Exploring VR Animation for Chinese Opera Dissemination: An Immersive and Interactive Approach to Multicultural Education

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Manuscript received September 3, 2024; revised October 12, 2024; accepted November 25, 2024; published March 12, 2025

***Abstract*—This study explores the innovative application of Virtual Reality (VR) animation to promote Chinese opera culture among international university students in multicultural educational settings. The research underscores its scientific contribution by integrating technological advancements in VR with cultural education, providing a novel framework for cross-cultural learning. Employing a mixed-methods approach, this study combines quantitative data from structured surveys with qualitative insights from open-ended responses. The sample comprised 300 students, stratified by nationality, age, and academic field to ensure diverse representation. Participants included students from China, Korea, Finland, Malaysia, India, and Australia, spanning age groups under 18, 18–35, and over 35, and academic fields such as Art and Design, Business, Computer Engineering, Architecture, and Education. Quantitative results indicate that 75% of respondents perceive VR animation as effective for understanding and appreciating Chinese opera culture, with significant variations observed based on age, cultural familiarity, and field of study. Notably, students from culturally proximate regions (e.g., China, Korea, Malaysia) demonstrated higher engagement, whereas students from culturally distant regions (e.g., Finland, Australia) exhibited lower receptivity. Younger students (18–23 years) and those in Art and Design displayed heightened interest in VR cultural content. Thematic qualitative analysis underscores the roles of immersion, interactivity, and cultural adaptability as critical factors influencing engagement, aligning with experiential and constructivist learning theories. These findings highlight the transformative potential of VR animation in fostering cultural understanding across diverse demographic groups. This research concludes that VR can serve as a pivotal tool in internationalizing Chinese opera culture, fostering inclusivity and appreciation across varied cultural contexts. Future research should focus on the longitudinal effects of VR in cultural education to develop adaptive VR-based learning models for a global audience.**

***Keywords*—virtual reality animation, Chinese opera culture, international communication, multicultural education, student interest and understanding**

I. Introduction

Chinese opera culture, an integral component of China's cultural heritage, has captivated global audiences with its distinctive artistic expression and profound cultural significance. Chinese opera encompasses a variety of forms, such as Peking Opera, Kunqu Opera, and Cantonese Opera, each characterized by unique performance styles and cultural contexts [1]. However, the global dissemination of Chinese opera culture faces significant challenges, particularly in enabling international students from diverse cultural backgrounds to comprehend and appreciate it [2]. Recently, Virtual Reality (VR) technology has demonstrated transformative potential in educational settings, particularly in enhancing multicultural understanding and promoting cultural appreciation through immersive experiences [3, 4]. Leveraging its capacity for interactive engagement, VR emerges as a promising medium for disseminating intangible cultural heritage, such as Chinese opera. With its rich visual, auditory, and performative elements, Chinese opera is a cornerstone of Chinese heritage; however, its intricate nature poses substantial challenges for international audiences who lack familiarity with its traditional forms and linguistic nuances [5]. VR animation provides an innovative solution, offering international students from diverse backgrounds an immersive and accessible experience that bridges both linguistic and cultural barriers. Despite remarkable progress in utilizing VR for educational purposes, empirical studies investigating VR's specific role in multicultural education for cultural heritage dissemination remain scarce [6]. Current research predominantly explores VR's effectiveness in traditional academic subjects, with its applications in cultural education, especially within multicultural contexts, remaining underexplored [7]. This study seeks to bridge this gap by investigating how VR animation can effectively convey Chinese opera culture to international audiences, promoting cross-cultural understanding and fostering cultural appreciation. Considering the growing globalization of education and the pressing demand for inclusive and culturally adaptive learning strategies, this study is both timely and essential [8].

This study is grounded in constructivist and experiential learning theories, which stress the importance of immersive and interactive experiences in fostering understanding and promoting knowledge retention [9, 10]. Constructivist theory asserts that learners actively construct knowledge through meaningful interactions, a process that VR facilitates by offering immersive and participatory experiences [11]. Similarly, the experiential learning model underscores the efficacy of hands-on and interactive environments in reinforcing conceptual understanding [12]. In the context of Chinese opera, VR animation enables users not only to observe but also to interact with the artistic and cultural dimensions of the performance, potentially cultivating a deeper sense of cultural empathy and appreciation [6]. VR, through its ability to deliver a sense of presence and

immersion, aligns with these principles and has been demonstrated to enhance both cognitive and affective engagement in educational settings [13]. Moreover, multicultural education theory forms the theoretical foundation of this research, advocating for educational environments that respect and incorporate diverse cultural perspectives [14]. Within this context, VR animation offers a unique opportunity to design culturally resonant educational experiences that overcome geographical and linguistic barriers. By developing a VR animation-based interactive platform that transcends linguistic and cultural barriers, this research seeks to contribute new insights into VR's potential for advancing intercultural communication and fostering a deeper understanding of Chinese opera.

This study holds significance in examining the role of VR animation within multicultural education frameworks, particularly in fostering cultural empathy and enhancing appreciation among international students. Employing a mixed-methods approach, this study integrates quantitative measures, such as a 5-point Likert scale to evaluate student engagement, with qualitative open-ended questions to capture nuanced responses to VR content. A sample of 300 students, stratified by nationality, age group, and academic field, enables a comparative analysis of VR's impact on diverse user experiences [15]. Consequently, this study investigates the effectiveness of VR animation in presenting Chinese opera to multicultural audiences, examining its ability to engage and educate students from diverse backgrounds. Specifically, it explores how VR can bridge cultural divides and cultivate a deeper appreciation for Chinese cultural heritage, which is vital in the context of globalized education. Furthermore, this research contributes to the broader discourse on VR's potential to address cultural divides, proposing that immersive and interactive VR experiences can serve as pivotal tools for fostering intercultural understanding and promoting respect for cultural diversity. Specifically, this study examines VR animation's potential to communicate intricate cultural narratives, such as Chinese opera, to international audiences while cultivating a deeper appreciation for Chinese cultural heritage, a necessity in the context of globalized education. The findings from this study could inform future educational initiatives, emphasizing the role of immersive and interactive learning in fostering intercultural competence among learners.

II. Literature Review

A. Application of VR in Education

In recent years, advancements in research on the application of Virtual Reality (VR) technology in education have significantly demonstrated its potential to revolutionize traditional learning methodologies. VR facilitates the creation of immersive learning environments that enhance experiential learning by rendering abstract concepts more tangible and comprehensible. For instance, Makransky and Lilleholt (2018) [16] demonstrated that VR's capacity to create authentic and interactive learning environments significantly enhances student engagement and improves learning outcomes. This interactivity aligns with cognitive theories of active learning, emphasizing the critical role of engagement in facilitating knowledge retention and application. Additionally, Freina and Ott (2015) [17, 18] emphasized that VR provides safe, repeatable scenarios in medical education, enabling skill mastery through experiential practice—consistent with Kolb's experiential learning theory, which posits that concrete experiences are pivotal for effective learning. Roussou (2004) [19] further underscored VR's value in cultural education by highlighting that virtual reconstructions of historical contexts deepen learners' understanding of historical and cultural narratives. This aligns with the constructivist paradigm, which posits that learners actively construct knowledge through dynamic interactions with their environment. VR's distinctive immersive capabilities surpass traditional educational tools by fostering deeper learner engagement and interaction [20]. Pantelidis (2010) [21] demonstrated that integrating VR into science education significantly enhances both conceptual comprehension and the practical application of skills. Moreover, VR proves beneficial for special education; for example, Smith *et al.* (2019) [22] observed significant improvements in social and self-management skills among children with autism, demonstrating VR's potential for personalized educational experiences. Standen and Brown (2006) [23, 24] corroborated these findings, indicating that the vocational training benefits of VR are consistent with Vygotsky's social development theory, which underscores the critical role of interactive and social learning.

Virtual reality (VR) has emerged as a transformative tool in contemporary education, offering unparalleled immersive and interactive learning experiences. Recent research highlights VR's potential to significantly enhance student engagement, comprehension, and knowledge retention. Serin (2020) [9], for example, explored VR from the perspective of educators and identified it as highly effective in fostering interactive environments that enhance comprehension, aligning with experiential learning theory, which posits that hands-on activities lead to improved learning outcomes. Lege and Bonner (2020) [25] emphasized that VR's immersive capabilities significantly enhance science education, resulting in higher retention rates compared to traditional teaching methods. Their study highlighted VR's pivotal role in bridging theoretical knowledge and practical application, consistent with constructivist learning theory, which posits that learners actively construct knowledge through interactions and experiences. Moreover, Marougkas *et al.* (2023) [26] conducted a comprehensive review of methodologies and concluded that VR effectively supports constructivist and experiential learning approaches, providing unique and interactive opportunities unavailable in conventional teaching methods. Their findings reinforce educational frameworks advocating active learner participation as a means to achieve deeper cognitive engagement and processing.

B. Animation's Role in Cultural Communication

Animation, as an engaging and intuitive medium of expression, finds extensive applications in the realm of cultural communication. Mayer (2009) [27] observed that animation enhances audiences' cultural experiences and

memory retention by leveraging the combined stimulation of visual and auditory senses. Animation's strength in education and communication lies in its capacity to visually present complex concepts, simplifying them for audiences to understand and remember effectively. Smith (2017) [28] corroborates this, emphasizing that animation significantly enhances the comprehension and retention of cultural content through effective visual representation. Animation technology is extensively utilized in the promotion of traditional culture. Chang (2016) [29] determined that employing animation to illustrate cultural narratives significantly enhances audiences' memory retention and strengthens their sense of cultural identity. By integrating storytelling with vivid visual elements, animation allows audiences to acquire cultural knowledge in an engaging and enjoyable manner. Additionally, Lasseter (1987) [30] highlighted that animation captures viewers' attention through distinctive visual effects, thereby enhancing the effectiveness and impact of cultural communication.

The application of animation in education is also highly impactful. Tversky and Morrison (2002) [31] demonstrated that animation significantly enhances students' interest and comprehension, especially in elucidating dynamic processes and complex systems. Similarly, Kozma (1991) [32] observed that animation facilitates the understanding of abstract concepts and intricate mechanisms within science education. The role of animation in facilitating cross-cultural communication is particularly noteworthy. Lowe (2003) [33] found that animation effectively bridges linguistic and cultural divides, communicating complex information through universal visual language. Liao *et al.* (2024) [34] highlighted that animation promotes deeper understanding and broader acceptance of different cultures by rendering content accessible to diverse audiences. The universal visual language of animation enables it to transcend linguistic barriers, establishing it as an effective medium for transmitting messages across diverse cultures. Adam, Bärnighausen, and McMahon (2020) [35] demonstrated that wordless animations effectively convey public health messages to diverse audiences, underscoring animation's capability in disseminating critical information on a global scale. Liu (2021) [36] examined the influence of policy on animation's role in cultural dissemination within the UK and China, illustrating how strategic initiatives can advance cultural content that resonates on an international scale. Furthermore, Fan and Feng (2021) [37] emphasized that animation preserves cultural heritage by creatively reinterpreting traditional stories, making them more engaging and memorable for contemporary audiences.

C. The International Diffusion of Chinese Opera Culture

Chinese opera, a critical pillar of China's cultural heritage, encounters significant challenges in its global dissemination due to its distinctive language, performance style, and deep cultural context [3]. Traditional methods of disseminating opera internationally, such as live performances and static texts, often prove insufficient in effectively reaching global audiences unfamiliar with these traditional forms [38]. However, with the advent of VR technology, immersive digital platforms present innovative avenues for experiencing Chinese opera, effectively bridging cultural divides by making it more accessible and engaging for international students [2]. VR animation allows international audiences to immerse themselves in a virtual environment where they can closely observe intricate details, including costumes, stage setups, and character expressions. Research indicates that VR's immersive capabilities significantly enhance audience engagement, enabling them to appreciate cultural elements that might otherwise remain obscure or inaccessible [26]. By establishing a three-dimensional interactive environment, VR aligns with experiential and constructivist learning theories, which argue that deep engagement fosters improved retention and deeper comprehension [16, 39]. This interactive dimension enables audiences from diverse backgrounds to not only understand but also form emotional connections with the cultural narratives embedded within Chinese opera. VR's significance in multicultural education is further emphasized by its ability to transcend linguistic and cultural barriers, allowing users to interact with cultural content through visual and auditory modalities without substantial reliance on language. According to [35] Adam *et al.* (2020), wordless VR animations effectively convey complex cultural narratives to diverse audiences, highlighting VR's potential as a universal platform for cultural exchange. This aligns with constructivist theories emphasizing the critical importance of contextualized learning environments, wherein learners actively engage with content instead of passively absorbing information [18].

Recent studies underscore the pivotal role of VR in cultivating a sense of cultural identity among users, particularly those from non-native backgrounds. For example, Kang *et al.* (2024) [40] contend that VR platforms enabling users to take on actor roles and engage in cultural storytelling significantly deepen learners' cultural understanding and empathy, particularly for traditional art forms such as Chinese opera. Such immersive engagement reinforces cultural identity among international audiences, enabling them to appreciate cultural nuances that transcend superficial elements. The integration of VR into Chinese opera aligns seamlessly with cognitive learning theories, which posit that multisensory engagement—encompassing visual, auditory, and interactive elements—enhances memory retention and comprehension [25]. Mayer's (2009) [27] multimedia learning theory corroborates this, emphasizing that content delivered through multiple modalities enhances learners' comprehension of complex material, a principle particularly pertinent to traditional art forms characterized by nuanced expression and elaborate staging. This educational approach not only makes Chinese opera more accessible but also aligns with the broader goals of multicultural education, fostering cross-cultural understanding and mitigating cultural bias [41].

In conclusion, VR animation functions as a transformative medium for the global dissemination of Chinese opera culture, offering an immersive and engaging solution to overcoming cultural and linguistic barriers. By harnessing VR's interactive and multisensory capabilities, educators can design content that resonates with multicultural audiences, fostering deeper engagement with Chinese opera while advancing cultural diversity. Future research should further investigate how VR can facilitate personalized, cross-cultural

educational experiences, broadening the reach and deepening the appreciation of traditional art forms such as Chinese opera on a global scale.

III. Research Methodology

A. Research Design

This study employs a mixed-methods research approach, integrating both quantitative and qualitative data to thoroughly evaluate the effectiveness of VR animation in disseminating Chinese opera culture among international university students from diverse nationalities. Specifically, the study will gather quantitative data through structured questionnaires and qualitative data via open-ended questions to provide a holistic assessment of the effectiveness of VR animation in disseminating Chinese opera culture among international students (Fig. 1).

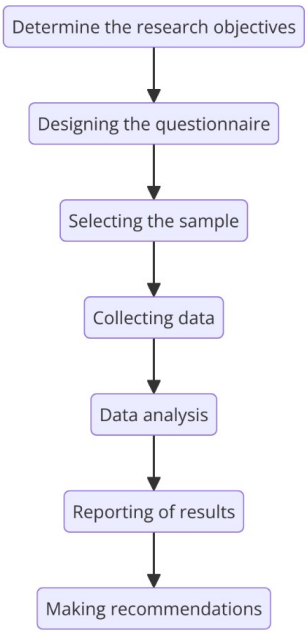

Fig. 1. Flow of the study.

B. Peking Opera Painted Faces (POPF) VR Simulation Experience

In this study, we selected the most iconic visual representation of Peking Opera face painting and developed a 3D Peking Opera face painting integrated with a VR interactive system, named VR POPF (Registration No. 2024SR1374369), to meet audience demands for understanding Peking Opera and to profoundly disseminate its cultural connotations. The Peking Opera characters are rendered in the VR environment with vivid Peking Opera face designs and engage users through animated facial expressions that convey emotional nuances. Users perceive the emotions of Peking Opera characters by observing their animated facial expressions, which subsequently influence users' decisions. The characters, in turn, respond dynamically to these decisions. This framework serves as an immersive medium within the VR environment, offering a scalable and deeply engaging cultural experience. We employed 3D animation to project face images onto a 3D model and evaluated the interactive capabilities of POPF within the VR environment, aiming to establish a direct connection between virtual reality and Peking Opera face painting. This approach leverages Six degrees of freedom (6DOF) technology to immerse users in the experience of Peking Opera face painting. Users engage in non-verbal communication with the POPF through visual cultural symbols and facial expressions, which influence cognitive processes, shaping emotions and guiding decision-making. Digital technology integrates POPF with virtual reality, enabling users to immerse themselves in the rich narratives of cultural heritage (Fig. 2).

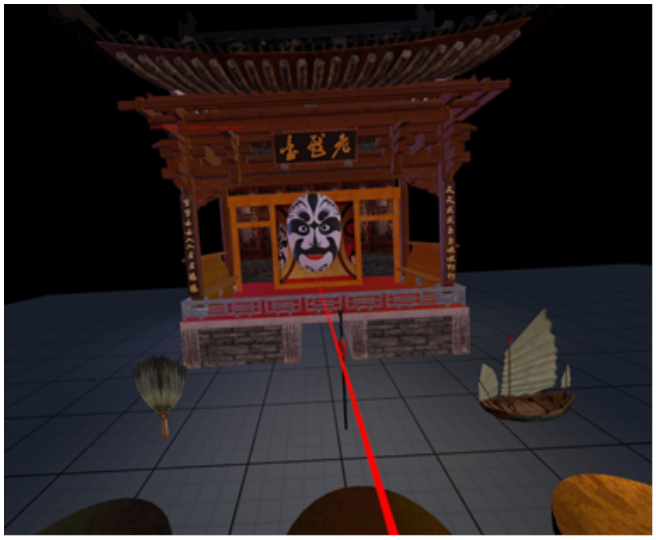

Fig. 2. Peking Opera Painted Faces (POPF) VR simulation experience.

C. Data Collection Methods

Questionnaire-based surveys served as the primary method of data collection. The questionnaire primarily targeted international university students from diverse nationalities, age groups, and academic fields to evaluate their reception and interpretation of Chinese opera cultural content presented through VR animation. As outlined in Table 1, the questionnaire comprised the following sections: personal background information (e.g., age, nationality, and academic field), prior knowledge of Chinese opera culture, and interest in as well as comprehension of opera content delivered through VR animation.

To investigate the effectiveness of VR animation in the international dissemination of Chinese opera culture, this study developed a questionnaire targeting international university students. The questionnaire comprised five sections: personal background information, knowledge of Chinese opera culture, interest in VR animation content, understanding of VR animation content, and open-ended questions. The personal background information section gathered data on respondents' age, nationality, and field of expertise, designed in alignment with the standard content of widely used demographic questionnaires [42]. The section assessing knowledge of Chinese opera culture evaluated respondents' familiarity with the subject and their sources of information, drawing on questionnaire designs used in cross-cultural communication and cultural studies [43, 44]. The section on interest in VR animation content examined respondents' engagement and attention towards Chinese opera content presented in VR animation, with questions

informed by multimedia content engagement frameworks in educational technology research [16, 45]. The section on understanding VR animation content evaluated respondents' comprehension of Chinese opera as depicted in VR animation, including characters, plot, and cultural context, with questions informed by cognitive theories in multimedia learning and educational psychology [27, 18]. The open-ended question section gathered respondents' general impressions, identified strengths and weaknesses, and collected suggestions for improving the Chinese opera content presented in the VR animation, based on open-ended question design principles in qualitative research methodologies [46, 47]. To ensure the robustness of the scales and the validity of the questionnaire, experts in the field were invited to review the content and provide feedback. Based on their suggestions, the questionnaire was revised to enhance the representativeness and comprehensiveness of its items, ensuring validity and reliability. This approach aims to accurately evaluate international university students' interest in and comprehension of Chinese opera's cultural content in VR animation and to generate actionable optimization strategies.

Table 1. Chinese opera culture and VR animation questionnaire

Section		Question	Options
Personal background information	1.1	Age	18-24 years old, 25-30 years old, over 30 years old
	1.2	Nationality	[fill in]
	1.3	Field of Expertise	[fill in]
Knowledge of Chinese opera culture	2.1	How much do you know about Chinese opera culture?	Not at all, Somewhat, Generally, Quite, Very much
	2.2	Have you ever watched a Chinese opera performance?	Yes, No
	2.3	Through which channels do you know about Chinese opera culture? (Multiple choice)	Classroom teaching, books, TV programmes, internet, friends' introduction, others (please specify) [fill in].
Interest in Chinese opera content in VR animation	3.1	Are you interested in watching Chinese opera content shown in VR animation?	Very uninterested, Not interested, Average, Interested, Very interested
	3.2	Does the Chinese opera content shown in the VR animation attract your attention?	Not at all, Less attractive, Average, Quite attractive, Very attractive
Understanding of Chinese Opera Content in VR Animation	4.1	After watching the VR animation, how well do you understand the characters in Chinese opera?	Not at all, Somewhat, Generally, Comparatively, Completely
	4.2	After watching the VR animation, how do you understand the plot of Chinese opera?	No understanding at all, Some understanding, General understanding, Comparative understanding, Complete understanding
	4.3	After watching the VR animation, how do you understand the cultural background of Chinese opera?	No understanding at all, Some understanding, General understanding, Comparative understanding, Full understanding
Open questions	5.1	What is your general feeling about watching the content of Chinese opera shown in the VR animation?	[Fill in]
	5.2	What do you think are the strengths and weaknesses of VR animation in spreading Chinese opera culture?	[Fill in]
	5.3	Do you have any suggestions on how to design better VR animation content to showcase Chinese opera culture?	[Fill in]

D. Sample

To ensure representativeness, the sample was drawn from universities with a high proportion of international students. The selected international students were grouped by age range (18–24 years, 25–30 years, and 30 years and above), academic specialization (arts, science, engineering, etc.), and nationality. The sample size for each subgroup was balanced as much as possible to facilitate robust comparative analyses.

1) Determining the scope and target population of the study: To ensure a diverse and representative sample, target universities were chosen based on their high percentage of international students. Selected universities had multicultural student bodies and sufficient resources for international students.

2) Establishing the sample frame: The primary nationalities included in the study were identified through predefined nationality subgroups to ensure diversity in the sample. Age grouping categorized international students into age ranges (18–24 years, 25–30 years, and 30 years and above) to analyze their reception and comprehension of Chinese opera culture in VR animation. Specialized area grouping categorized international students by academic specialization to investigate variations in their interest and comprehension of VR animation content across diverse fields of study.

3) Research needs and resource constraints determined the total sample size. Typically, the sample size was set large enough to ensure the validity and reliability of statistical analyses. A total sample size of 300 or more was required to ensure the representativeness and generalizability of the analysis results. Sample allocation ensured that the sample size was as balanced as possible across each nationality, age range, and academic specialization subgroup.

4) Sample Selection: Step 1: Identify and select target universities with a high proportion of international students and multicultural environments, such as Taylor's University in Malaysia, which is known for its abundant international student resources and supportive academic environment. Step 2: Obtain a list of students. Contact the international student office or relevant departments at the target universities to obtain a comprehensive list of international students, including details such as nationality, age, and field of study. Step 3: Random Sampling: Use random sampling methods, such as random number generators, to select students from the list, ensuring fairness and randomness. Step 4: Invitation to Participate: Contact sampled students via email or telephone to invite them to participate, providing detailed information on the study's purpose, content, and significance. Step 5:

Disseminate the questionnaire via online platforms such as Google Forms and SurveyMonkey to facilitate student completion and submission.

The scientific rigor and representativeness of the sample selection were ensured through the methods and steps outlined above, providing reliable data support for analyzing the impact of VR animation on the dissemination of Chinese opera culture among international university students from diverse nationalities.

E. Data Analysis Methods

1) Quantitative data analysis

Descriptive statistics are employed to summarize and characterize the fundamental properties of the data, facilitating an understanding of the sample's overall structure and the distribution of data characteristics. By calculating statistical measures such as the mean, median, standard deviation, frequency, and percentage, researchers obtain a comprehensive understanding of international university students' interest in and comprehension of Chinese opera content presented in VR animation. For instance, researchers can calculate the mean score and standard deviation for each response option in the questionnaire concerning international students' interest in and comprehension of Chinese opera content in VR animation, enabling an analysis of overall trends and data dispersion. The mean represents the overall level of student evaluations for specific questions; the median mitigates the impact of extreme values on the results; and the standard deviation quantifies the degree of data dispersion, indicating the consistency or variability in student responses. Frequency and percentage are employed to illustrate the number and proportion of individuals selecting each option, facilitating an understanding of response distributions for specific questions among students from diverse backgrounds. Descriptive statistics not only enable researchers to identify underlying patterns and characteristics within the data but also establish a foundation for subsequent statistical analyses. Correlation analysis is employed to investigate the relationships between two or more variables, providing insights into connections between students' background characteristics—such as age, nationality, and academic specialization—and their reception and comprehension of VR animation content. The analysis examines correlations between age and interest in VR animation, nationality and comprehension, and other factors. This analytical approach reveals potential connections between various background characteristics and provides researchers with valuable insights into the influence of these factors on students' reception and comprehension of VR animation content.

2) Qualitative data analysis

Thematic analysis represents a fundamental approach in qualitative data analysis. Through the organization and categorization of coded data, and the extraction of key themes and patterns, researchers can systematically summarize students' primary views and recommendations regarding the cultural content of Chinese opera in VR animation. To identify key themes and patterns during thematic analysis, researchers must first code responses to open-ended questions. For instance, responses could be coded under categories such as "immersion," "interactivity," and "cultural differences" when analyzing students' overall impressions of Chinese opera and its cultural content within VR animation. Key terms such as "immersion," "interactivity," and "cultural differences" were coded. Subsequently, researchers can identify major themes and patterns in the data through the organization and categorization of these codes. By analyzing the identified themes, researchers can synthesize students' opinions and recommendations concerning the immersion evaluation, interactivity experience, and cultural adaptability of Chinese opera content in VR animation. For example, students frequently highlighted the immersion offered by VR animation, a theme that could be further subdivided into sub-themes such as visual effects, sound design, and character performance. Additionally, students' feedback on the interactive experience often pertained to specific aspects, including the user interface's friendliness, the interaction design's coherence, and the sense of involvement in the narrative. Students' feedback on cultural adaptability often addressed the adequacy of cultural background introductions, the integration level of cross-cultural elements, and the management of cultural differences.

Through in-depth thematic analyses, researchers can acquire a comprehensive understanding of students' authentic perceptions and specific recommendations regarding the cultural content of Chinese opera in VR animation. This process will not only enhance the design and production of VR animation but also offer valuable insights for future applications in cultural communication and education. Meanwhile, researchers can identify the specific needs and preferences of diverse background groups by analyzing feedback from students of varying nationalities, age groups, and academic specializations, thereby offering data-driven support for personalized and diversified cultural communication strategies. By employing the above methods, researchers can comprehensively evaluate the effectiveness of VR animation in disseminating Chinese opera culture among international university students from diverse nationalities and propose targeted optimization strategies, thereby offering a scientific foundation and practical recommendations for the global dissemination of Chinese opera culture.

IV. Results and Analyses

To evaluate the effectiveness of VR animation in disseminating Chinese opera culture among international university students from diverse nationalities, a questionnaire survey was conducted involving 300 participants. The survey results indicated that the majority of students (75%) perceived VR animation as a helpful tool for enhancing their understanding and acceptance of Chinese opera culture. These findings align with results reported in existing literature [48]. Additionally, students generally reported that the immersive experience provided by VR animation facilitated their memory retention of details and storylines in the opera. This study ensured sample representativeness by selecting participants from universities with diverse international student populations. Participants were stratified by age range (under 18, 18–23, 24–29, 30–35, and 35 and above), field of specialization (e.g., Art and Design, Business, Computer

Engineering, Architecture, Education, Hospitality and Tourism), and nationality (e.g., Chinese, Korean, Finnish, Malaysian, Indian, Indonesian, Pakistani, Iranian, Australian, Japanese, Irish). Efforts were made to balance the sample size across subgroups to facilitate meaningful comparative analyses. Data analysis encompassed descriptive statistics, subgroup mean calculations, and data visualization techniques.

A. Descriptive Statistics

Descriptive statistics are employed to summarize and characterize the fundamental properties of the data, facilitating an understanding of the sample's overall structure and the data distribution by calculating measures such as the mean, median, standard deviation, frequency, and percentage. Table 2 presents the results of descriptive statistics regarding international students' interest in and comprehension of Chinese opera content in VR animation.

Table 2. The results of descriptive statistics about international students' interest in and understanding of Chinese opera content in VR animation

Indicator	Interest	Understanding
Sample size	300	300
Mean	2.59	2.41
Standard deviation	1.24	1.18
Minimum	1	1
25th percentile	2	1
Median	2	2
75th percentile	3.25	3
Maximum value	5	5

The analyses indicated that the sample size for both variables, interest and understanding, was 300, ensuring that the statistical results were representative. The mean values of interest and understanding were 2.59 and 2.41, respectively, indicating that overall, students' interest in and comprehension of Chinese opera content in VR animation were at a moderate level. The standard deviations for interest and understanding were 1.24 and 1.18, respectively, indicating that while the students' ratings for these two variables exhibited some dispersion, they were overall relatively concentrated. The minimum and maximum values for all variables were 1 and 5, reflecting that students' responses spanned the entire range of the rating scale. The majority of students' ratings were clustered in the middle range, with the 25th, 50th (median), and 75th percentiles being 2, 2, and 3.25 for interest, and 1, 2, and 3 for comprehension, respectively.

The study's results indicate that students' ratings for interest and understanding of Chinese opera content in VR animation exhibit some variability, though the overall level is moderate. These findings suggest that the diverse needs of students should be considered when designing educational content to enhance the effectiveness of VR animation as a tool for disseminating Chinese opera culture. The next step involves conducting group mean calculations and data visualizations to gain deeper insights into students' interest in and comprehension of Chinese opera content in VR animation across diverse backgrounds.

B. Results of Graphical Analysis

Fig. 3 illustrates the general trends and levels of dispersion in international university students' interest in and comprehension of Chinese opera content in VR animation. It depicts students' interest in and comprehension of Chinese opera content in VR animation across different age groups, nationalities, and fields of study. Students aged 18–23 demonstrated the highest levels of interest and comprehension in VR animation, with scores of 3.02 and 3.05, respectively. This suggests that students in this age group are more receptive to innovative forms of technology-mediated cultural communication, while students aged 35 and above recorded the lowest ratings, with scores of 2.76 and 2.79, respectively, indicating a preference for traditional learning methods. In terms of nationality, students from China, South Korea, and Malaysia exhibited higher ratings for their interest in and comprehension of VR animation, possibly due to greater exposure to and familiarity with Chinese culture. Conversely, students from Iran, India, and Pakistan recorded lower ratings, suggesting a lower receptiveness to this cultural form. Regarding areas of specialization, students majoring in Art and Design and Hospitality and Tourism exhibited the highest ratings, with scores of 3.10 and 3.12, and 2.98 and 2.98, respectively, indicating a stronger interest in innovative forms of cultural communication. Conversely, students majoring in Business and Education recorded lower ratings of 2.80 and 2.91, and 2.79 and 2.79, respectively, suggesting reduced sensitivity to the integration of technology and culture.

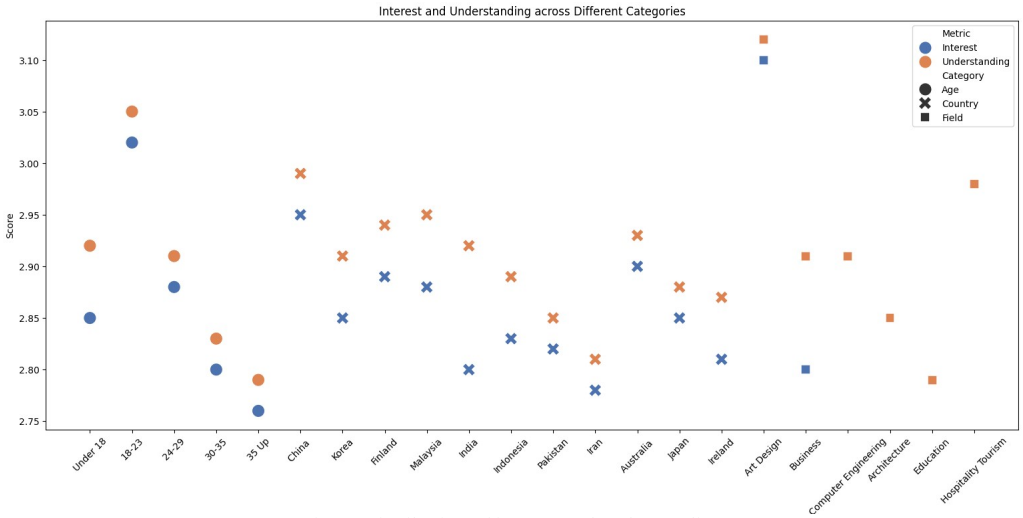

Fig. 3. Distribution of interest and understanding.

These findings indicate that age, nationality, and area of specialization significantly influence students' interest in and comprehension of Chinese opera content in VR animation. The design of educational content should fully account for these differences to enhance the effectiveness of VR animation in disseminating Chinese opera culture. More targeted educational content may be required, particularly for older students and those with diverse cultural backgrounds, to enhance their interest and comprehension. Future research should further investigate the underlying reasons for these differences to develop more effective cultural communication strategies.

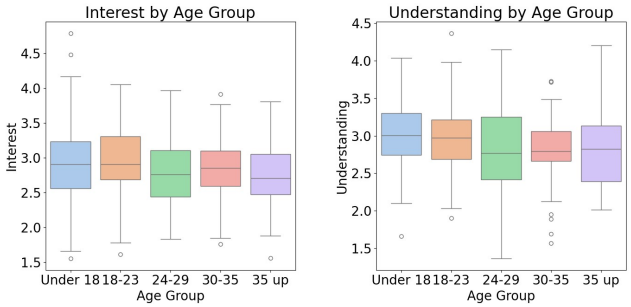

Fig. 4. Interests and understandings of different age groups.

Fig. 4 illustrates students under 18 years old exhibited an average interest score of 2.85 and an average comprehension score of 2.92 for Chinese opera content in VR animation, indicating that both interest and comprehension levels in this age group were relatively low. Students aged 24–29 had an average interest score of 2.88 and an average comprehension score of 2.91 for Chinese opera content in VR animation. Interest and comprehension levels among this age group were moderate, slightly lower than those of the 18–23 group but higher than those of other age groups. Students aged 30–35 recorded a mean interest score of 2.80 and a mean comprehension score of 2.83 for Chinese opera content in VR animation. These results suggest that students in this age group were less interested in and less accepting of new technologies. Students aged 35 and above recorded a mean interest score of 2.76 and a mean comprehension score of 2.79 for Chinese opera content in VR animation. This age group demonstrated the lowest levels of interest and comprehension, possibly due to a preference for traditional learning methods.

The data indicated that students aged 18–23 demonstrated the highest levels of interest in and comprehension of Chinese opera content in VR animation. This could be attributed to students in this age group being more accustomed to technology and more open to innovative learning methods. Conversely, students aged 30 and above exhibited significantly lower levels of interest in and comprehension of Chinese opera content in VR animation. This could be due to students in this age group being more familiar with traditional learning methods and less receptive to emerging technologies. To better facilitate the application of VR animation in disseminating Chinese opera culture, educational content design should prioritize the needs of the primary audience group, students aged 18–23. Incorporating interactive and engaging elements could further enhance their interest and comprehension. For students aged 30 and above, educational content design should consider their preference for traditional learning methods and incorporate a blend of traditional and modern technologies to gradually encourage acceptance of VR animation as a learning tool. In the future, researchers could investigate how students of different age groups accept and comprehend VR animation content, as well as the underlying reasons and factors influencing these behaviors. Experimental studies could also be employed to examine how different types of educational content influence students' interest and comprehension across age groups, providing more scientifically grounded insights for utilizing VR animation in educational settings.

In VR animation, Chinese students exhibited an average interest score of 2.95 and an average comprehension score of 2.99 for Chinese opera content, suggesting a higher receptiveness to this innovative educational approach. Korean students exhibited an average interest score of 2.85 and an average comprehension score of 2.91 for Chinese opera content in VR animation, indicating relatively high ratings, though slightly lower than those of Chinese students. Finnish students exhibited an average interest score of 2.89 and an average comprehension score of 2.94 for Chinese opera content in VR animation, suggesting that this educational approach is well received among European students. Malaysian students exhibited an average interest score of 2.88 and an average comprehension score of 2.95, with ratings comparable to those of Chinese and Korean students. Indian students exhibited an average interest score of 2.80 and an average comprehension score of 2.92 for Chinese opera content in VR animation, suggesting relatively lower ratings that could benefit from more targeted educational content design. Indonesian students exhibited an average interest score of 2.83 and an average comprehension score of 2.89 for Chinese opera content in VR animation, reflecting more moderate ratings. Pakistani students exhibited an average interest score of 2.82 and an average comprehension score of 2.85 for Chinese opera content in VR animation, indicating relatively low ratings. Iranian students exhibited an average interest score of 2.78 and an average comprehension score of 2.81 for Chinese opera content in VR animation, representing the lowest ratings among the groups. Australian students exhibited an average interest score of 2.90 and an average comprehension score of 2.93 for Chinese opera content in VR animation, reflecting higher ratings and suggesting that this educational approach is well received by students in Oceania. Japanese students exhibited an average interest score of 2.85 and an average comprehension score of 2.88 for Chinese opera content in VR animation, reflecting more moderate ratings. Irish students exhibited an average interest score of 2.81 and an average comprehension score of 2.87 for Chinese opera content in VR animation, reflecting moderate ratings.

Fig. 5 reveals that students from China, South Korea, Finland, and Malaysia exhibit higher levels of interest in and comprehension of Chinese opera content in VR animation. These students are likely more open to adopting new technologies and exhibit a notable interest in Chinese culture. Conversely, students from India, Pakistan, and Iran demonstrated lower levels of interest in and comprehension of Chinese opera content in VR animation, indicating a need for

more targeted educational content to enhance their engagement. To better facilitate the use of VR animation in disseminating Chinese opera culture, educational content design should prioritize addressing the specific needs of students from diverse countries. Incorporating interactive and engaging elements could enhance students' interest and comprehension, particularly for those from countries with lower ratings, who may benefit from additional cultural context and points of interest to gradually adopt VR animation as a learning tool. Future research should further investigate the specific ways in which students from various countries accept and interpret VR animation content, analyzing the underlying reasons and influencing factors to provide more scientifically grounded guidance for the educational application of VR animation.

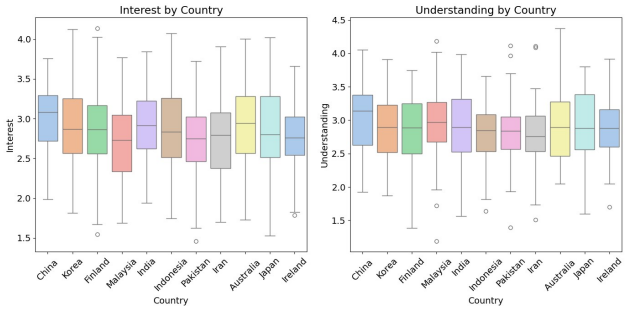

Fig. 5. Interests and understandings in different countries.

Fig. 6 illustrates students' levels of interest in and comprehension of Chinese opera content in VR animation across various fields of study. Art and design students exhibited an average interest score of 3.10 and an average comprehension score of 3.12 for Chinese opera content in VR animation, suggesting that they were the most receptive to this innovative educational approach. Business students exhibited a mean interest score of 2.80 and a mean comprehension score of 2.91 for Chinese opera content in VR animation, reflecting lower interest but a relatively higher level of comprehension. Computer engineering students exhibited a mean interest score of 2.91 and a mean comprehension score of 2.91 for Chinese opera content in VR animation, suggesting that their interest and comprehension levels were moderate. Architecture students exhibited a mean interest score of 2.85 and a mean comprehension score of 2.85 for Chinese opera content in VR animation, reflecting relatively consistent and moderate levels of interest and comprehension. Education students exhibited a mean interest score of 2.79 and a mean comprehension score of 2.79 for Chinese opera content in VR animation, suggesting that both their interest and comprehension levels were low. Hotel and tourism students exhibited an average interest score of 2.98 and an average comprehension score of 2.98 for Chinese opera content in VR animation, reflecting high levels of interest and comprehension, though slightly lower than those of art and design students.

The analysis in Fig. 6 indicates that students majoring in Art and Design and Hospitality and Tourism exhibited higher levels of interest in and comprehension of Chinese opera content in VR animation, possibly because students in these disciplines are more receptive to new technologies and demonstrate greater interest in cultural content. Conversely, students majoring in Business and Education exhibited lower levels of interest in and comprehension of Chinese opera content in VR animation, highlighting the need for more targeted educational content to improve their engagement. To better facilitate the use of VR animation in disseminating Chinese opera culture, educational content design should prioritize addressing the specific needs of students across various professional fields. Incorporating interactive and engaging elements could further enhance students' interest and comprehension, particularly for those in professional fields with lower ratings. These students may benefit from more practical application scenarios and culturally relevant points of interest to gradually adopt VR animation as an effective learning tool. Future research should further investigate how students in various professional fields accept and interpret VR animation content, analyzing the underlying reasons and influencing factors to provide more scientifically grounded guidance for the educational application of VR animation.

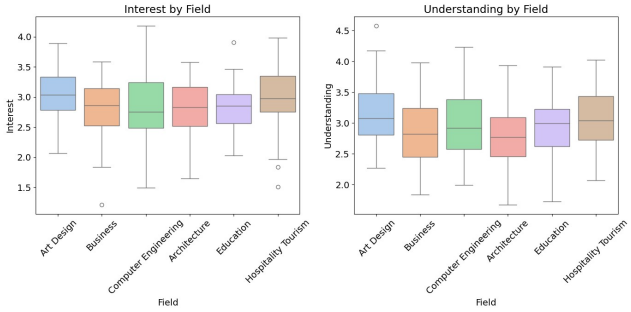

Fig. 6. Interests and understanding in different areas of expertise.

In summary, VR animation significantly enhances the international dissemination of Chinese opera culture and serves as an effective medium for conveying its essence. Variations in how students from diverse backgrounds receive and interpret VR animation content necessitate that educators fully integrate multicultural considerations into the design and promotion of VR educational content to maximize its educational impact. Future research should expand the sample size and delve deeper into the specific variations in how students from diverse backgrounds receive and interpret VR animation content, providing a robust theoretical framework and actionable guidance for the global application of VR technology in education. These findings suggest that VR animation has substantial potential in disseminating Chinese opera culture, but its success requires tailored design and promotion to meet the diverse needs and preferences of students from various backgrounds. Future research and practice should address these differences, requiring educators to thoroughly consider multicultural factors when designing and promoting VR educational content to enhance the acceptance and dissemination of VR animation among international students. By comprehensively analyzing international students' interest in and comprehension of Chinese opera content in VR animation, we can gain deeper insights into the needs and preferences of students from diverse backgrounds, providing a scientific foundation and practical guidance for future design and promotion efforts.

C. Thematic Analysis

The coding process was based on responses to open-ended questions, including those presented in Table 3.

The coding allows for the identification of the following major themes and sub-themes in Table 4.

Table 3. Examples of responses to open-ended questions

No.	Respondent	Coding
1	The VR animation provides a very strong sense of immersion, especially the visual effects and sound design, which are excellent. However, I feel that the character performance is sometimes not realistic enough.	Immersion: visual effects, sound design, character performance
2	Interactivity is a major advantage of VR animation, and I enjoy being able to participate in the plot design. However, there are times when the user interface lacks friendliness and requires improvement.	Interactivity: plot involvement, user interface
3	I think the VR animation does a decent job of introducing the cultural background, but the integration of cross-cultural elements could go further, especially in dealing with cultural differences.	Cultural adaptability involves introducing cultural background, incorporating cross-cultural elements, and managing cultural differences.
4	The overall feeling is good, but sometimes it feels like the cultural content is too esoteric to be easily understood. The VR animation did a fantastic job in terms of visual and interactive aspects, but there is still room for improvement in terms of detailed presentation.	Overall feeling: rich cultural content, challenging to understand
5	The VR animation provides a very strong sense of immersion, especially the visual effects and sound design, which are excellent. However, I feel that the character performance is sometimes not realistic enough.	Immersion encompasses visual effects, interactivity, interaction, and detailed performance.

Table 4. Example of three-level coding

No.	Primary code	Secondary code	Tertiary code	Frequency
1	Immersion	Visual Effects	Picture Clarity	40
			Colour reproduction	40
			Colour Saturation	37
			Colour Vividness	37
			Scene detail realism	36
			Scene realism	36
		Sound Design	Sound clarity	35
			Stereo sound	35
			Accurate Sound Positioning	32
			Surround Sound Positioning	33
		Character Performance	Emotional richness of expression	30
			Subtlety of expression	30
			Smoothness of movement	28
			Naturalness of movement	27
		Detailed Performance	Scene realism	35
			Scene finesse	38
			Props realism	35
			Props detail richness	36
2	Interactivity	Plot Participation	Interactive Creativity	42
			Design Versatility	43
			User Decision Influence	40
			Engagement	38
		User Interface	Ease of use	34
			Intuitive	34
			Simplicity of operation	32
			Quick Response	34
		Interactive Experience	Timely interactive feedback	35
			Highly interactive	35
			Highly immersive	41
			Immersive participation	40
3	Cultural adaptability	Cultural Background	Detailed	32
			Rich in information	33
			Higher accuracy	30
			Accuracy	30
		Cross-cultural elements	Higher degree of graphics fusion	40
			Image recognition compatibility	42
			Innovative presentation	39
			Graphic colour symbolism	38
		Handling cultural differences	Inclusive treatment	41
			Flexibility	38
			Dynamic expression easy to recognise	40
			Easily accepted	39
4	Overall feeling	Cultural content comprehension	Moderately difficult to understand	45
			Information complexity	40
			Barriers to comprehension	38

By coding responses to open-ended questions using thematic terms and conducting thematic analysis, the

researcher systematically summarized students' primary views and suggestions regarding the cultural content of Chinese opera in VR animation. Specifically, students broadly agreed that VR animation offers significant advantages in immersion and interactivity; however, improvements are needed in character performance and user interface friendliness. The main thematic terms were categorized into four dimensions using three-level thematic refinement coding: immersion, interactivity, cultural adaptability, and presence, which revealed students' specific comments and suggestions regarding Chinese opera and cultural content in VR animation. This information enables the researcher to gain a comprehensive understanding of students' perceptions and needs regarding VR animation, thereby offering valuable insights for future design and improvement. Additionally, cultural adaptation emerged as another critical theme, particularly regarding the integration of cross-cultural elements and the management of cultural differences. Identifying these major themes and sub-themes enables the researcher to develop a comprehensive understanding of students' perceptions and provide specific recommendations regarding the cultural content of Chinese opera in VR animation. This will not only contribute to enhancing the design and production of VR animation but also offer valuable insights for future cultural communication and educational applications. The specific needs and preferences of diverse demographic groups can be identified by comparing feedback from students of various nationalities, age groups, and professional fields, thereby providing data-driven support for personalized and diversified cultural communication strategies. Using these methods, the researcher can thoroughly evaluate the effectiveness of VR animation in disseminating Chinese opera culture among international university students from diverse nationalities and propose corresponding optimization strategies to offer a scientific foundation and practical guidance for its global dissemination.

V. Discussion

The results of this study affirm the effectiveness of VR animation in fostering cross-cultural understanding and appreciation of Chinese opera among international students, emphasizing its potential as a transformative educational tool for traditional art forms. The immersive and interactive qualities of VR align with constructivist and experiential learning theories, which emphasize active engagement and enriched contextual environments to facilitate deep learning [26, 27]. The findings indicate that VR has the potential to bridge cultural divides by making complex cultural forms, such as Chinese opera, more accessible and engaging to global audiences. Constructivist learning theory posits that learners construct knowledge through direct and meaningful interactions with their environment [24]. VR's immersive design situates students within an authentic cultural context, fostering active engagement and enabling them to construct knowledge about Chinese opera through personal exploration and interaction with visual and auditory elements [48]. As evidenced by the results, students reported that VR animation enhanced their ability to retain cultural details, suggesting that the immersive environment effectively supported memory retention. This finding aligns with Mayer's (2009) [27] multimedia learning theory, which posits that integrating multiple sensory stimuli—visual, auditory, and interactive—enhances cognitive processing and facilitates the retention of complex information. Moreover, VR's alignment with experiential learning theory was evident in the high levels of engagement observed among younger participants and those specializing in creative fields (e.g., Art and Design). Experiential learning theory underscores the importance of learning through experience, positing that students achieve optimal learning outcomes when actively engaged in the learning process [18]. For instance, students aged 18–23 demonstrated the highest levels of engagement and comprehension, likely attributable to their receptiveness to new technologies and preference for active learning environments [15]. This suggests that VR's immersive qualities strongly resonate with digitally native students, offering them an engaging platform tailored to their educational preferences.

The study identified significant demographic-based variations in engagement and comprehension levels. Specifically, students from China, South Korea, and Malaysia exhibited higher levels of interest and comprehension, likely attributable to their greater cultural familiarity with Chinese opera [39, 25]. Conversely, students from Iran, India, and Pakistan exhibited comparatively lower engagement, highlighting the challenges associated with introducing culturally distant content. This finding aligns with research by Shadiev and Huang (2021) [4], who contend that VR's effectiveness in cross-cultural learning is shaped by prior cultural exposure and familiarity. Addressing this variability is essential for multicultural education, as it underscores the importance of culturally adaptive VR content that incorporates additional background information for students less familiar with Chinese culture. The influence of academic background was also significant, with students in Art and Design and Hospitality and Tourism exhibiting the highest levels of interest and comprehension, while those in Business and Education demonstrated lower scores. These findings suggest that students with an inherent interest in cultural and creative content are more receptive to VR-based cultural learning, emphasizing the necessity of discipline-specific adaptations in VR educational design [33]. Business and Education students may benefit from VR content that integrates practical applications or frameworks tailored to their fields, enhancing the relatability and engagement of the learning experience [12].

The findings of this study carry substantial implications for multicultural education. By enabling students from diverse backgrounds to engage with cultural content in an immersive and interactive setting, VR aligns with the objectives of multicultural education, promoting intercultural competence and empathy [41]. However, the observed variability in engagement across cultural and disciplinary backgrounds underscores the necessity of designing culturally adaptive and accessible VR content to accommodate diverse learners [7]. For instance, students with prior exposure to Chinese culture could benefit from introductory segments contextualizing

Chinese opera within a broader cultural narrative, facilitating connections with their prior knowledge and experiences. Additionally, thematic analysis of the qualitative data highlighted the critical importance of cultural adaptability and user-friendliness in VR educational content. Participants underscored the need for intuitive interfaces and culturally relevant elements to enhance engagement, particularly for students less familiar with VR technology or Chinese culture [14]. This indicates that VR content should incorporate flexible design, providing options that cater to diverse user preferences and cultural backgrounds, thereby fostering a more inclusive educational approach [13]. This study offers foundational insights into the potential of VR animation for the internationalization of Chinese opera culture. However, further research is essential to expand upon these findings. Expanding the sample to encompass a broader spectrum of cultural backgrounds could yield a more comprehensive understanding of VR's effectiveness in multicultural education.

VI. Conclusion

This study explores how Virtual Reality (VR) animation serves as an effective medium for disseminating Chinese opera culture to international university students from diverse cultural backgrounds. The research illustrates that VR animation significantly improves engagement and comprehension by utilizing its immersive and interactive capabilities. VR animation aligns with principles of constructivist and experiential learning theories, promoting active participation and fostering a profound cultural understanding and appreciation. The findings reveal that VR animation effectively bridges cultural divides, with heightened engagement observed among students aged 18–23 and those in creative fields such as Art and Design. Students originating from culturally familiar regions, such as China, South Korea, and Malaysia, demonstrate greater interest and comprehension, whereas those from culturally distant regions, such as Iran and Pakistan, display comparatively lower receptivity. These results underscore the necessity of culturally adaptive VR content designed to accommodate differing levels of cultural familiarity. Participant feedback emphasizes the necessity of refining user interface design and enhancing cultural adaptability to optimize the overall user experience. This study substantiates the transformative potential of VR animation in multicultural education, establishing it as an invaluable tool for advancing cross-cultural communication and inclusivity. Future research should broaden participant diversity and evaluate the longitudinal effects of VR-based learning on cultural attitudes. Such efforts will contribute to the development of adaptive VR educational content that effectively captivates global audiences and cultivates a deeper appreciation for Chinese opera culture.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

T.L. and C.S.N. conducted the research; Author T.L. analyzed the data; Author T.L. and C.S.N. wrote the paper; all authors had approved the final version.

Acknowledgment

The authors would like to thank the Taylor's University Vortex XR Lab for providing user experience of the venue and equipment support for data collection.

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