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Developing a Mixed-Reality Framework for Innovative Movement Education: A Mixed-Methods Study

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Abstract

The advent of the emerging technologies era opened up new modes of digital learning tools, such as Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR). As an expressive form of physical education, performing arts (e.g., dance/movement processes) require individualised learning modes to respond to students' diverse needs guided by physical educators. Literature shows that MR is a transformative tool for the rapidly evolving field of movement/physical education. This mixed-method research aims to develop a survey instrument to examine the 'Needs' of physical education learners, as well as their understanding and acceptance of hybrid learning modes. The study also proposes the 'MENG' framework to guide module design and support students' online learning through MR. Instrument validation showed high learner acceptance, evidenced by an 85% survey response rate. Correlation analysis revealed statistically significant relationships (p < .01) among 'Internet Usage'(IU), 'Students' Understanding'(SU) of MOOC+SPOC, and 'Students' Attitudes'(SA) towards Blended Learning, with correlation coefficients of .644, .712, and .962, respectively, indicating a moderate positive relationship among these three variables. Complementing these findings, the qualitative research using 'Exemplary-case Analysis'(ECA) revealed that MR-driven educational systems enable the creation of personalised and engaging learning experiences tailored to learners' individual styles and diverse preferences. Through integrating MR into physical education, educators can create engaging and contextualised learning environments to meet the needs of learners from diverse sociocultural backgrounds. Moreover, it also facilitates curricular adjustments for students' learning through hybrid mode. This study contributes to advancing Sustainable Development Education by leveraging MR to innovate and personalise physical education.

Keywords:
sustainable development education, individualised learning, innovative physical education module, mixed-reality, educational system, quality education

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Introduction

The advent of the emerging technologies era has opened up different modes of digital learning tools such as Augmented Reality (AR), Virtual Reality (VR) and the most recent Mixed Reality (MR). As an expressive form of performing art, physical education guided by educators requires individualised learning modes to respond to students' diverse needs. This article details the development of a framework for an innovative movement education module using MR technology. The framework is grounded in a mixed-methods approach, combining quantitative findings from survey validation with qualitative insights from literature and Exemplary-Case Analysis (ECA). MR integrates virtual elements into the real environment, creating an immersive learning experience (Azuma, 1997; Milgram & Kishino, 1994). In other words, MR is a further development of VR. It allows people to experience current objects or scenes things that don't literally exist. This technology projects virtual elements into the real-world environment, creating an interactive feedback loop between the physical and virtual realms, thereby enhancing the immersion and effectiveness of the learning experience.

Problem Statement

The online teaching mode is friendly for subjects that focus on theory, because even in the classroom, teachers will use PPT, multimedia, projection and other teaching equipment. The shift to online teaching mode itself will not lower the quality of teaching (Elhaty et al., 2020; Gamage et al., 2020). However, in fields that emphasise movement demonstration, such as sports (Griffiths et al., 2022), dance (Li et al., 2022), piano (Topalak, 2022), calligraphy (Li, 2020), and musical instruments (Vaizman, 2022), there is a significant mismatch between current teaching methods and the effective presentation and breakdown of 3D movements.

This approach fails to offer action demonstrations, immediate evaluations or interactions, resulting in three issues: a) One-way, two-dimensional video transmission limits learners' ability to observe the instructor's movement demonstrations from multiple perspectives, thereby hindering their comprehension of movement intent and increasing cognitive load. b) The network latency and the absence of co-located interaction with the instructor significantly diminish kinesthetic feedback and real-time correction, thereby increasing the likelihood of errors in students' motor learning (Svatos et al., 2022). c) The isolation inherent in virtual learning environments impedes the nuanced and embodied interactions between teachers and students, making it imperative to develop online teaching frameworks capable of addressing these limitations.

Gaps in Existing Digital Learning Tools for Physical Education

Scholars have explored the application of augmented reality and virtual reality technologies in education. For instance, Li et al. (2022) conducted a study during the pandemic, revealing that online dance instruction via the ZOOM platform could substantially enhance students' 4C skills, including creativity, communication, collaboration, and critical thinking. Dastane et al. (2024) proposed integrating metaverse, virtual reality, and extended reality technologies into organisational development, as well as optimising training programmes to enhance employee productivity. Griffiths et al. (2022) found that social media platforms, blogs, and mobile applications are increasingly utilised in career development. Although most studies have primarily focused on theoretical frameworks rather than practical, kinesthetic learning experiences, empirical research examining the positive impact of digital tools on learning and practice within physical education remains limited. This study addresses a critical gap by leveraging the unique features of mixed reality, such as the overlay of virtual movements onto real limbs, multi-angle visualisation, and real-time performance assessment, to improve the efficiency of motor skill instruction in online physical education, offering a technical solution that surpasses the limitations of traditional AR/VR tools.

Limitations of AR/VR in Physical Education Transfer

Although AR/VR technologies have demonstrated initial potential in the domain of sports education (Dastane et al., 2024), they predominantly rely on a passive observation-based instructional model and have not effectively addressed the fundamental challenges inherent in sports education:

a) a) Cognitive gap: learners are unable to visualise their own bodies during virtual instruction, leading to an absence of movement-based feedback (Li et al., 2022);

b) Technical gap: VR normally locks students into a single viewpoint, limiting their ability to see 3D movements or break down effectively, thereby compromising learning effectiveness (Xu et al., 2023);

c) Pedagogical gap: current implementations of AR/VR and other information and communication technologies (ICT) lack functionality for real-time error detection and correction. In other words, "timely corrective feedback" allows learners to acquire skills more efficiently (Salmoni et al., 1984). Current AR/VR/digital teaching tools are limited in providing real-time assessment and precise observation of learning during complex motor tasks, such as rapid jumps, turns, flips, and joint angle adjustments. MR technology can address this limitation through skeletal tracking and instantaneous performance evaluation.

MR as an Integrative Solution: Addressing the Deficiencies of Online Teaching and AR/VR

Although the online teaching format has made significant contributions to the dissemination of theoretical knowledge (Griffiths et al., 2022), it presents certain limitations in disciplines such as physical education and dance.

a) Assessment constraints, as they are unable to accurately evaluate movement execution (Elhaty et al., 2020);

b) Deficiencies in interactive instruction, particularly the absence of embodied, real-time guidance during remote online learning (Lakoff, 2012);

c) Contextual shortcomings, as two-dimensional video-based or prerecorded instructional formats may neglect individual differences in motor skill development (Gardner, 2011; Özdemirci, 2025; Pasandi & Abadi, 2025).

The application of AR/VR technology has been largely confined to passive observation and cannot address the aforementioned pedagogical challenges. In contrast, the MR-based physical education approach proposed in this study has the potential to bring about transformative changes in the field of education by effectively addressing the identified gaps：

1. Cognitive gap (lack of kinesthetic feedback): By utilising the capability of MR technology to integrate virtual environments with real-time interaction, students are able to observe and imitate the movements of virtual instructors, thereby effectively addressing the challenge of delayed correction of movement errors that occurs in traditional online teaching settings (Lee & Schmidt, 2025).
2. Technical gap (Perspective Limitation): By leveraging the flexibility and transparency inherent in MR technology, students can observe the virtual teacher’s movements from multiple vantage points. This effectively overcomes the limitation of a singular visual perspective commonly encountered in traditional online teaching settings, where instructors are restricted to a fixed frontal view of the screen (Chavez et al., 2025).
3. Teaching gap (lack of real-time assistance): By using the real-time motion-capture capability of MR technology, the system can synchronise learners' movements with those of a virtual teacher, thereby enhancing instructional effectiveness. This "timely correction and feedback" mechanism offers essential support to individuals undergoing motor learning (Salmoni et al., 1984). Furthermore, it functions as a virtual digital instructor operating within the learner's "Zone of Proximal Development" (ZPD), facilitating guided learning in accordance with Vygotsky's theory (1978).

Integrating MR technology and an innovative teaching model addresses the limitations of previous online teaching approaches. By synthesising Mayer's multimedia learning principles with Vygotsky's sociocultural theory, this model effectively mitigates a key challenge in distance education the "disconnect between physical engagement and cognitive processing." Operating within a deeply realistic simulated environment, it has overcome significant technical barriers. The author posits that this represents a novel pedagogical framework capable of achieving scalability, sustainable development, cost-effectiveness, and pedagogical innovation in physical education (Chu & Feng, 2021; Xu et al., 2023).

Theoretical Foundations of MENG Framework

The design of the MENG (Mixed-Reality in movement to ENGage students) module is grounded in three foundational theoretical perspectives, each underpinning a distinct dimension of the MR learning environment. Mayer's Cognitive theory of Multimedia Learning (Mayer, 2005) emphasises that learning is enhanced through the coordinated use of multiple processing channels. This principle directly informs the MR system's dual-channel presentation approach, integrating visual demonstrations with physical feedback to minimise extraneous cognitive load. Vygotsky's sociocultural theory (1978), particularly the concept of the ZPD, serves as the foundational theoretical framework for designing the MR physical system. Through features such as real-time bone overlap and corrective feedback, it is designed to act as a digital scaffold within the learner's ZPD.

In addition, to better accommodate the diverse preferences of learners in the design of mixed reality (MR) teaching scenarios, this study employed Gardner's theory of multiple intelligences (MI) as a heuristic design framework (Gardner, 2011). Given the ongoing debate about its empirical validity in educational contexts, this study does not interpret MI as a psychological or cognitive science-based theory for explaining learning mechanisms. Instead, within the scope of this research, MI functions primarily as a systematic classification tool. The proposed intelligence dimensions such as bodily-kinesthetic, musical-rhythmic, and logical-mathematical serve as practical categories for observing, describing, and classifying the varied learning tendencies and strengths exhibited by students in MR environments.

The Synthesis of Theoretical Frameworks: An Integrated Perspective

This study synthesises Mayer's and Vygotsky's theories to address core gaps in online physical education. Salomon's (1981) view of media as symbolic systems is integrated to elucidate how MR representations reshape motor cognition. Gardner's multiple intelligences theory is then applied as a heuristic to personalise instruction. This integrated framework operates through three mechanisms:

a) *Kinesthetic Feedback as an Extension of Multimodal Learning*

Real-time skeletal overlay, as a signature feature of MR technology, provides kinesthetic feedback in sports education and, together with visual demonstration, forms a dual-channel learning system, providing effective visual assistance for learners.

b) Providing Scaffolding Feedback Within the ZPD

This real-time feedback functions as a digital guide within students' ZPD, helps students progress towards autonomous performance (Vygotsky, 1978). Virtual teachers continuously offer expert guidance, support the development of motor skills, and gradually achieve learning autonomy.

c) A Pathway to Personalised Learning

MR technology integrates virtual and real worlds to create rich and fascinating learning scenarios. And meets the needs of personalised education by supporting a variety of learning activities, such as action imitation, rhythm synchronisation and self-assessment.

The Advantages of MR Technology in Physical Education

First, MR addresses mainly challenges for students from the technology perspective: low efficiency, insufficient accuracy, and difficulty keeping pace with movement rhythms. By superimposing the virtual teacher's avatar directly onto the learner's own body, it creates an immersive teaching scene to promote the embodied learning (Schack & Mechsner 2006), effectively solving the above problems. From the teaching perspective, MR provides students with actionable feedback, such as correcting their movements, helping them improve and remember better, which reduces their workload (Lindgren & Johnson-Glenberg 2013; Sigrist et al. 2013).

Second, MR transforms teaching models by supporting contextualised and interactive learning. It can be equipped with a remote teaching training and operation evaluation system, providing multiple materials such as dance works, physical teaching demonstrations, and test teaching content, so students can master the teaching content at multiple levels and dimensions and learn independently and effectively execute and internalise the movements.

Third, it ensures high-quality physical skill practice that students are not subject to space or geographical restrictions (Osman et al., 2024), and can conduct online training anytime and anywhere, verify learning results, supervise learning intensity, mobilise learning enthusiasm, and conduct tests and questionnaires through students' learning results, information feedback, and other means are used to continuously improve the teaching process to ensure that the teaching level is not inferior to offline teaching.

In summary, by addressing the documented shortcomings of online practical education, this study provides a feasible and systematic MR-based hybrid module for fields such as dance and sport.

Research Objectives and Research Questions

According to the review and analysis, it can be concluded that several research issues remain unresolved by previous studies:

1. How can learners' individualised motor skill learning needs be effectively quantified within a blended learning environment, thereby overcoming the limitations of MOOC and SPOC in providing personalised support?
2. How can corrective guidance be delivered for learners' movement performance through a mixed reality interface, addressing the shortcomings of AR and VR in terms of real-time feedback mechanisms?

This study proposes an online sports teaching model that integrates MR (Mixed Reality) technology, grounded in the instruction of online movement-based courses such as dance. The model aims to effectively address the limitations inherent in MOOC/SPOC teaching approaches, including the lack of optimal perspective observation, educational supervision, and real-time feedback. Furthermore, it seeks to enhance the constrained functionalities currently present in sports education, training, assessment, and learning processes. The main research objectives of this paper are as follows：

RQ1: How can students' learning needs in MR-based movement education be identified through a validated survey instrument?

RQ2: How can MR be exemplified as an innovative pedagogical tool grounded in established learning theories?

Mixed Research Method

This study employs a mixed-methods research design in accordance with the principle of methodological triangulation and validation strategies that enhance replication of findings (Creswell & Clark, 2017; Tashakkori & Teddlie, 2010). This mixed-research study integrated quantitative research (instrument validation) as well as qualitative research [module development following the 'Design and Development Research' (DDR) (Richey & Klein, 2007) but with only exemplary cases (i.e. students involved in the piloting of the module) reported in this article]. In the quantitative research part, the author made a survey instrument, namely "Blended Arts Curriculum Awareness Survey Questionnaire (BACASQ)" refer to Figure 1, and conducted construct validation of survey items through Exploratory Factor Analysis using SPSS.

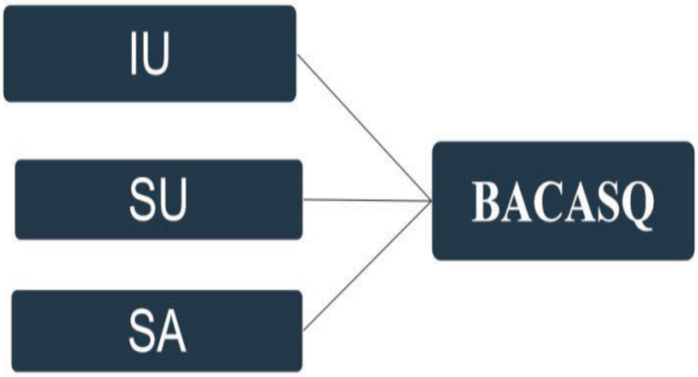

Figure 1. Conceptual framework for Blended Arts Curriculum Awareness Survey Questionnaire (BACASQ)

Research Variables Definition and Measurement Framework

BACASQ developed in this study served as the core instrument for the author's doctoral research. It was designed to collect data on students' background information, their acceptance of blended learning, and their attitudes towards MR technology. Two experts in artificial intelligence and education jointly developed the questionnaire. Following a small-scale pilot test (n = 10), it was refined for logical structure, item numbering, and instructional clarity before being distributed online. The theoretical framework of the questionnaire is grounded in three independent variables:

Internet Usage (IU)

This variable evaluates students' engagement with digital tools during online courses, including frequency of use, study duration, proportion of daily study time, and level of interest. It assesses students' proficiency with digital devices and internet usage habits—specifically accessibility, average daily online time, study time allocation, and preference for MOOC platforms. IU serves as an indicator of students' readiness to adapt to future educational technology environments and functions as a prerequisite for implementing MR-based instruction.

Students' Understanding of MOOC+SPOC (SU)

This variable measures students' cognitive understanding and practical experience with the blended learning model (MOOC + SPOC). It includes items related to familiarity with platform functionalities, frequency of use, and intrinsic motivation for learning. SU is used to gauge students' willingness to adopt MR educational technologies and to evaluate their foundational knowledge prior to implementation.

Students' Attitudes towards blended learning (SA)

This section analyzes students' attitudinal tendencies and behavioural intentions towards the "online + offline" hybrid learning model. It explores the relationship between the innovative sports education module and students' attitudes towards online learning, predicts their potential acceptance of the MR module, and identifies their demands and interests in MR technology-based instruction with particular emphasis on its interactive capabilities.

The *Dependent Variable (DV)* is defined as students' expectations and awareness regarding MOOC/SPOC courses or hybrid physical courses. Measurement items for this variable are adapted from existing literature and tailored to the context of this study. Figure 3 further situates the proposed MENG module within the contemporary blended learning landscape, depicting its role as an MR-enhanced layer interacting with MOOC and SPOC environments.

The quantitative data, collected through validated instruments, are utilised to identify patterns in learner needs, subsequently, the qualitative data were subjected to an in-depth analysis using 'Exemplary-Case Analysis' (ECA), to provide insights into how these needs are manifested within the context of MR sports education. The term "Exemplary-Case Analysis" (ECA) was introduced by Patton (2014), denotes the purposeful selection of information-rich cases. The cases selected in this study effectively illustrate how MR addresses individualised learning needs. We conducted a thematic analysis (Braun & Clarke, 2006) of the data extracted from student logs to identify recurring patterns and themes pertinent to the research questions.

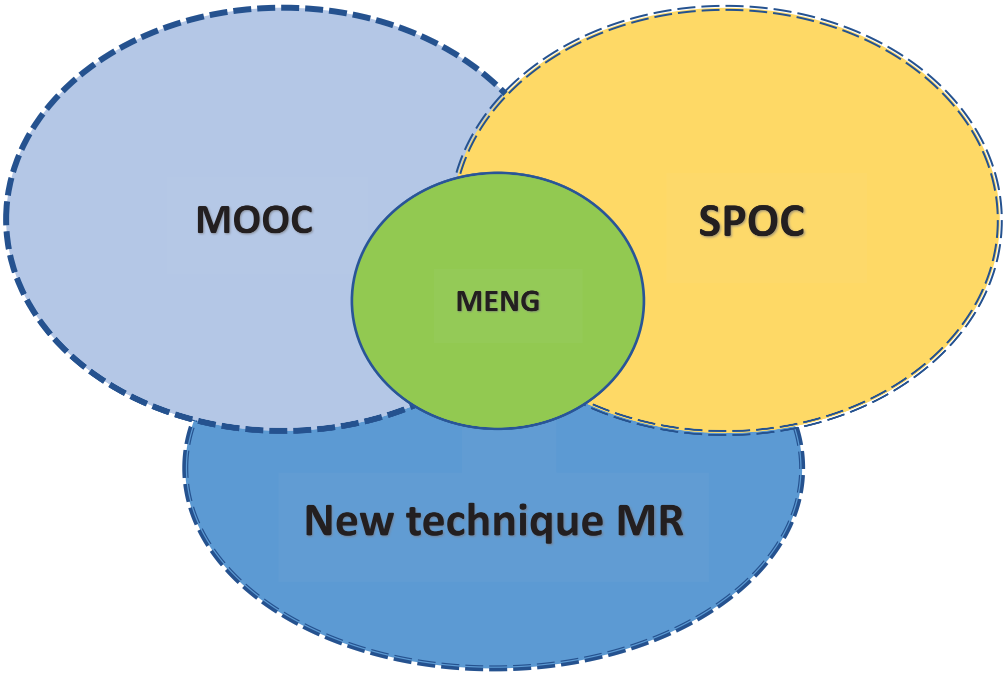

Figure 3. Visualisation of the relationship between variables Conceptual Design

The Rationality of the Research Background

According to the article by Chu and Feng, MR technology can reduce site maintenance costs by 60%, decrease the labour costs associated with repetitive teaching by educators, and extend the reusable cycle of teaching resources, thereby significantly lowering overall expenses for schools (Chu & Feng, 2021). Shaanxi Province is a region where educational inequality is particularly pronounced (Liu, 2024). In this province, rural students who constitute 43.5% of the sample (as shown in Table 1) face significant challenges in accessing quality physical education. This study employed a purposive sampling approach to recruit preschool education majors from a private university in Shaanxi province. Although they were not physical education majors, their curriculum extensively incorporated action demonstration components such as dance and motor skill training, making them suitable participants for research in physical education. Conducting research at the preschool education level holds strategic significance for the following reasons: a) Rural students often encounter issues such as limited funding, a shortage of qualified physical education teachers, and inadequate teaching facilities. MR technology offers a cost-effective solution to these challenges. For example, learning can be facilitated using standard headsets, virtual instructors can substitute for human teachers, and instruction can take place remotely, such as at home. b) The findings of this study may offer scalable solutions applicable to similar educational environments worldwide. Thus, this research in Shaanxi province aligns with the resource constraints typical of developing regions. MR is well-suited for implementation in such contexts due to its affordability, which justifies the initiation of this research.

Table 1. Basic information about the case sample in frequency statistical analysis

Frequency analysis results				
Name	Options	Frequency	Percentage	Cumulative Percentage
Gender	Boy	10	11.8	11.8
	Girl	75	88.2	100
Level of interest in dance	Not interested at all	1	1.2	1.2
	Lose interest in	1	1.2	2.4
	Normal/Neutral	59	69.4	71.8
	Quite interested	10	11.8	83.5
	Very interested	14	16.5	100
Foundation in dance	Very poor	6	7.1	7.1
	Poor	23	27.1	34.1
	Normal/Neutral	43	50.6	84.7
	Good	10	11.8	96.5
	Beyond comparison or Very good	3	3.5	100
Use which way to seek solutions	Ask the teacher for advice	15	17.6	17.6
	Communicate with classmates	36	42.4	60
	Search online	26	30.6	90.6
	Think for oneself	7	8.2	98.8
	Skip directly	1	1.2	100
Come from countryside/city	Countryside (estimated 300 km)	37	43.5	43.5
	City (estimated 100 km)	48	56.5	100
	Total	85	100	100

Quantitative Analysis and Discussion on Results

RQ1: How can students' learning needs in MR-based movement education be identified through a validated survey instrument?

A survey instrument was designed by the author to develop a research model based on the framework identified with hypothesis testing activities. The investigation items were validated through review by 2 experts and pilot testing and adhered to best practices of the mixed-methods approach (Tashakkori & Teddlie, 2010). This survey consists of 21 questions to measure the constructs relevant to this study and aims to investigate students' understanding and awareness of distance online movement, including physical, art, dance, etc. Each question was measured by a five-point Likert scale. For instance, '1' denotes 'strongly disagree', '2' denotes 'disagree', '3' denotes 'neutral', '4' denotes 'agree' and '5' denotes 'strongly agree'. Data were collected through the 'Wenjuanxing' platform online, with a total of 100 respondents. However, 85 respondents completed the survey; another 15 provided no feedback. Hence, the response

rate was 85%. The specific data analysis results are as follows：

Socio Demographic Data

The socio-demographic data are shown in Table 1. Among the samples participating this time, there were 75 girls, accounting for 88.2% of the total. Among them, the highest level of interest in movement demonstration education is average, at 69.4%, and 43 (50.6%) people with a basic level of body movements chose average. There are 36 students (42.4%) are willing to choose to solve learning difficulties through communication with their classmates, and 56.5% of them are from cities. The author summarises the Internet usage of these samples in Table 2.

Table 2. Results of students' frequency analysis of Internet use

Name	**Options**	**Frequency**	**Percentage(%)**	**Cumulative Percentage(%)**
Can use electronic devices	strongly disagree	1	1.2	1.2
	Disagree	2	2.4	3.5
	Neutral	37	43.5	47.1
	Agree	28	32.9	80
	strongly agree	17	20	100
Average time online per day	<1h	0	0	0
	1-3h	7	8.2	8.2
	3-5h	47	55.3	63.5
	5h-7h	24	28.2	91.8
	>7h	7	8.2	100
The ratio of online study time to my total study time	0	1	1.2	1.2
	<20%	2	2.4	3.5
	20%-30%	58	68.2	71.8
	30%-50%	17	20	91.8
	>50%	7	8.2	100
The main reasons to use the Internet	Other	1	1.2	1.2
	Recreation	6	7.1	8.2
	Live	53	62.4	70.6
	Work	20	23.5	94.1
	Study	5	5.9	100

Favorite way to communicate online	Other	1	1.2	1.2
	Email	2	2.4	3.5
	QQ	43	50.6	54.1
	Weibo	25	29.4	83.5
	WeChat	14	16.5	100
	Total	85	100	100

According to the questionnaire statistics, approximately half of the students have equipment that supports their online learning. The students who choose online time between 3–5 hours a day are the most, accounting for 55.3%, and 68.2% said they spend 20%-30% of their study time online; 62.4% of students said their biggest reason for using the Internet was for life, followed by work, entertainment and life. It can be seen that students' frequency of using the Internet for learning is not high. Regarding how students use the Internet to communicate, 50.6% chose QQ, followed by Weibo, WeChat, and Email. This evidence shows that students have sufficient hardware conditions to engage in online course learning and are familiar with using the Internet. If teachers can guide and make use of their daily online time, students' learning efficiency can be considerably improved.

Reliability and Validity Analysis

The data collected from the respondents were analysed using SPSS 26.0 statistical software with the following output of reliability and validity analysis as summarised in Table 3: Alpha α of the instrument variables, respectively, .808, .717, and .976; all of them were greater than 0.7, indicating that the overall reliability of the instrument is relatively excellent and has good internal consistency. Before using factor model analysis, factor model adaptability analysis was carried out on the scale data. The KMO value of the scale data was .881 > .6, and Bartlett's test of sphericity at the 0.05 significance level was passed ($P < 0.05$). This report indicates that the data of scale in this survey is particularly suitable for factor analysis.

Table 3. Test results of reliability and validity

Reliability Statistics			**KMO and Bartlett's Test**
Scale	Number of Items	Alpha	
Internet Usage	5	0.808	0.881
Students' understanding of MOOC+SPOC	3	0.717	
Students' attitudes towards blended learning	14	0.976	

Exploratory Factor Analysis (EFA) result

An exploratory factor analysis (EFA) was conducted. It should be noted that although the sample size (n = 85 for 21 items) is sufficient for the initial exploration in the framework development research, it is relatively small. Therefore, the identified factor structure should be regarded as provisional and awaits validation with a larger sample in the future. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was satisfactory (KMO = .881). Bartlett's test of sphericity presented values of chi-square (χ^2) = 2057.885, df = 210, and $p < .001$, which are extremely significant, thus assuming that the variables present elevated correlations.

Structural validity is to investigate the dimension division of the scale. The results of factor analysis will be discussed as follows:

According to the variance contribution rate analysis Table 4, a total of three main factors can be extracted from the 21 questions with reliability, which can reflect 74.595% > 60% of the information in the total table. Therefore, the three factors extracted this time are ideal in completely extracting and explaining the information of the original scale. Further, combined with the Table 5 Scree plot, it is clear to show that the 21 items of the scale can be divided into 3 dimensions according to the similarity of content.

After the three dimensions are obtained, it is necessary to continue to investigate which items are included in each dimension, and continue to analyse the following post-rotation load matrix in Table 6.

Looking at the Rotated Component Matrix, we can understand the result of EFA:

a) a) The load of Q13-Q22 on component 1 is relatively large, higher than 0.5, and the load of these items in other dimensions is inferior than 0.5, which means that it can be summarised as factor 1. In combination with the research content of these items, factor 1 can be named "Students' attitudes towards blended learning" (SA).

b) b) The load of Q9, Q11, and Q12 on component 2 is relatively large, higher than 0.5, and the load of these items in other dimensions is less than 0.5, which means that it can be summarised as factor 2. Combined with the research content of these items, factor 2 can be named "Students' understanding of MOOC+SPOC”（SU）.

c) The load of Q6, Q7, Q8, and Q10 on component 3 is relatively large, higher than 0.5, and the load of these items in other dimensions is less than 0.5, which means that it can be summarised as factor 3. Combined with the research content of these items, factor 3 can be named "Internet Usage"(IU).

After the adaptability verification, it is determined that the data of the scale in this survey is highly suitable for factor analysis.

Correlation Analysis Result

Pearson correlation analysis was selected to investigate the correlation between SA, SU and IU, and the results were as follows Table 7.

There was an extremely significant positive correlation ($p < .01$) between SU and IU (.477**). Moreover, there was a highly significant positive correlation ($p < .01$) between SA and IU (.439**). At the same time, there was a very significant positive correlation ($p < .01$) between SA and SU (.583**). As well as the overall satisfaction with IU, SU, and SA, respectively, the correlation values were .644, .712, and .962, and all the correlation values indicate a significant positive correlation ($p < .01$). It means there is a positive correlation between those three variables. These significant positive correlations, particularly the strong association between SA and IU ($r = .962$, $p < .01$), indicate that the sampled learners exhibit a relatively high level of acceptance of technology-enhanced learning. To further explore the nature of this acceptance and its specific manifestations in the MR learning environment, this paper employs the qualitative method of exemplary case analysis (ECA). The detailed analysis results are presented as follows.

Ethical Considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their involvement. Participants were fully informed about the purpose and procedures of the study, as well as the intended use of their data for academic research. Anonymity and confidentiality were maintained throughout the study to protect participants' privacy.

Table 4. Explained total variance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.983	57.063	57.063	11.983	57.063	57.063	9.836	46.84	46.84
2	2.192	10.436	67.499	2.192	10.436	67.499	3.069	14.616	61.456
3	1.49	7.096	74.595	1.49	7.096	74.595	2.759	13.139	74.595
4	0.941	4.48	79.075						
5	0.647	3.081	82.157						
6	0.619	2.947	85.104						
7	0.562	2.677	87.781						
8	0.503	2.396	90.177						
9	0.405	1.929	92.106						
10	0.323	1.536	93.642						
11	0.283	1.346	94.988						
12	0.228	1.085	96.073						
13	0.2	0.952	97.025						
14	0.159	0.759	97.785						
15	0.125	0.597	98.382						
16	0.099	0.474	98.856						
17	0.078	0.372	99.227						
18	0.059	0.283	99.51						
19	0.053	0.25	99.76						
20	0.035	0.165	99.925						
21	0.016	0.075	100						

Extraction Method: Principal Component Analysis.

Table 5. Scree Plot

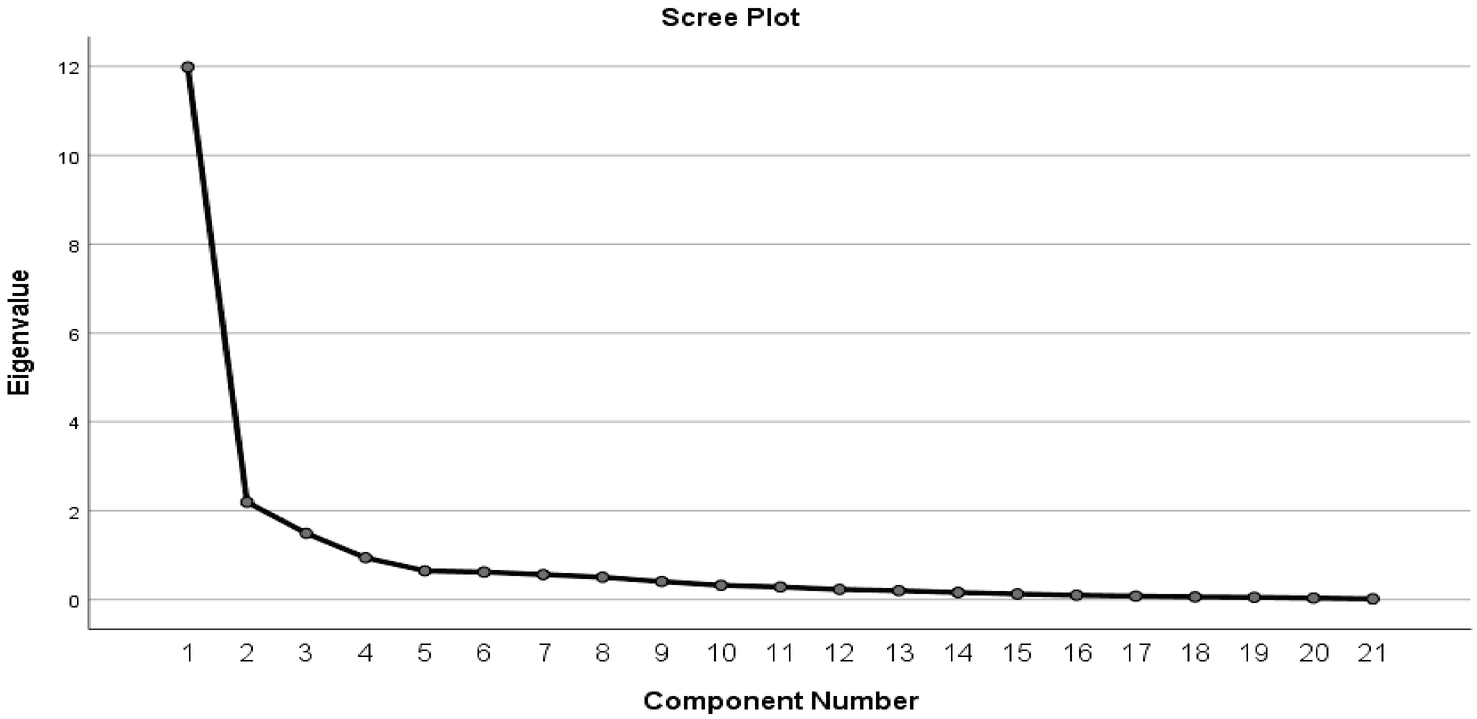

Table 6. Rotated Component Matrixa and Factor Loadings

Rotated Component Matrixa				
Items	Scale Description	Component		
		Factor 1	Factor 2	Factor 3
20	I think blended learning based on network platform can promote learning better	0.911		
19	For online + physical classroom, I need to get the teacher's guidance	0.898		
21	I am willing to take the initiative to do the exercises or tests released before the class in blended learning	0.896		
17.E	The following is the learning style I prefer: Online + Classroom teaching	0.891		
22	Blended learning will issue self-evaluation or after-class test, I am willing to take the initiative to review and summarize	0.89		
18	If the teacher uses the teaching method of network + physical classroom, my attitude	0.886		
15	If there is an online platform to aid earning, I am willing to learn the relevant resources on this platform	0.878		
17.C	The following is the learning style I prefer: Online learning	0.878		
17.D	The following is the learning style I prefer: Online + physical class	0.859		
16	If there is an online platform to assist learning, I am willing to interact with teachers and classmates through this platform	0.783		
17.A	The following is the learning style I prefer: Neither like	0.718		
17.B	The following is the learning style I prefer: Classroom teaching	0.666		
13	Which of the following MOOCs and SPOC platforms I have visited	0.657		
14	I prefer a results-only evaluation	0.554		
11	I am familiar with MOOCs and SPOC?		0.745	
12	I have visited MOOC or SPOC platforms		0.69	
9	The main reason I use the Internet is Others/Entertainment/Life/Work/Learning		0.623	
7	The average time I spend online per day is approximately			0.808
6	I have access to use electronic devices with Internet access (such as mobile phones, computers, iPads, etc.)			0.767
10	My favorite way to communicate online is Others/Email/QQ/Weibo/WeChat			0.685
8	According to previous experience, the proportion of my online study time as compared to my total study time is			0.662

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 6 iterations.

Table 7. Pearson correlation analysis result

	1 IU	**2 SU**	**3 SA**	**4 Overall awareness**
1 IU	1			
2 SU	.477**	1		
3 SA	.439**	.583**	1	
4 Overall awareness	.644**	.712**	.962**	1

N = 85; **p < .01

Qualitative Analysis and Discussion on Results

Exemplary cases were selected using purposeful sampling (Patton, 2014), guided directly by the quantitative findings. Specifically, the strong positive correlation between SA and IU (r = .962) reflects a high degree of technological acceptance. Therefore, a two-step screening approach was implemented: 1) quantitative screening to identify students exhibiting elevated composite scores on the SA and IU scales; 2) qualitative purposeful sampling to deliberately select individuals with diverse self-reported learning preferences from this subgroup.
RQ2: How can mixed reality be exemplified as an innovative pedagogical tool grounded in established learning theories?

Qualitative Analysis Anchoring on Relevant Theories

Qualitative data analysis is implemented in response to RQ2. The researchers' exemplary-case analysis (ECA) revealed that MR-driven educational systems can create individualised, engaging experiences. To analyse and address the diverse learning preferences reflected in the data, MI theory serves as a heuristic framework, and this approach aims to promote quality education (SDG No.4) in sustainable development education. This study is anchored in the sociocultural theoretical framework of Soviet psychologist Lev Semenovich Vygotsky, as the samples involved come from diverse sociocultural backgrounds before entering a physical or movement education programme. He believed that parents, caregivers, peers, and culture play a major role in a person's higher-order brain functions. He thought that human development relies on social interaction and, therefore, can differ among cultures (Vygotsky, 1978; Daramola et al., 2024).

The concept of multiple intelligences is a theory developed by Harvard psychologist Howard Gardner, who first outlined his theory in his 1983 book Frames of Mind: A Theory of Multiple Intelligences, arguing that there are nine types of human intelligence: 1. Visual-spatial, 2. Linguistic-verbal, 3. Logical-mathematical, 4. Body-kinesthetic, 5. Musical, 6. Interpersonal, 7. Intrapersonal, 8. Naturalistic, 9. Existential intelligence. This theory offers a comprehensive understanding of the various abilities and talents people possess and is widely welcomed by educators (Gardner, 2011). This article just needs four of them. The author, according to the learner's unique style, creates a personalised MR movement education (Gardner, 2011; Al-Qatawneh et al., 2021). By integrating MR into the learning process with exemplary cases extracted from the movement education module, as illustrated in Figure 2, movement educators can promote illustrative, engaging, and contextualised learning environments that meet the needs of learners from diverse socio-cultural backgrounds. Moreover, it facilitates curriculum implementation by enabling flexible adjustments to support students' learning in a hybrid mode.

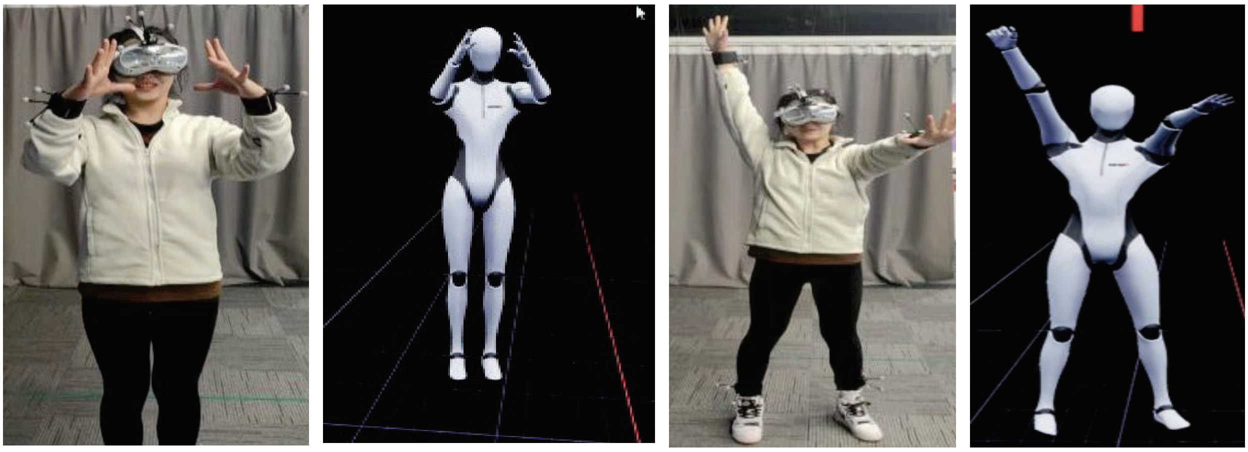

Figure 2. Facilitating the Development of Students' Motor Skills through Virtual Teacher Guidance

Data Collection Methods Supported by Blended Mode Platforms

This study integrates the aforementioned concept into the design of the questionnaire items, ensure the systematic consistency and coherence between the application of theoretical frameworks and the utilisation of empirical evaluation tools, for example: Q19 highlights the necessity of teacher guidance for learners, which is closely associated with the theory of social interaction. In this context, the online platform within the "online + physical classroom" model can be considered a cultural tool that facilitates learning and interaction. Q16 talks about interaction with teachers and classmates, social interaction theory and cultural tools theory. The learning process is collaborative and interaction with teachers and peers is the basis of Vygotsky's theory (social interaction promotes cognitive development), online platform can be used as digital tool for interaction and learning, Q10 talks about cultural tools theory, QQ, WeChat, Weibo and other online communication methods are language and symbols system emphasised by Vygotsky for communication, and communication itself is social interaction.

Email/QQ/Weibo/WeChat is used for information exchange and cognitive development, and understand the key to students accept blended learning and MR. At the same time, Salomon's theory of symbolic representation (1981) also highlights the significance of symbolic systems in cognitive processing. This theoretical framework is evident in Q10 emphasis on digital communication platforms such as QQ and WeChat. As digital symbolic systems, these platforms facilitate kinesthetic feedback, such as virtual bone overlay in MR technology, thereby effectively reshaping an individual's cognitive structure related to motor skills. Mayer's theory of multimedia learning (2005) suggests that the integration of multiple modalities can enhance cognitive processing. Q20 investigates the incorporation of visual and kinesthetic dual feedback by learners in blended learning environments. Q21 corresponds to the concept emphasised in Mayer’s theory, which highlights the importance of active participation in constructing deeper understanding.

Under this platform, students train on movement learning that is divided into two parts. Through the MR system, a virtual bone map is designed in advance in the system (as aforementioned in Figure 2), based on the motion capture technology, forming a virtual human, and completing a series of movements. The students follow the movements according to the demonstration movements made by the skeleton diagram. No matter where students come from or where they are, they can learn online movement through this technology.

Analytical Procedure

This study conducted a systematic coding of the relevant content using a set of thematic labels (e.g., Bodily/Kinesthetic, Music/Rhythm) to categorise student feedback, as presented in Table 8. The qualitative data obtained from student journals. The thematic analysis method proposed by Braun and Clarke (2006) was employed for data analysis. The analytical process rigorously adhered to the six phases of thematic analysis:

1) Familiarisation with the data content;
2) Generation of initial codes (e.g., "interaction with virtual teachers," "perceived improvement in accuracy," "appreciation of multi-angle views");
3) Identifying themes related to personalised learning experience and learning needs;
4) Reviewing these themes;
5) Ultimately defining them;
6) Preparing the report.

The analysis was guided by key concepts from Vygotsky's sociocultural theory of learning, which were used to interpret how the features of MR support student learning and address diverse educational needs.

Qualitative Insight: Confirming the Impact of MR on Diverse Learning Needs

The journal of the students additionally substantiated the quantitative findings on SA. They conveyed a strong level of enthusiasm and interest in the application of MR in physical learning. Notably, these qualitative responses included specific examples illustrating how MR effectively addressed key limitations identified in the research, such as the lack of kinesthetic feedback, offering a clear explanation for the students' highly positive attitudes, as reflected in their high SA scores. For example, students commonly noted a "reduced motion error rate," a finding that aligns closely with the factor loading of Q20 (.911). This demonstrates the perceived efficacy of the real-time feedback mechanism provided by MR in enhancing learning outcomes. Similarly, students reported being "more willing to communicate with the instructor" within the virtual environment. This observation corresponds directly with Q19 (.898) and provides empirical support for Vygotsky's theory, which emphasises the importance of social interaction in cognitive development.

The reduction in error rates observed during motor learning, along with the emphasis on real-time feedback assessment, illustrate the advantages and preferences associated with body coordination and motor skill acquisition in the MR physical environment. These findings are categorised as experiences related to the domain of BK. Moreover, within the virtual environment, they were more inclined to communicate with teachers, finding the experience highly engaging. This aligns with Vygotsky's (1978) perspective that social interaction and guided support are essential factors in cognitive development, particularly within the Zone of Proximal Development. The students believe that these characteristics are essential for improving the acquisition of physical skills and enhancing cognitive engagement. On the other hand, participants believed that innovative teaching methods would enhance their motivation to actively explore knowledge. The reflections documented in the journal illustrate the varied learning preferences among students. Some learners rely on visual feedback, others engage in rhythm-synchronised learning, and some are accustomed to action-stack strategies for self-correction. This MR-based teaching approach can effectively support learners with diverse needs while also promoting the development of a range of motor skills. Combined with factor analysis, the findings indicated that "I think blended learning based on network platform can promote learning better" (Q20 = .911) and "For online + physical classroom, I need to get the teacher's guidance" (Q19 = .898) in the questionnaire. Additionally, "I am willing to take the initiative to do the exercises or tests released before the class in blended learning" (Q21 = .896). The three factors with the highest factor loading values exhibit consistency, thereby ensuring the reliability of the qualitative analysis presented in this study. These qualitative insights not only confirm the high factor loadings of items such as Q19 and Q20 but also deepen our understanding by illustrating specific learning outcomes, including reduced error rates and increased willingness to communicate that support the observed positive statistical associations.

Discussion

The results presented in Table 6 indicate an extremely strong loading value for SA (e.g., Q19 = .898, Q20 = .911, Q21 = .896), which aligns with the findings from the qualitative analysis. Both quantitative (Q19, Q20) and qualitative data indicate that a reduction in movement errors is associated with a greater willingness to communicate with the coach, which reflects the core mechanism of the proposed framework.

Specifically, the reduction in movement errors and the high scores on items related to instructional clarity (Q20) indicate that the MR system effectively reduced unnecessary cognitive load, which is consistent with the principles of multimedia learning. Additionally, the increased interaction with the virtual coach and the improvement in movement accuracy suggest that the MR-based feedback functioned as a digital scaffold within students' ZPD, providing targeted support for skill acquisition. Features such as rhythm synchronisation further demonstrate that MENG is capable of adapting to different learning preferences and offering practical design insights for educators. Figures 4–6 show how MR effectively engages students in movement learning.

This real-time embodied experience of observation and learning is believed to enhance learning outcomes by grounding cognitive representations in physical actions (Wilson, 2002; Barsalou, 2008). The primary advantage of this study lies in the ability of MR technology to completely harness this potential to support physical education (Lindgren & Johnson-Glenberg, 2013). The movements observed through MR technology can reduce errors, suggesting that real-time skeleton overlay and enhanced feedback play a critical role in physical education, particularly for novice learners (Wulf & Shea, 2002; Schmidt & Lee, 2019).

The above findings validate the conceptual framework constructed in this study (Table 9). This framework systematically integrates motor learning theories with specific functions through four theory-driven MR innovations: (1) real-time skeletal overlay, (2) multi-angle observation, (3) rhythm-synchronised feedback, and (4) scaffolded self-comparison. It aims to address core shortcomings in online sports education, such as the lack of feedback and limited perspectives. These functions collectively transform traditional passive video learning into an interactive and immersive educational experience.

In conclusion, the empirical results of this study support the validity of the MENG framework. In the immersive learning environment constructed by MR, the multimodal design based on multimedia learning theory reduced students' cognitive load, while the real-time feedback provided in accordance with the theory of the zone of proximal development effectively promoted the acquisition of motor skills. Embodied interaction achieved through symbolic media (Salomon, 1981) has reshaped the cognitive representation of movement. Furthermore, the system’s inclusive design demonstrates accommodating diverse intelligence profiles, as illustrated through scenarios inspired by concepts such as Gardner’s multiple intelligences, enabling personalised and differentiated learning experiences. The collaborative effect of these theories in the teaching process has jointly verified the potential of the MENG framework in enhancing students’ motor skills and learning engagement, providing a blueprint for designing future human-centered immersive learning environments.

Table 8. Classify student feedback using Gardner's theory of multiple intelligences as a heuristic framework

Criterion	Student A	Student B	Student C
Body/Kinesthetic (BK)	The body movements are well-coordinated.	It provides a comprehensive perspective on the virtual teacher, thereby enhancing cognitive understanding.	Appreciating an issue from multiple perspectives is highly intriguing and offers valuable insights.
Music/Rhythm (MR)	Motor skills are generally easier to acquire and master through practice and repetition.	The accuracy of controlling music has improved.	With the integration of technology, learning efficiency can be significantly enhanced compared to independent learning.
Logical/Mathematic al (LM)	It is evident that the error rate associated with the movement has decreased.	The success rate of the action has increased.	The movements can now be synchronised with the beats, and individuals are able to independently perform a sequence of movements in a timely manner.
Intrapersonal (INR)	The interaction with the virtual teacher is highly engaging, and I find this teaching method to be both effective and enjoyable.	I find this technology to be highly innovative. The kinesthetic feedback feature facilitates regular self-reflection.	This technology has effectively reduced the communication barriers between myself and my instructor.

Table 9. Motor Learning Mechanisms Embedded in MENG Framework

MR Design Feature	**Motor Learning Theory**	**Theoretical Action Mechanism**	**Target Dance Deficit**
Real-time Skeleton Overlay (Fig 5)	Visuomotor Coupling (Lee & Schmidt, 2025)	Virtual bones function as an instantaneous spatial reference for the detection and analysis of errors.	To address the issue of inaccurate limb positioning and positioning discrepancies during the online teaching process.
Multi-angle Observation (Fig 4 - 6)	Egocentric Encoding (Chavez et al., 2025)	Enable learners to observe movements from critical angles, including the positioning of the arms above the head and low-angle footwork, among others.	To address the limitation of a single teaching screen in online education, Mixed Reality (MR) enables students to observe the teacher's movements from a full 360-degree perspective within a virtual environment.
Rhythm-synchronised feedback （Fig 5）	Symbolic Mediation of Rhythm (Salomon, 1981)	Real-time auditory cues, such as metronome pulses, elicit precise muscle adjustments to align with the choreography tempo, thereby synchronizing movement phrasing with musical beats.	When the limbs are moving rapidly, such as during a teacher's demonstration of high-speed actions like rotation, jumping, and flipping, students can control the teaching screen within the MR environment and utilize functions such as pause, acceleration, deceleration, and repetition for enhanced instructional viewing.
Student's First-Person Perspective (Fig 5)	Scaffolded Feedback & Comparison (Vygotsky, 1978; Salomon, 1981)	The learner's actions partially coincide with those of the teacher, facilitating timely comparison and enabling effective error correction.	To address the issue of the absence of kinesthetic feedback during online learning

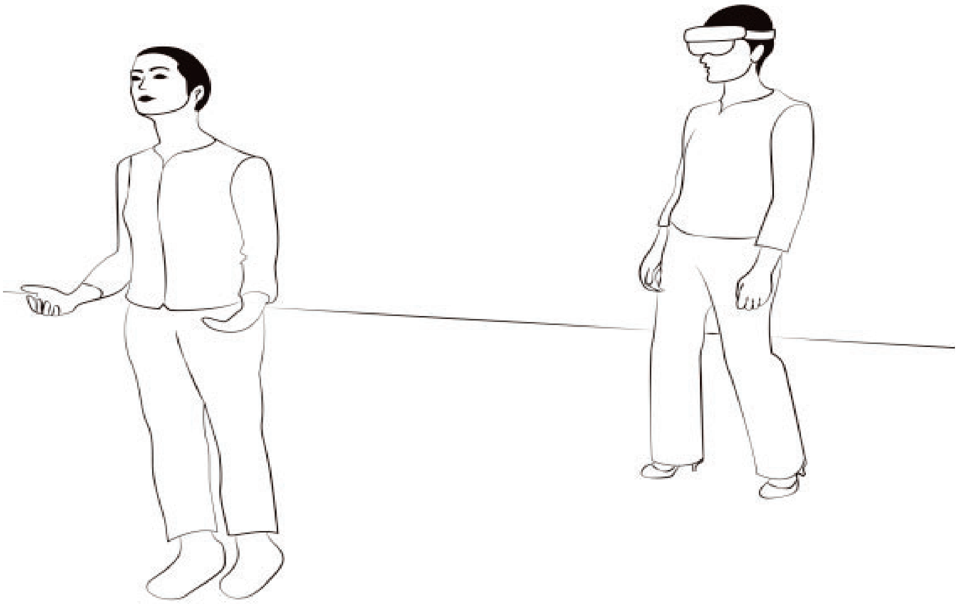

Figure 4. Student's First-Person Perspective: Virtual Instructor Superimposed in the Real-World

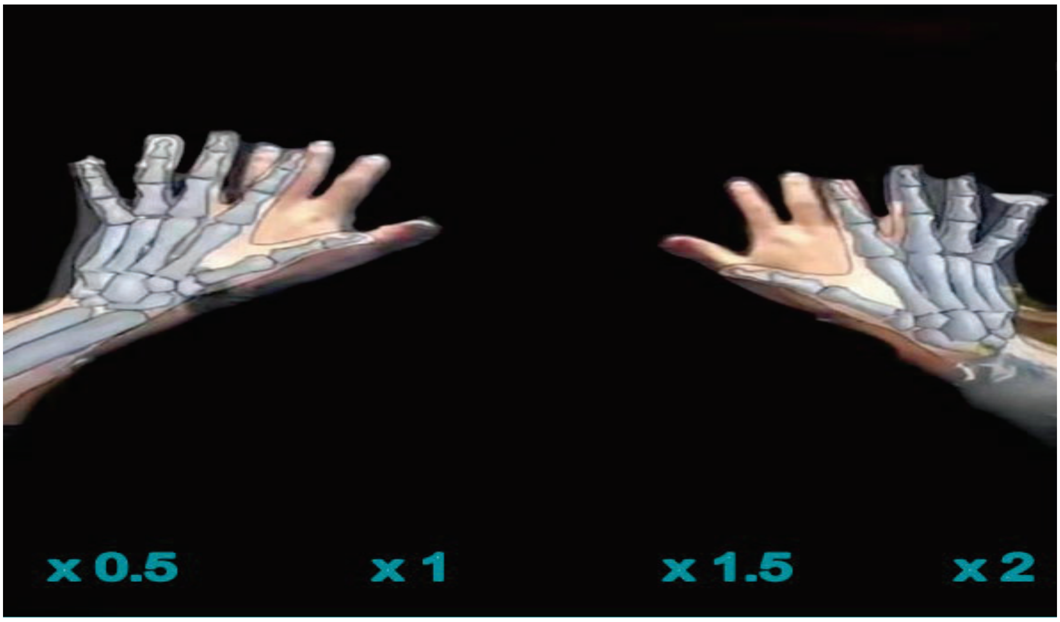

Figure 5. Student's First-Person Perspective: Exploring Embodied Cognition within the Overlap of Virtual and Real Actions

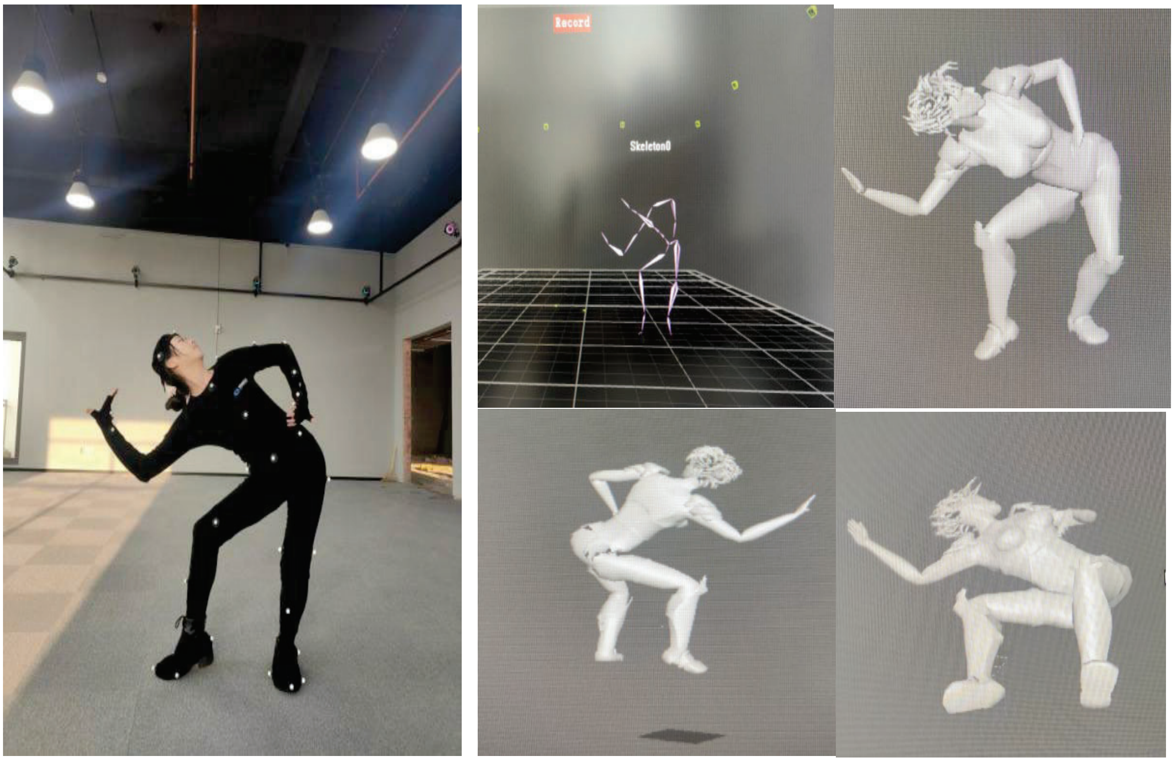

Figure 6. MR Omnidirectional Perspective: Enabling Multi-dimensional Observation and Knowledge Acquisition

Conclusion

The advent of the emerging technology era has opened up different models of digital learning tools, such as AR, VR and the latest MR (Meng et al., 2025). As a form of performance art, movement education requires a personalised learning model to influence the diverse needs of students under the guidance of educators. This study demonstrates that MR can transform physical education by providing personalised, cost-effective learning that adapts to student needs (Wu et al., 2023). This article reports on a mixed methods study that has developed a survey instrument to examine the module's learners' needs and understand their understanding and acceptance of hybrid models in physical education including dance and sport.

Furthermore, by integrating MR into the learning process outlined in the module, educators can promote an engaging and contextualised learning environment. Since mixed reality promotes personalised learning, it provides inclusive education for all, including students from different socio-cultural backgrounds, thereby actively contributing to the integration of quality education with new emerging technologies, which is also part of the Sustainable Development Goals. Moreover, MR technology not only facilitates curriculum implementation in hybrid modes but also holds significant promise for the education sector by promoting sustainability and contributing to several Sustainable Development Goals.

Summary and Implications for Academia

Theoretical and Methodological Contributions

By analyzing the shortcomings of online movement teaching, this study provides a feasible, systematic and targeted curriculum or module using hybrid teaching for college teaching. This will not only improve the theoretical explanatory power but also enhance the practice of blended teaching in college movement education. It also contributes to the theoretical and methodological advancement of training, providing a framework for integrating modern educational resources into college movement teaching and fostering innovation in the AI era.

Practical Implications for Teaching and Curriculum Design

The significance of this study lies in creating a novel teaching module using a mixed research method to enhance the online teaching mode. It examines whether mixed reality teaching may be a useful method for movement education in higher vocational colleges in Shaanxi Province, China. The research serves as an example of how MR techniques can be used to teach students physical education to facilitate learning and demonstrate the effectiveness of this course. The research findings indicate that MR can serve as a valuable tool for educators by enabling the development of a comprehensive teaching framework encompassing instructional design, management, assessment, and supervision, thereby supporting learner success.

Limitations of MR Technologies for the Education Sector and Future Research

First, due to time constraint, no more Confirmatory Factor Analysis (CFA) is made.

Second, the sample size for the exploratory factor analysis was moderate. Future research could validate it in a larger sample. Third, it was found that the correlation between the two variables in the quantitative analysis, 'students' attitudes towards blended learning (SA) and 'Internet Usage (IU)', was extremely high (r = .962). This might reflect a certain degree of construct overlap in the measurement tools or be influenced by common method bias. Future research should further distinguish and validate these different related constructs.

Fourth, since this research will incorporate different technologies, the first difficulty faced is the possible lack of support from MR-related technology companies to provide technical services/experience for this project. As the researcher's background is not in computer science, it was challenging to identify the most suitable MR-related technology company for collaboration. Thus, this area presents numerous novel challenges, such as nomenclature, modern technology involves tools. Fifth, this research requires collaboration with content/technology experts because MR is a modern concept. Due to no researcher who is studying physical major and computer major at the same time, it is a challenge for the author to find the best experts who are really proficient in both specialties. Sixth, it might face technical failures. New technology must involve extra facilities and systems, which is one part of the problem will make the progress of this research more difficult. For example, there may be issues with the digital divide and Internet access, etc. Seventh, the experiment took place in Shaanxi province, China, and the subjects were students from higher vocational colleges in private universities in the province, majoring in preschool education. This is also the restriction of this technology in the programme process. If more professional students can try to experience MR technology, and more universities and provincial and municipal schools participate in this project, the data obtained will be more perfect and reliable.

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The author declares no conflicts of interest related to this research.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors used DeepSeek to assist with improving language clarity, grammar, and phrasing. The authors carefully reviewed and revised the output to ensure accuracy and consistency with the intended meaning and take full responsibility for the content of the final manuscript.

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