and feedback. Then, the teaching contents are openly reconstructed based on the analysis and processing of data. Subsequently, the integration and flow based on data flexibly switch the form of participation. Then, data-based insight and decision-making dynamically deploy teaching activities. Finally, data-based representation and verification visually reorganize teaching evaluation. This driving mechanism guarantees the accuracy and credibility of adjustment direction and teaching decisions, and promotes the improvement of flexible teaching effect.

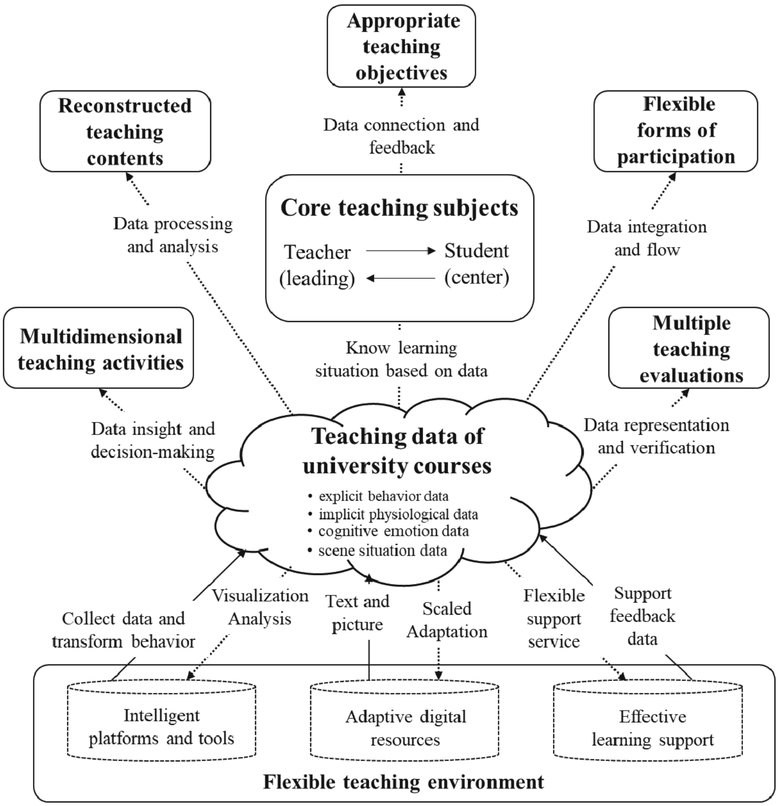


Fig. 2. Driving mechanism of data on flexible teaching of university courses

Driving Functions of Data on Flexible Teaching of University Courses

Dynamic Identification and Analysis of Learning Situation. It emphasizes through data collection, cross-domain correlation and fusion analysis of multimodal data, we can intelligently diagnose the characteristics of students' group learning behavior and individual learning behavior. This enables effective identification of student groups and individual learning situations, and lays a scientific foundation for teachers' scaled adaptation and students' personalized regulation.

Flexible Adaptation to Give Direction. It emphasizes based on dynamic teaching data, scientifically diagnoses existing teaching problems, and clarifies the direction of flexible teaching adjustments. On the basis of the original teaching design, a series of measures or actions are designed flexibly to effectively meet the needs of students and guide students to achieve the teaching objectives of the course.

Human-Machine Collaboration Promotes Decision-Making. It emphasizes using process data as evidence to explore the essence of the occurrence of teaching problems. At the same time, in collaboration with our empirical wisdom, human-machine collaboration determines the optimal solution for teaching objectives achievement. Finally, prudently make instructional decisions that are consistent with the teaching context and students' cognitive development, and put them into practice.

Integration and Circulation to Verify the Effect. It emphasizes that based on the circulating data evidence, intelligent storage and analysis of group teaching data portrait and individual learning data portrait are carried out. It can present the whole scene dynamically to facilitate the accurate evaluation and effective proof of learning effect, and further adjust the whole teaching process flexibly based on learning effect.

Ubiquitous Creation to Empower. It emphasizes establishing a ubiquitous digital connection, promoting dynamic data sharing and circulation, and exploring the law of value in the unknown. It gives teachers and students the basic energy to cope with uncertain teaching situations and support flexible teaching activities, and promotes teachers and students to shift from self-improvement to empowerment.

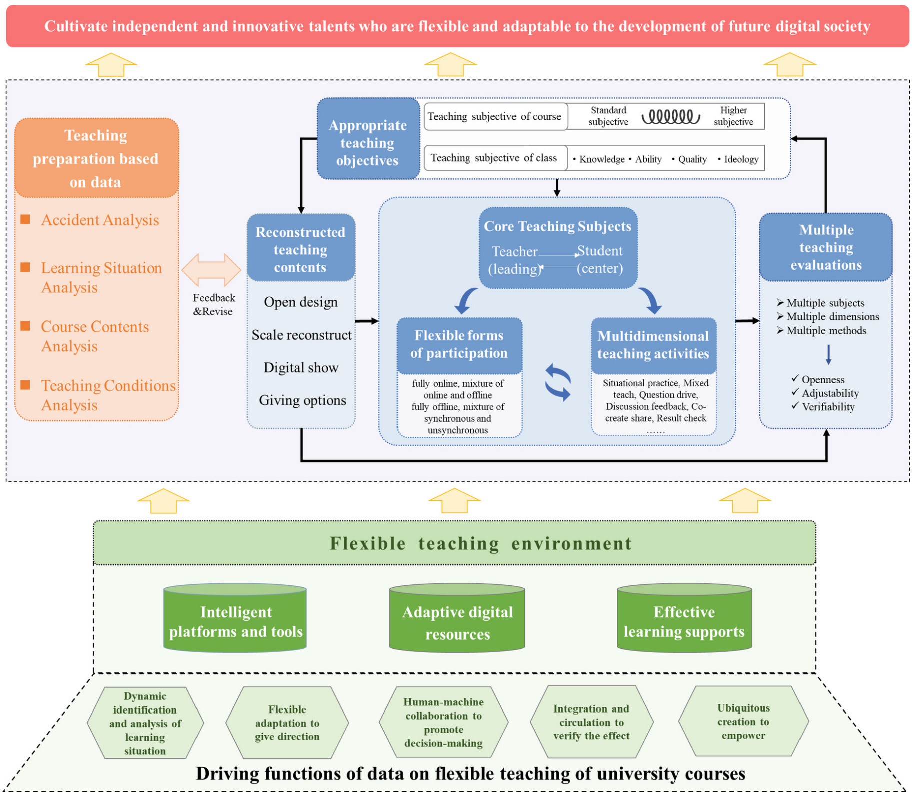


Fig. 3. The data-driven flexible teaching model of university courses

3.4 The Construction of the Data-Driven Flexible Teaching Model of University Courses

This study analyzes the elements and relationships of flexible teaching of university courses, clarifies the logic of data-driven flexible teaching of university courses, and then constructs the data-driven flexible teaching model of university courses, as shown in Fig. 3.

4 The Implementation of the Data-Driven Flexible Teaching Model of University Courses

4.1 Implementation Process

This study adopts design-based research and carries out three rounds of teaching practice relying on the course *Research Methods in Educational Technology* for undergraduate students of educational technology in a university.

The First Round of Design-Based Research

Design and Implementation. At this stage, due to the impact of the epidemic, some students were unable to return to school on time. From the questionnaire of learning needs issued before class, we can know that among the students who cannot return to school, 36.4% prefer to participate in learning through online videos and live broadcasting tools, 45.5% prefer to participate in learning through self-organization such as MOOC platforms. In addition, most students want to learn new and practical content in the course, and hope to provide rich online resources, strengthen the course reminder, and guide paper writing.

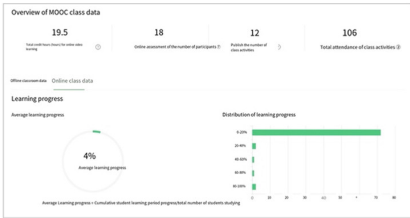
Therefore, this study adjusts the original teaching plan in a timely manner, keeps up with the frontiers of subject development, and takes *Educational Digital Transformation and Educational Technology Research Frontiers* and *Research on Educational Evaluation Reform Empowered by Intelligent Technology* as the teaching content of the first round of practice. At the same time, Live broadcasting tools are prepared to provide live teaching for students who are unable to return to school and prefer to live study.

Analysis and Reflection. The first round of flexible teaching data report was formed by collecting and analyzing the first round of teaching practice data, as shown in Fig. 4. In the first round of teaching practice, most of the students were able to initially achieve cognition, and had high expectations for the content and form of the course learning. However, in this stage of teaching, there are still problems such as teachers' and students' teaching forms and teaching activities are not flexible enough, the effect of real-time data is not good. Therefore, in the second round of teaching practice, it is necessary to enhance the flexibility of teaching sites, use intelligent teaching tools that support instant feedback data.

The Second Round of Design-Based Research

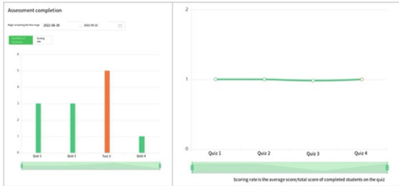
Design and Implementation. The second round of teaching practice takes *Content Analysis* and *Educational Technology Action Research* as teaching contents. In response

Online live teaching data screen



MU Classroom data overview

Online live streaming viewership trend chart



MOOC assessment completion and score rate

Fig. 4. Part of the data graph from the first round of flexible teaching data report

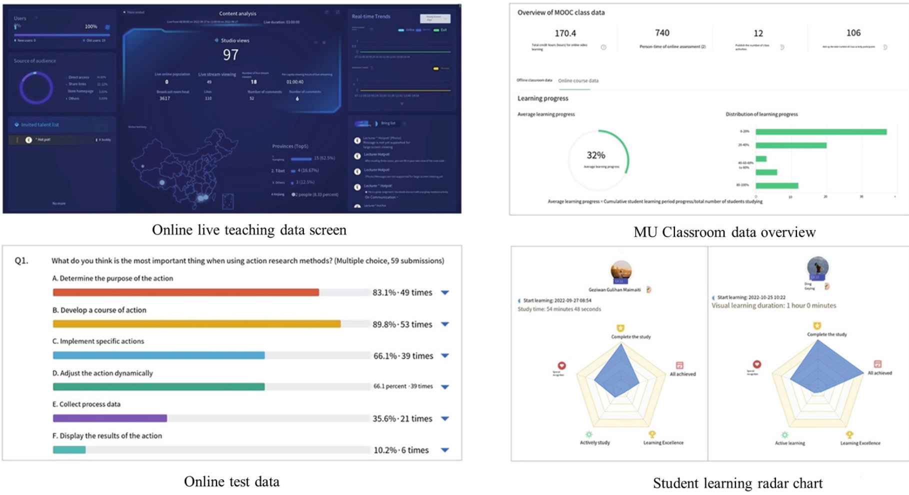
to the problems reflected in the first round of flexible teaching data reports, at this stage, teachers encourage students to flexibly change positions in class based on learning needs. At the same time, the teaching contents and teaching activities were further adjusted. In addition, teachers have selected more interactive and intelligent teaching tools that can provide instant feedback on learning situations.

Analysis and Reflection. Through the collation and analysis of the second round of teaching practice data, the second round of flexible teaching data report is formed, as shown in Fig. 5. In the second round of teaching practice, students have developed shallow flexible learning thinking. However, in this stage of teaching, there are still problems, such as difficulties in understanding discriminatory topics, and low enthusiasm in online learning. Therefore, in the third round of teaching practice, flexible switching modes between platforms and tools should be explored, and discussions and guidance on divergence, heterogeneity and discrimination should be appropriately increased.

The Third Round of Design-Based Research

Design and Implementation. In the third round of teaching practice, the teaching contents were *Digital Transformation Empowered Classroom Teaching Innovation* and *Digital Transformation Empowered Classroom Teaching Model Research*. In this stage, due to the impact of the epidemic, all school courses were converted to online teaching in the first half. In the second half of the time, the epidemic situation was fully opened, and 5% of the students voluntarily chose to study in the smart classroom. At the same time, based on the problems reflected in the second round of flexible teaching data report, the functions of each platform tool for teaching were further clarified. Then, the discussion and guidance of divergence, heterogeneity and discrimination were increased around real problem situations.

Analysis and Reflection. Through the collation and analysis of the third round of teaching practice data, the third round of flexible teaching data report is formed, as shown



Online live teaching data screen

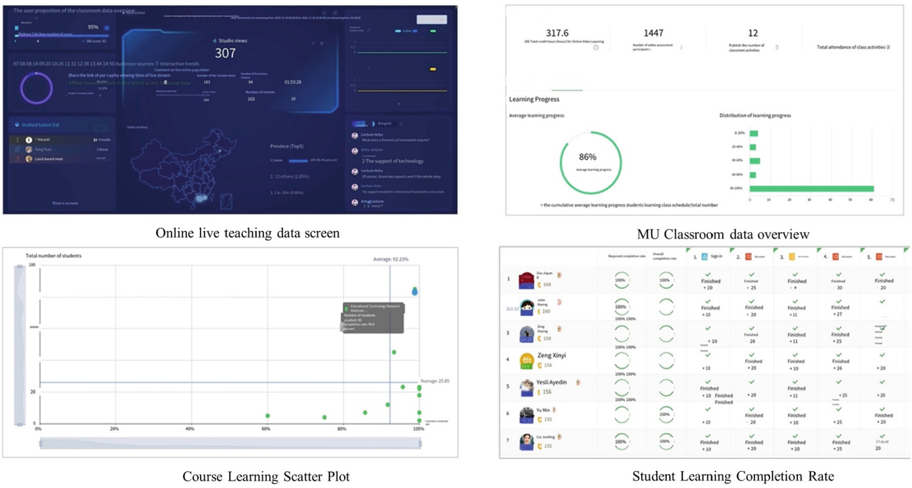
MU Classroom data overview

Online test data

Student learning radar chart

Fig. 5. Part of the data graph from the second round of flexible teaching data report

in Fig. 6. In the third round of teaching practice, students have developed deep flexible learning thinking. At the same time, students have a good grasp of the course knowledge, and can organically combine theory with practice. What's more, students have enhanced their self-awareness and self-thinking, and effectively improved their abilities.



Online live teaching data screen

MU Classroom data overview

Course Learning Scatter Plot

Student Learning Completion Rate

Fig. 6. Partial of the data graph from the third round of flexible teaching data report

4.2 Effect Analysis

Excellent Learning Performance

This study compares the average unit test score of the experimental subjects with the average unit test score of MOOC students over the same period, as shown in Fig. 7. It can be seen that the average score of the unit test of the experimental subjects is higher than the average score of the unit test of MOOC students in the same period, and it is infinitely close to the total score of the unit test, which is at an excellent level. It could indicate that the experimental subjects can better grasp the professional knowledge points and form their own knowledge system of educational technology research methods.

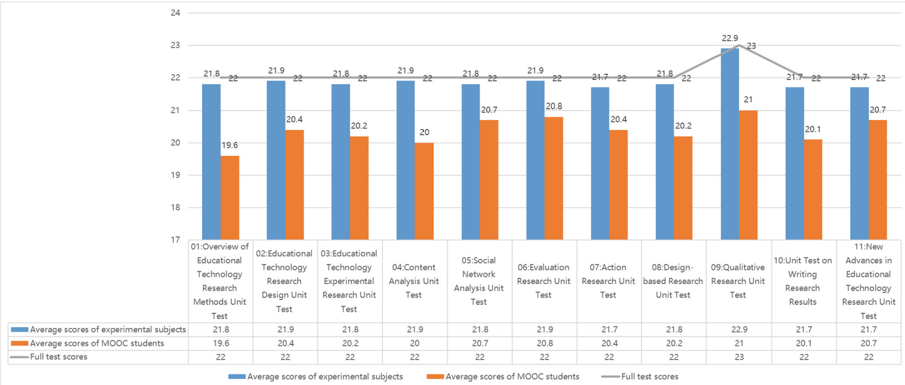


Fig. 7. Comparison of the average unit test score of the experimental subjects and MOOC students

The final grades of the course of the experimental subjects are further analyzed. The results are shown in Table 1. It can be seen that the average score of the final grade of the students' course is about 88.3. The standard deviation is about 2.07, indicating that the overall achievement level of the experimental subjects is relatively high and concentrated.

Table. 1. Descriptive statistical results for final grades

	Numbers	Minimum value (M)	Maximum value (X)	Average value (E)	Standard deviation
Final grades	79	84.00	93.00	88.3038	2.06531
Valid N(in columns)	79				

Flexible Learning Ability Improved

This study was adapted to form the Flexible Learning Ability Scale, which has a high reliability coefficient of 0.967 in Cronbach's α. The scale was issued before and after the experiment for pre-test and post-test. The results are shown in Table 2.

Table. 2. Paired-samples t-test for pre-test and post-test of the flexible learning ability

		Paired Differences					t	df	Sig
		Average Value(E)	Std Dev	SE	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test - Post-test	−.34740	.64269	.07231	−.49135	−.20344	−4.804	78	.000

It can be seen from the Table 2 that the average value of the difference between the scores of students' flexible learning ability before and after the experiment is −.34740, Sig (two-sided) = 0.000 < 0.01, indicating that there was a significant difference in students' flexible learning ability before and after the experiment.

5 Conclusion

Flexible teaching is not only a forced measure to cope with the outbreak of the COVID pandemic, but also a new teaching method which could promote students' personalized development during the normalization of teaching in the post-pandemic period. Therefore, it is of positive practical significance to deeply explore the data-driven flexible teaching model of university courses in the context of digital transformation of education. This study adopted literature research method and design-based research method. Guided by *Curriculum and Pedagogy*, the connotation, elements, and their relationship of flexible teaching in university courses were clarified firstly. Then, this study explored the driving mechanism and functions of data on the flexible teaching of university courses, and the data-driven flexible teaching model of university courses is constructed. Finally, this study through the implementation of the courses, the teaching model is continuously iteratively improved. At the same time, the teaching effect of the courses is detected and analyzed to verify the effectiveness of the flexible teaching model. We hope this study could provide useful references for promoting the reform of university courses teaching, helping the modernization of Chinese-style higher education as well as cultivating high-quality digital and innovative talents.

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Design and Effect of Guided and Adaptive Tutoring Tips for Helping School Mathematics Problems Solving

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Abstract. In the present post-pandemic era, it is both governmental policy and parental demand to provide the students in need with personalized tutoring for difficult mathematics problems solving. However, few studies about the design, implementation and effect of such personalized tutoring systems have been reported previously in the literature. This study attempts to fill the research gap of customised tutoring systems. As a concrete implementation of the patent "Guided Problem-Solving Tutoring Method and System" created by the authors and rooted in Polya's problem solving theory and Bloom's taxonomy of educational objectives, we designed a set of Guided and Adaptive Tutoring Tips (GATT) within a Mathematics Intelligent Assessment and Tutoring System (MIATS) for senior high school mathematics problems, including the knowledge about power functions, logarithmic functions, exponential functions and others. To evaluate the system's effect on students' learning performance, a quasi-experiment was conducted in a secondary school in Beijing during the winter vacation 2022–2023. Two cohorts of Grade Ten students volunteered to participate in this experiment, one as the treatment group using the GATT, and the other using regular answer-based feedback. In the pretest the control group got a better average score than the treatment group at statistically significant level. In the posttest after the experiment there was no statistically significant difference between the two groups. The GATT system is effective on improving students' learning performance and can give full play to the advantages of personalized tutoring.

Keywords: Intelligent tutoring system · Guided and adaptive tutoring tips · adaptive feedback · Mathematics problem

1 Introduction

During the pandemic, students have to study at home. Online learning, with its lack of time and space constraints, has gone from an optional way of learning to a preferred and required form of education, and its viability has been tested by reality. In addition,

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a series of important policy documents promulgated by the Central Government in the past three years on reducing burden and increasing efficiency have further emphasised the need to take advantage of the intelligent tutoring of online education. Therefore, it is the general trend to continue in the post-pandemic era.

This then requires online learning to seize the opportunity to develop in a complementary way to offline education, i.e. its positioning should change from an expedient and a “wartime measure” to a magic formula and a “permanent mechanism”, and its goal should change from replacing offline education and counteracting the impact of the pandemic on the education system to compensating for the disadvantages of offline education and extending the time and space limitations of the classroom. However, as offline classes resume, how should we harness the power of technology and integrate various teaching resources in order to meet the differentiated needs of different students? How to set up the teaching format to provide students with real-time feedback and personalised tutoring, so that they can be taught according to their aptitudes and needs? The solution to these problems is related to the advantages of blended education and the implementation of the Ministry of Education’s policy requirements, and has received much attention from scholars at home and abroad.

2 Related Work

Over the past three years, the massive online education can be seen as a social experiment. From 1 January 2020 to 13 February 2023, a search of the Web of Science for the combination of “online education” and “post-pandemic era” yielded 27 studies and 745 papers related to intelligent tutoring system (ITS). Online education has great promise, but ITS technology still has considerable scope for further research and application to meet the needs of K-12 students (Jia and Miao, 2021).

At present, online education is relatively mature and well established, and given the gradual adaptation of teachers and students, as well as their experience and willingness to continue using it, researchers generally believe that blended education has greater potential to improve the quality of learning by combining the strengths of both teaching methods. Yu et al. (2021) used a cluster sampling to compare the effects of blended and offline case-centered learning for second-year undergraduate nursing students, showing that the use of blended case-centered learning gained good results in improving students’ academic performance and more significant improvements in their critical thinking self-confidence. Ye et al. (2023) analysed 819 validated questionnaires completed by students in Chinese vocational institutions, and found that most students still wanted to continue learning online after the pandemic.

However, the incomplete use of ITS over the past three years has led to a lack of interactivity and personalisation in online education, with many courses online and offline showing severe homogenisation and the advantages not being fully exploited. Mousavinasab et al. (2021), based on 53 original studies of ITSs developed for different educational domains from 2007 to 2017 in databases, provide an overview of the purpose of AI technologies, learner characteristics, etc., stating that ITSs that can facilitate reasoning in the learning process are rarely used in experimental courses. Li (2022) and Liu (2022) found, through literature review and survey respectively, that there are still some problems with online teaching, such as poor student self-discipline and independent learning ability, and the blurring of the boundaries between online and offline teaching, which still need to be transformed and developed.

In addition, the Ministry of Education China recently issued a notice stating that "the difficulty of the 2023 college entrance examination will be significantly adjusted", which means complex scenarios will be added to the mathematics exam, emphasising mathematical ideas and methods, suggesting that extensive "doing questions" is ineffective and that high school students need more targeted tutorials in mathematics to cope with highly flexible and variable test questions.

However, to our literature search knowledge, there is still no research on the design of ITS-based customised instructional systems to provide timely and effective assistance to high school students in their mathematics learning in response to their large and urgent needs. This study attempts to fill this research gap.

3 Theoretical Foundation

The education for high school students, whose learning is focused on the understanding of fundamental theories and basic models, is hoped to guide students heuristically and regularly through the various parts of the theory and the ideas of model building, and to develop an objective overall understanding of them. However, as they vary greatly in their level of basic knowledge, are not yet psychologically mature, traditional teaching methods tend to ignore individual differences and lack ideas of students' learning situation, then the use of ITS can be considered. This is an artificial intelligence technology that simulates a good teacher and provides intelligent coaching to students in a subject, area or point of knowledge, offering one-to-one bespoke courses (Jia et al., 2023). Therefore, the patent "Guided Problem-Solving Tutoring Method and System" (Jia et al. 2022) is chosen to simulate a more personalised and interactive virtual teacher, shifting the emphasis from preaching and teaching in the classroom to solving problems.

For the subject of mathematics, which is characterised by a strong logic and step-by-step approach, the key to true mastery lies in the enhancement of subject literacy, i.e. the ability to come up with a good solution when faced with a practical problem. This has created a major dilemma in traditional mathematics teaching, as teachers have difficulty in explaining how they came up with the solution and in guiding students to discover it. Therefore, we consider using Polya's problem solving theory. By breaking down the thinking process of problem solving, the mathematician Polya came up with a list of four steps: "understanding the problem", "formulating a solution", "implementing the solution" and "reviewing", together with five inspiring suggestions and 23 questions. The design of the Guided and Adaptive Tutoring Tips (GATT) is based on this theory, which inspires students to bridge multiple knowledge points and develop useful habits of thinking, shifting from "learning to know" with an emphasis on the number of questions in traditional teaching to "learning to learn" with a focus on the quality of questions in online learning (Le and Jia, 2022).

For the purpose of providing timely feedback and differentiated tutoring, it is necessary to distinguish students' deviations in learning. Bloom's taxonomy of educational objectives can be helpful. Educational objectives can be divided into three major domains: cognitive, affective and motor, which can be further divided into six levels from low to high: "knowledge, understanding, application, analysis, synthesis and evaluation" in the cognitive domain. By posing questions at different levels, it is possible to enhance interactivity, examine students' cognition, then dynamically adjust teaching and learning and give immediate personalised guidance depending on individual differences. The design of this GATT attempts to move education from being teacher-led in the classroom to being student-led online, helping students internalise knowledge in a step-by-step manner and develop their self-evaluation systems.

4 The Design of GATT for Senior High School Mathematics Problems

Following the guideline given by the patent "Guided Problem-Solving Tutoring Method and System", we designed a set of GATT within a Mathematics Intelligent Assessment and Tutoring System (MIATS) for 24 senior high school mathematics questions, including the knowledge about power functions, logarithmic functions, exponential functions and others. A large problem is broken down into several smaller problems that follow the normal thinking process of problem-solving, each with carefully designed options based on the points of vulnerability. Because the guidance for every problem differs from each other, we just introduce the design of GATT for one question as one example.

Question. It is known that $f(x) = 1+\log_a(x+2)$ ($a > 0$ and $a \neq 1$) and $g(x) = f(x-2)$.

(1) If the graph of the function f(x) passes through the fixed point A at a constant, find the coordinates of the point A.
(2) If the maximum value of the function g(x) on the interval [a, 2a] is greater than the minimum $\frac{1}{2}$, find the value of "a".

For this question, the generic feedback given in traditional offline teaching is generally as follows.

Step 1. For question (1), according to the properties of logarithmic functions, the graph of $q(x)=\log_a x$ ($a > 0$ and $a \neq 1$) passes through the fixed point (1,0) at a constant, then we can find the coordinates of the fixed point A through which the function $f(x) = 1+\log_a(x+2)$ ($a > 0$ and $a \neq 1$) passes at a constant.

Step 2. For (2), first find the expression for g(x), then according to the relationship between the increasing and decreasing nature of logarithmic functions and base numbers, classify and discuss different cases, noting that $a > 0$ and $a \neq 1$. Combining the results obtained, we can obtain all the values of "a" that satisfy the question.

Again for this question, GATT is designed as follows. Due to space constraints, only the timely feedback for the first sub-question and the design ideas for each step are presented below. In fact, each option comes with an instant intelligent hint, helping students to understand their own thinking deficiencies in order to achieve the effect of targeted coaching.

Step 1. For question (1), the coordinates of the fixed point through which the graph of the logarithmic function $q(x)=\log_a x$ ($a > 0$ and $a \neq 1$) passes at a constant are?

A. (0,0)

Intelligent hint: According to the properties of logarithmic functions, the domain of definition of q(x) is $(0, +\infty)$, i.e. it cannot take $x = 0$, so it cannot pass through the point (0,0), then the coordinates of the fixed point should be? (turn to Step 1).

B. (1,0)

Intelligent hint: According to the properties of logarithmic functions, the value of the logarithmic function q(x) is always 0 when $x = 1$, i.e. the function passes through the fixed point (1,0) at all times. (turn to Step 2).

C. (0,1)

Intelligent hint: According to the properties of logarithmic functions, the domain of definition of q(x) is $(0, +\infty)$, i.e. it cannot take $x = 0$, so it cannot pass through the point (0,1), then the coordinates of the fixed point should be? (turn to Step 1).

D. (1,1)

Intelligent hint: According to the properties of logarithmic functions, the value of q(x) is 1 only when $x = a$, and "a" is not always equal to 1, so it does not necessarily pass through (1,1), then the coordinates of the fixed point should be? (turn to Step 1).

This guiding step is designed to implement the advice in Polya's problem solving theory that "teaching concepts should be strengthened and mathematical abstraction should be reinforced", and to guide students through the two steps of "understanding the problem" and "formulating a solution". By familiarising themselves with the question, students should be able to identify the unknown quantity of the fixed point of f(x) and associate it with the fixed point of q(x) based on the known function expression, thus specialising and abstracting the problem. In addition, this is in line with Bloom's taxonomy of educational objectives at the "knowledge" level, i.e. recognising and remembering the fixed points of logarithmic functions they have learned.

Step 2. For (1), the graph of the logarithmic function $q(x)=\log_a x$ ($a > 0$ and $a \neq 1$) passes through the (1,0) at a constant, then the coordinates of the fixed point A through which the function $f(x) = 1+\log_a(x + 2)$ ($a > 0$ and $a \neq 1$) passes at a constant are?

A. (−2,1) (turn to Step 2)
B. (−2,2) (turn to Step 2)
C. (−1,1) (turn to Step 3)
D. (−1,2) (turn to Step 2)

This guiding step further directs students through the two steps of "implementing the solution" and "reviewing". By using the expression for f(x), students can relate the known to the unknown and calculate the quantity to be found using holistic substitution. This also fits in with the "understanding" level, where the most fundamental meaning of "the logarithmic function is constant at 0 when the true number equals 1" is dissected and re-expressed through different forms of the true number and the unknown "x".

Step 3. For (2), the function $f(x) = 1+\log_a(x + 2)$ ($a > 0$ and $a \neq 1$), and $g(x) = f(x - 2)$, what is the expression of the function g(x)?

A. $1+\log_a x$ ($a > 0$ and $a \neq 1$) (turn to Step 4)
B. $-1+\log_a x$ ($a > 0$ and $a \neq 1$) (turn to Step 3)
C. $1+\log_a(x - 2)$ ($a > 0$ and $a \neq 1$) (turn to Step 3)

D. $-1+\log_a(x-2)$ ($a > 0$ and $a \neq 1$) (turn to Step 3)

This guiding step can be seen as the beginning of a new problem, then the design of it runs through Polya's recommendation of "improving computational training and analysis", guiding students to "understand the problem". Students should be able to calculate a clearer representation of the g(x). This step can also be seen as a further step from previous sub-questions, as the design is in accordance with the "application" level, where the meaning of the independent variable and the corresponding law in the function f(x-2) is applied to this context, thus translating it into an expression for g(x).

Step 4. For (2), the function $g(x) = 1+\log_a x$ ($a > 0$ and $a \neq 1$), is increasing or decreasing on the interval [a,2a]?

A. monotonically increasing (turn to Step 4)
B. monotonically decreasing (turn to Step 4)
C. monotonically increasing when $0 < a < 1$; monotonically decreasing when $a > 1$ (turn to Step 4)
D. monotonically decreasing when $0 < a < 1$; monotonically increasing when $a > 1$ (turn to Step 5)

The design of this guiding step follows the advice to "emphasise the integration of numbers and shapes to enhance intuitive imagination" and guides students to "formulate a solution". Students should find the link between the increasing and decreasing nature of logarithmic functions and base numbers. With relevant graphs, they can categorise and discuss the function according to the size of its base number "a". This also matches the "analysis" level, where the complex logarithmic function with a parameter "a" is broken down into situations that have already been studied, and where the difference between the two is the range of values of the parameter "a".

Step 5. For (2), when $0 < a < 1$, given the function $g(x) = f(x-2) = 1+\log_a x$ ($a > 0$ and $a \neq 1$), if its maximum value on the interval [a,2a] is greater than the minimum $\frac{1}{2}$, then the value of "a" at this point can be?

A. $\frac{1}{4}$ (turn to Step 6)
B. $\frac{1}{2}$ (turn to Step 5)
C. 2 (turn to Step 5)
D. 4 (turn to Step 5)

Step 6. For (2), when $a > 1$, given the function $g(x) = f(x-2) = 1+\log_a x$ ($a > 0$ and $a \neq 1$), if its maximum value on the interval [a,2a] is greater than the minimum $\frac{1}{2}$, then the value of "a" at this point can be?

A. $\frac{1}{4}$ (turn to Step 6)
B. $\frac{1}{2}$ (turn to Step 6)
C. 2 (turn to Step 6)
D. 4 (turn to Step 7)

The above two steps follow through on the advice to "focus on logic practice and reasoning" and guide students to "implement the solution". What students do at this stage is to solve the equations for each of the two clearly categorised situations based on the discussion above, in which logical rigour and computational accuracy are key. In addition, this is consistent with the "synthesis" level, where the properties of logarithmic functions, known conditions and other bits and pieces are integrated into a holistic system with g(x) at its core, from which the possible values of "a" can be deduced.

Step 7. For (2), if maximum value of the function $g(x) = f(x - 2) = 1+\log_a x$ ($a > 0$ and $a \neq 1$) on the interval [a,2a] is greater than its minimum $\frac{1}{2}$, then the value of "a" can be?

A. $\frac{1}{4}$ (turn to Step 7)
B. 4 (turn to Step 7)
C. $\frac{1}{4}$ or 4 (end of tutorial for this question)
D. $\frac{1}{2}$ or 2 (turn to Step 7)

Finally, this guiding step aims to guide students to "review" the whole process of those problem-solving activities described above, and to arrive at an answer to the original question, during which learners can check whether the solution process and conclusion are correct, and also summarise the thinking behind the problem, so as to grasp the root causes and deepen their core mathematical literacy. Meanwhile, it is in line with the "evaluation" level. Students can sense the value of the completed problem, both in terms of its internal organisation and the applicability of the external ideas.

5 Pilot Application and Evaluation of the GATT

To evaluate the system's effect on students' learning performance, a quasi-experiment was conducted in a secondary school in Beijing during the winter vacation 2022–2023. Two cohorts of Grade Ten students volunteered to participate in this experiment, one as treatment group using the GATT, and the other using regular answer-based feedback, with neither cohort knowing which group they were in or that the other was using a different system. The students in both classes were randomly assigned at entry to the class, in a sense already controlling for their initial level, and were taught by the same teacher, with negligible differences in past learning content and format, and had learned the power, logarithmic and exponential functions and other knowledge points encapsulated in the system. However, the students in the two classes were of varying levels of mathematics, and according to the final examinations of the previous semester, it was evident that the students in the treatment group generally performed worse in mathematics than those in the control group. In view of this, the collected samples were analysed using an ANCOVA (Analysis of Co-Variances) to eliminate the effect of students' initial levels to observe changes in performance and to further ensure randomisation of the quasi-experiment.

The holiday is a "critical period" for checking gaps and making up for high school students, and the main purpose of the winter holiday homework is to review what they have learnt and to lay the foundation for the next term; at the same time, the holiday is also a "golden period" for rest and relaxation, and students need sufficient time to adjust in order to be in a better frame of mind to meet new challenges. Therefore, winter holiday assignments need to be carefully designed, avoiding being mechanical and repetitive, and feedback needs to be enhanced in order to help students consolidate knowledges with high quality and efficiency. These needs coincide with the highlights of the GATT designed in this study. Based on this, we have chosen this time period to open the system to some of those students. Each participating student has an account of their own and can freely access the system at any time and from any location, using any browser, through different electronic devices such as mobile phones, computers and tablets, to start a tailor-made mathematics learning.

All students in the two groups were required to complete three modules in sequence: pretest, drill with different approaches, and posttest. The pretest and the posttest included the same 10 questions for all students. Both the appearing sequence of the questions and their options are randomised to avoid copying between students. The time limit is one hour and each student can only answer once.

After completing the pretest, the two groups of students were allowed to move on to the "drill" session, where they completed the same questions from the question bank to train their problem-solving skills. The treatment students used the GATT, where each wrong question was given a step-by-step prompt and each answer received immediate personalised feedback. The control students used traditional methods, where the feedback received was similar to consulting a reference answer offline and only knew whether their answer was correct or not. In order to avoid memorising answers and passing on copies of answers, no standard answers were given directly in the feedback to students in both groups.

To encourage students to participate, a series of incentives have been set up. Students who complete all the learning activities can receive not only a "Star of Mathematics" medal, which is a virtual medal set up on the system, consisting of a flower-like pattern and words of encouragement, but also a souvenir, which will be distributed by post to each student who meets the criteria. Because of the conditional relationship between these learning activities, students who complete the "posttest" have completed all the activities and will receive both two rewards listed above.

After systematic counting, out of a total of 80 students in the two classes, 66 received the "Star of Mathematics" medal. This high completion rate 83% is of analytical value.

6 Findings

Of the 66 students who completed all the learning activities in the quasi-experiment, one student in the treatment group took 49 s and 31 s to complete the pretest and posttest respectively, which were much lower than the average completion time, and scored 22.22 and 0 respectively, which can be presumed to be completed with a very unserious attitude, so this individual was excluded from the analysis. Therefore, 28 and 37 samples from the treatment and control group, respectively, were valid.

In terms of absolute scores, the changes in scores are listed in Table 1. Considering the fact that the difficulty, the test points and the scores for the same knowledge points of the two tests were similar, the two scores are comparable. It can be seen that both types of "drill" improved students' mastery of those knowledges, with a relatively small improvement in the control group and a larger one in the treatment group.

In the pretest, the mean difference between the treatment and control groups was -11.06, which was statistically significant ($p = 0.0023 < 0.01$) in an independent sample t-test. The effect size between the 2 groups in terms of Cohen's d was -0.553, which

Table 1. The grade statistics in the pretest and posttest

Classes	Pretest	Posttest	Increment	Growth rate	Cohen's D of increment
Treatment (N = 28)	77.08 (23.55)	89.03 (9.52)	11.94**	15.50%	0.665
Control (N = 37)	88.14 (17.47)	92.66 (8.66)	4.52**	5.13%	0.379
Difference between treatment and control group	−11.06**	−3.63	7.42	9.36%	
Cohen's D of difference between groups	−0.553	−0.340			–

*: $p < 0.05$, **: $p < 0.01$

is a moderate to large difference size. In the posttest, the mean difference between the treatment and control groups was −3.63, which was not statistically significant ($p = 0.113 > 0.01$) in the independent sample t-test. The effect size in terms of Cohen's d was −0.340, which is a small to moderate difference size.

From the pretest to the posttest, the treatment group made a great increment of 11.94 or 15.50%, and the increment was statistically significant ($p < 0.01$) in a paired sample t-test. However, the control group also made an increment of 4.52 or 5.13%, and the increment was statistically significant ($p < 0.01$) in a paired sample t-test. Compared with the pretest, the treatment group achieved a better progress in the posttest than the control group.

Because of the statistical significance of the two groups' score difference in the pretest, an ANCOVA is conducted to adjust the two groups' difference in the posttest considering the difference in the pretest. The result is shown in Table 2.

Table 2. ANOCA result (confidence interval: 95%)

Classes	average	standard error	lower confidence limit	upper confidence limit
Control (N = 37)	92.040	1.467	89.106	94.973
Treatment (N = 28)	89.856	1.697	86.465	93.248

As seen from the Table 2, the average score of the treatment group was still 2.184 points lower than that of the control group in the posttest, even if we consider the pretest scores. However, the difference was not statistically significant ($p = 0.344 > 0.05$). Compared with the large disadvantage of 11.06 points in the pretest, the use of this system greatly narrowed the gap between the two groups, which indicates that the use of the intelligent teaching system has significantly benefited the treatment students in the treatment group.

In summary, by using the GATT designed in this study, the treatment group's performance improved significantly in absolute terms, and in a relative comparison with the control group, those students closed the gap that they had initially lagged behind.

7 Conclusion

At a public high school in Beijing, China, the GATT designed in the study was used to guide online revision during the winter holiday of the 2022–2023 academic year. In the system, we designed step-by-step detailed intelligent guided prompts based on different students' learning pace and thinking habits, so that the number of questions and time each individual needs to complete are tailored to better target training on weak points.

A quasi-experiment was conducted to compare the effectiveness of personalised tutoring provided by the GATT with the effectiveness of fixed tutoring provided by traditional teaching methods, so as to explore more effective ways of online education. Before the experiment, there was a significant difference in mathematics proficiency between the control and treatment groups, and there was no statistically significant difference in the acquisition of relevant knowledge after using the traditional method and the guided instruction system respectively. Both the absolute scores and the relative differences indicate that the intelligent tutoring supported by the GATT is effective and can better exploit the advantages of online education.

8 Discussion and Implication

For online education, "online" is the form and means, while "education" is the foundation and purpose. The GATT designed and practiced in the study is a high-quality way to exploit the advantages of blended education and develop students' professionalism.

For the control group, the education they received online was similar to the traditional offline education model, i.e. the practice problems students needed to complete were transferred from the exercise books to the electronic forms, and the feedback they received was the same as the analysis they looked at in the offline education. In this case, online education is homogeneous with offline learning, because it is centered on a technology-led, knowledge-infusing virtual teacher, and has not fundamentally changed the structure and ecology of education.

However, the online learning that the treatment group received was very different. Their answers were crossed with the feedback from the system, i.e. each answer received immediate feedback, and after each step of the prompt, they were given a chance to correct their answers, and a new hint would appear next. This leads students to think clearly about the relationship between each step and to pay attention to the steps they tend to make mistakes in. The system provides students with an immersive, supportive and highly engaging studying environment in which they can gain a holistic learning experience, broaden their academic horizons and achieve self-growth. In this context, education is student-centered, learning-centered, thus giving full play to the unique advantages of online education.

It is worth noting that, as with all experiments that require the participation of people, the result of this quasi-experiment needs to avoid the Hawthorne effect, i.e. the methodological artefact of the research subject being aware that he or she is being studied. In this paper, we conducted the experiment over a period of time and the Hawthorne effect, a short-term influence, is no longer significant. Furthermore, what is observed in this quasi-experiment is not the behavior of a single treatment group, but rather the gap in performance between the treatment and the control group, both of which aim to achieve better grades in order to obtain rewards, and the resulting Hawthorne effect can be offset to some extent. Therefore, the achievement and student mastery levels tested in this experiment are real and valid, and the conclusions obtained from the analysis are objective and scientific.

In summary, with this GATT, tutorial strategies can be automatically adjusted according to learners' abilities and characteristics, and the effectiveness of learning can be dynamically assessed. The result of this research will not only contribute to the achievement of educational equity, enabling every student to receive personalized tutoring and students from ordinary districts to easily share the resources of prestigious schools, but also innovate teaching and learning and reduce the burden of teachers and students, foster innovative talents and promote the development and progress of students' inquiry-based self-learning, self-monitoring, self-motivating and other skills.

9 Limitation and Further Study

Due to the limited time available, the GATT designed in this research was only put into practice on a small scale. If the use could be extended and a sample of students could be interviewed to gather their real attitudes and feelings of using the system, the effects would be more evident and the reasons leading to the positive effects would be revealed in more detail.

In addition, this paper is only a small pilot, with very few mathematics questions required, all of which are currently compiled manually. However, with the help of the artificial intelligence, it is already maximizing the value of human labor by providing tailored guided instructions for all users by only having to compose the guidance once for the same question. It would be more informative for exploring teaching models in the post-pandemic era if teaching hints could be automated using advanced technology and applied to regular school teaching.

In the future post-pandemic period, opportunities should be seized to further study how similar online education tools can complement offline classes, and how to deeply integrate the advanced technology possessed by online learning with the high-quality teachers in offline classes, so as to maximize the advantages of blended education and build a modern education system for the future.

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