

Using Virtual Reality Technologies in Cello Teaching in China

Qiong Wu

Harbin Conservatory of Music, Department of Vocal Opera

Abstract

In recent years, approaches to cello teaching in China have undergone significant changes due to the implementation of innovative technological methods. These new methodologies not only enhance students' technical skills but also contribute to the preservation and development of the national orchestral tradition. The aim of this study was to analyze the effectiveness of using virtual reality technologies in cello teaching in China. To study the approaches to cello performance, 215 students who were learning to play the cello were chosen to participate in the research. This study employed an experimental approach, which assumed the use of a testing method. Students were divided into two groups: experimental group, which was taught using VR technologies, and control group, which received traditional instruction. The results showed that the average technical skills of students in the experimental group improved significantly, by 25 %, while the same skills of students in the control group improved only by 5 %. In theoretical testing, the experimental group demonstrated a 34 % increase in knowledge, significantly surpassing the control group's improvement of 10 %. The experimental group also showed a 47 % improvement in the interpretation of musical pieces, compared to a 16 % improvement in the control group. The application of VR technologies in cello instruction proved to be effective, as confirmed by statistical tests. The study's results indicate that VR technologies help students better understand and feel the music, which enables more accurate interpretations of musical works. The practical value of this research lies in the integration of cutting-edge technologies into the music education process, as the use of VR creates a more engaging and effective learning environment, which aids students in better acquisition of the material and enhancement of their skills.

Key words: circular bowing technique; computer technologies; guitar technique; innovative teaching; melodic line; play point; VR

Introduction

The expressiveness of musical compositions is created through the voice and accompaniment of musical instruments (Kielian-Gilbert, 2020). The use of string instrument playing techniques with simultaneous tapping produces noises and variety of sounds (Zhao et al., 2021). The cello is used to accompany falsetto (Kruger & Jacobs, 2020). The use of the cello in Chinese orchestra contributes to the onomatopoeia of sounds and images of nature, the sound of folk instruments and overall music expression (Xiaolin, 2021). The Chinese orchestra is a significant element of musical culture because it conveys national elements displayed via traditional musical instruments (Leung & Cheung, 2020). China's national orchestras use a variety of musical instruments to create new melodies. These melodies are rich in renewed rhythms and timbres that convey the national identity based on folk music (Corbalán et al., 2019). The following phases are distinguished in Chinese orchestral creativity (Fung, 2018):

- 1900-1949: the period of interaction between Chinese and Western culture;
- 1949-1976: the period of the Cultural Revolution;
- 1976 to the present: the spread of Chinese music in the world.

Periods of national orchestra development have influenced the use of European techniques in the Chinese music performance, which entails new approaches. Playing and learning to play the cello is an important part of academic Chinese music, which is common both in Chinese orchestral music as well as in local and international music competitions (Zhang & Fyr, 2021). Wang Jian, who was inspired by the style of J. Bach (Lu et al., 2020), is one of the most famous Chinese cello players. His music is unique and overlaps with classical music. Wang Jian's music has travelled far beyond China and has been featured in the Berlin Philharmonic, the Chicago Symphony Orchestra and the London Symphony Orchestra (Lu et al., 2020).

The Chinese cello teaching tradition originates from the training which utilizes European musical culture methods. Researchers note that Chinese historical characteristics have little effect in this context (Gudozhnikova, 2019; Leung & Cheung, 2020). For the most part, traditional music education has only manifested itself in training approaches similar to those used to teach stringed instruments (Kielian-Gilbert, 2020). Chinese musicians are characterized by teacher-driven perseverance, dedication and high competition with high-quality foreign performers (Wang et al., 2021; Wei et al., 2022).

Simple exercises are initially used to develop the reflexes for more complex movements (Johnson, 2021) to build cello skills. The pizzicato technique, where the bow is played on open strings, which helps to learn the bow's proper positioning, is among them. The swing technique is used to coordinate the movements, with 1st and 4th finger in play and the main axis of the cello passing between the thumbs (Lin et al., 2021). To facilitate the learning process, a consistent approach should be used. The learning process should seek to apply improved techniques that identify new approaches to cello playing (Yantian et al., 2021).

The cello conveys the unique melody that is created by the sound's timbre when played. With this in mind, when playing the cello, more emphasis should be placed on the study of timbre. It contributes to the non-traditional interpretation of the instrument and the molding of tonality and form. This involves exploring the breadth of the cello's sound, which is achieved through string study as well as improvisational and virtuoso performance (Beavers, 2019). The design and material of musical instruments determine their acoustic properties. The wood cell structure helps to produce low-pitched sounds, with natural wood yielding more vibrant sounds.

When playing the cello, chordal playing of the figured bass based on traditional baroque performance should be applied. To achieve a chordal bass, harmonious combination of chords should be achieved. It requires building a bassline and assigning numbers to the notes, making it easier to play the cello. Figured bass is achieved through improvisation (Whittaker, 2021). Playing melodies on the cello requires the performance of a variety of sonatas, categorized by genre and expression. This is because each of the composers conveys extended artistic solutions, which helps improve the cello player's technique when learning to play. This approach contributes to an understanding of the techniques of timbre interfusion, the equivalence of instrumental parts and the dialogic interplay between musical elements. An analysis of the cello repertoire showcased the use of themes, folk music intonation formulas and original timbres (Gudozhnikova, 2019). Cello playing should be built on logical thinking, which facilitates the identification of the missing elements to play the melody. Applying the principles of forced vibrations based on spiccato helps to learn the basis of musical composition and the technique of bowing with crossed strings. In pieces for orchestra, the cello enables playing an expressive solo. The cello can be used in concerts in individual pieces, as a solo instrument or an accompanying instrument.

Special compositions were written for independent cello playing. They use transcriptions and adaptations of pieces written for other instruments, such as the violin. While playing the cello, the repertoire should be studied, with identification of its strong and weak elements. When playing the cello, compositions that reveal a vibrant melody and a smooth and virtuoso timbre should be chosen (Bekenova et al., 2020). However, cello teaching in China has undergone significant changes over the past decades due to the implementation of innovative technological methods. These methods not only transform educational approaches but also impact the national orchestral tradition. The integration of cutting-edge technologies, such as virtual reality (VR), artificial intelligence (AI) and online platforms, creates new opportunities for music education and the training of highly skilled musicians (Hamilton, 2019a; Hosek, 2023; Rutkowski et al., 2021; Wei et al., 2022).

In recent years, interest in innovative methods of teaching musical instruments, particularly the cello, has significantly increased. Research indicates that integrating new technologies into music education enhances learning outcomes and boosts student motivation (Vasil, 2019; Waddell & Williamon, 2019). Various countries

widely use VR and AI technologies to create interactive learning environments that enable students to improve their skills in a more engaging and effective manner (Dai, 2021; Hamilton, 2019a; Rutkowski et al., 2021; Wei et al., 2022). Leading countries are actively implementing online platforms for music education. These platforms allow students to access learning materials anytime and anywhere (Park, 2019). They often include video lessons, interactive exercises and opportunities for feedback from instructors (Hamilton, 2019b).

However, not all studies unanimously support the effectiveness of innovative technologies in music education. For example, some researchers argue that the use of VR distracts students from traditional teaching methods and does not adequately develop musical skills (Kamińska et al., 2019). It also affects their emotional state (Gómez-Rios et al., 2023). Others point out issues of accessibility and cost of such technologies, which may limit their implementation in resource-constrained educational institutions (Marougkas et al., 2023).

Nevertheless, innovations also pose several challenges and problems. Traditional teaching methods, based on years of experience and cultural specifics, require adaptation to new technologies. This raises the question: How can national traditions of cello playing be preserved while simultaneously utilizing the advantages of innovative technologies? This issue is particularly relevant in the context of globalization, where cultural boundaries are becoming increasingly transparent, and information exchange is instantaneous. The relevance of this topic is driven by the rapid development of technologies and their impact on all aspects of life, including art and education.

The motivation for writing this article stems from the need to investigate the effectiveness and impact of new technologies on cello education in China, specifically virtual reality technologies. Attention is given to how these innovations can be integrated into the educational process while preserving the unique characteristics of the Chinese musical tradition. The article aims to emphasize the importance of adapting modern technologies in music education. It reveals that virtual reality allows for the creation of interactive learning environments where students can practice in realistic conditions and receive real-time feedback (Hosek, 2023; Park, 2019).

The novelty of this study lies in its focus on cello teaching within the context of the Chinese musical tradition. Compared to previous research, this work provides a detailed analysis of how innovative technologies can be integrated into the educational process, taking into account the cultural characteristics and specificities of the national orchestral tradition. The results obtained can be used to develop new teaching approaches that incorporate both modern technological capabilities and traditional musical practices. This will enhance the quality of music education and preserve the national musical heritage in the context of globalization.

The hypothesis of the study is that the use of virtual reality (VR) technologies in cello teaching will positively impact students' technical skills, knowledge of music theory and musical interpretation.

The aim of the study was to analyze the effectiveness of using VR technologies in cello teaching in China.

Research Objectives:

1. Analyze the potential of virtual reality in cello teaching by examining its advantages and limitations.
2. Conduct an experiment using virtual reality during cello instruction and collect data regarding its impact on students' learning outcomes.
3. Evaluate the effectiveness of VR technologies and draw conclusions about their impact on the quality of teaching and their contribution to the preservation of national orchestral traditions.

Methodology

Research design

This study employed an experimental approach, which allowed for a detailed assessment of the impact of virtual reality (VR) technologies on the process of cello instruction within the Chinese context. An experimental approach was chosen due to its ability to provide a clear comparison between different groups of participants. The study was conducted in the form of a quasi-experiment, with participants divided in two groups. The research utilized a testing method.

Sample

To study the approaches to cello performance, 215 students who were learning to play the cello at the time were chosen for the sample. The students attended Xi'an Conservatory of Music at Lishui University. To participate in the study, the students had to be in their 3rd, 4th and 5th year of studying the cello. The sample of students was made up of seniors since they were already familiar with the different ways of playing the cello and understood the theoretical aspects, which was confirmed by the research program provided by the university's Dean's Office. The participants were selected from the aforementioned Conservatory since it was the first to apply for the research announcement made among universities in China. Pursuant to ethical standards, the participant students provided consent to participate in the study. They were randomly allocated to groups using an online randomizer programme. Table 1 provides a more comprehensive description of the sample.

Table 1
Participants' Characteristics (N=215)

		Total	CG (107)	EG (108)
Gender	Male	101	56	45
	Female	114	51	63
Age	>20	11	3	8
	20-23	197	98	99
	<26	7	6	1

		Total	CG (107)	EG (108)
Average training time (before training, seconds)	>900	33	10	23
	900-1260	128	76	52
	1260-1620	40	13	17
	<1920	14	8	6
Average training time (after training, seconds)	900-1620	12	10	0
	1620-1920	85	86	2
	1920-2700	89	9	80
	<3600	29	2	27

Procedure

At the outset of the study, all participants underwent initial assessment, which comprised tests on technical skills, music theory and musical interpretation (see Appendix 1). Over the course of three months, students from both groups underwent instruction using respective methodologies. In the experimental group, VR applications were employed in each session to provide interactive and immersive learning experiences. The control group adhered to traditional teaching methods. Following the completion of three months of instruction, all participants underwent post-assessment, similar to initial assessment, to compare the results and determine changes in skills and knowledge.

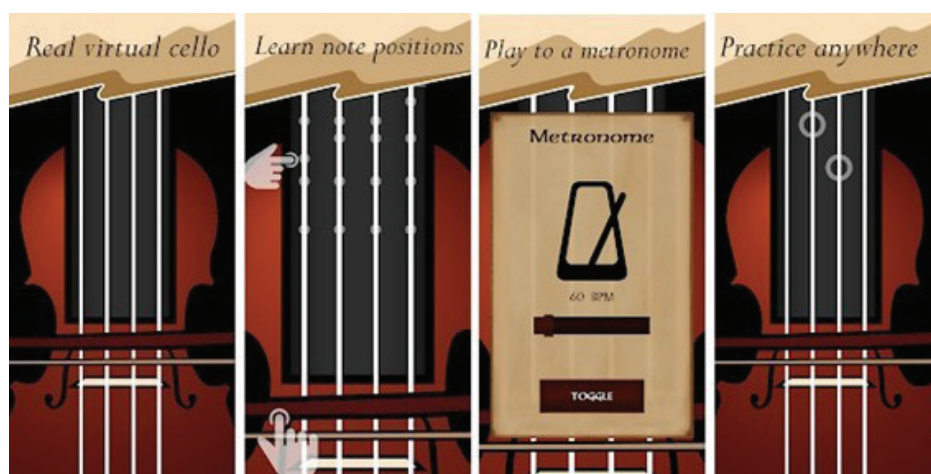


Figure 1. View of the Cello Simulator: Play & Learn Programme

The experimental group comprised 108 individuals. Students in this group were instructed to use VR technologies. Specialized VR applications were utilized, which enabled the creation of interactive educational environments. The Cello Simulator: Play & Learn programme was employed (Figure 1). During the training, participants used the available and cheap but functionally suitable Generic Smartphone VR Viewer as a virtual reality viewer. Students could practice in a virtual environment, receiving real-time feedback from the software. Lessons included exercises on playing technique, music theory and musical interpretation.

The control group consisted of 107 individuals. Students in this group received instruction through traditional methods without the use of VR technologies. Instruction included both individual and group sessions with the teacher and the utilization of printed musical scores, audio recordings and video lessons. Lessons also incorporated exercises on playing technique, music theory and musical interpretation.

Data collection

To assess the effectiveness of the new cello instruction programme utilizing VR technologies, several metric instruments were chosen to comprehensively evaluate students' academic performance. Key indicators used to measure the outcomes included technical skills, music theory and musical interpretation.

The test for cello playing technical skills included finger warm-up exercises (scales and arpeggios), execution of etudes covering various technical aspects (legato, staccato, double stops), and performance of musical excerpts from different musical eras (Baroque, Classical, Romantic, Contemporary music). This test was developed based on existing programmes from music academies and was validated in consultation with advising instructors. It demonstrated high validity, which was measured by the concordance coefficient and yielded values not lower than 0.64. These results indicated a good level of methodological validity as they covered all major technical aspects of cello playing. The reliability of the test was confirmed by Cronbach's alpha coefficient, which was 0.96.

The test on knowledge of music theory comprised identifying notes in a musical score, recognizing intervals and chords by ear, and analyzing musical compositions (harmony, form, melody). This test is based on a standardized music school curriculum. Its validity was confirmed by the concordance coefficient assessment, which yielded a value of 0.67. The reliability of the test was ensured by Cronbach's alpha coefficient, which was 0.98.

The test on musical interpretation involved performing two selected musical compositions from different eras. It evaluated the interpretation in terms of expressiveness, dynamics, articulation and stylistic appropriateness. Musical interpretation serves as a significant indicator of a student's musical development, which reflects their ability for artistic self-expression. The test was developed in collaboration with leading consulting instructors and aligned with international competition programs. Its

validity was supported by the concordance coefficient, which yielded values not lower than 0.65. Additionally, the reliability of the test was confirmed by Cronbach's alpha coefficient, which was 0.94.

The analysis of lesson videos encompassed recordings of sessions that utilized VR and traditional methods, which assessed student-teacher interaction and the use of technology and monitored student progress throughout the instruction. Video recordings provided detailed scrutiny of the instructional process and student progress, which facilitated an objective evaluation of the effectiveness of VR technologies. The utilization of the specified testing instruments and evaluation methods enabled comprehensive assessment of the impact of VR technologies on cello instruction.

Statistical processing

Before conducting parametric tests, the normality of the distribution was verified using the Kolmogorov-Smirnov test. For each indicator, the p-value exceeded the significance level of 0.05 (technical skills – 0.73; music theory – 0.69; musical interpretation – 0.81). These results confirmed the null hypothesis, i.e., the normal distribution of the data. It was therefore optimal to use parametric tests.

The F-test was employed to assess the equality of variances. All three F values were found to be less than the critical F value at a significance level of 0.05 (technical skills – 0.87; music theory – 0.94; musical interpretation – 0.91). Consequently, the hypothesis that assumed equal variances cannot be rejected, as there is no significant difference in variances.

To account for outliers, the z-score was calculated using the following formula:

$$(z\text{-score}) = \frac{X - \mu}{\sigma}$$

The calculations showed that none of the values had an absolute value greater than 3, and therefore no abnormal values were detected. Data analysis in this study was conducted using SPSS (Statistical Package for the Social Sciences) version 26. This software was selected for its extensive capabilities in conducting statistical tests and data analysis in the social and behavioural sciences. Additionally, SPSS facilitates easy processing of large datasets and provides a user-friendly interface for the visualization of results. The Student's t-test (t-test) was employed to compare the mean values of the indicators before and after the implementation of traditional and innovative cello instruction methods. This test allowed for determining whether significant differences existed between the two groups, which was crucial for assessing the effectiveness of the innovative methodology. Two types of t-tests were conducted. A paired t-test was used to compare the mean values of technical skills, music theory and interpretation indicators before and after the implementation of VR technologies within each group (experimental and control). Independent t-test was utilized for comparing the results between the experimental and control groups after completing the instruction.

Analysis of variance (ANOVA) was employed to determine the presence of statistically significant differences among multiple groups. In our study, ANOVA helped assess the

influence of various factors, such as teaching methodology (traditional or VR-based), on overall student performance indicators. This allowed for the explanation of data's variability and the identification of statistical significance of the difference between the groups.

Multivariate analysis of variance (MANOVA) was used for simultaneous analysis of several dependent variables. In our case, these variables included technical skills, knowledge of music theory and interpretation of musical compositions. MANOVA enables determining the overall effect of teaching methodology on multiple dependent variables, which provides a more comprehensive approach to data analysis.

Ethical issues

Ethical issues were explored using ESOMAR (2016) criteria based on confidentiality and reliability of the provided data, as well as the participants' rights and responsibilities.

Research limitations

While the employed instruments ensure high-quality data, there are certain limitations, including the subjectivity of assessments of musical interpretation, which may influence the results. Possible technical difficulties and challenges in students' adaptation to new technologies should also be noted. The limitations of this study also include the need for expensive equipment and specialized knowledge for its use. Although the experiment was conducted in accordance with the standards of confidentiality and ethical considerations, it failed to account for the impact of expectations on the outcomes. The results were presented as objectively as possible; however, this phenomenon may require further research. Furthermore, the study did not consider any potential changes in the participants' behaviour that could have been influenced by their desire to show themselves in the best possible light in order to enhance the experiment's outcomes. Instead, our analysis was based on the assumption of the participants' virtuous behaviour.

Results

Before the start of the study, the experimental and control group were compared in terms of three indicators. According to the p-values (technical skills – 0.068; music theory – 0.071; musical interpretation – 0.066), it was impossible to reject the null hypothesis regarding the differences between the two groups based on the pretests. Thus, no significant discrepancies were found.

This section presents the results of the study on the effectiveness of using VR technologies in cello-playing education. The results are presented in the form of tables and their descriptions, which allows for a better understanding of the impact of the innovative methodology on the learning process. Figure 2 demonstrates the mean values of students' technical skills before and after training. The experimental group, which utilized VR technologies, showed a significant improvement of 25 %,

whereas the control group improved their results by only 5 %. These results indicate that VR technologies more effectively contribute to the development of technical skills in cello playing due to interactivity and the possibility of real-time visual monitoring and error correction.

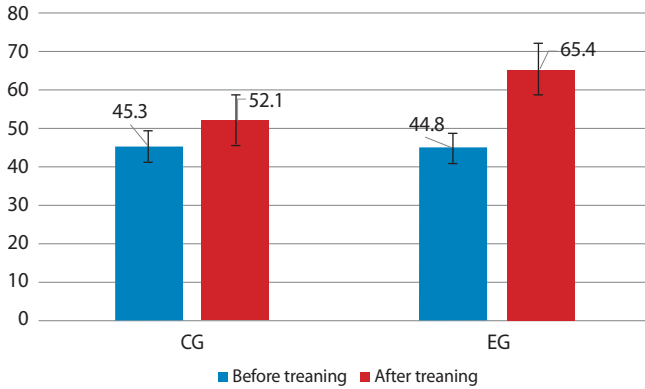


Figure 2. Dynamics of technical skills (M and SD) in A) the control group and B) the experimental group

Figure 3 illustrates the results of tests on music theory knowledge. The experimental group demonstrated a 34 % increase in knowledge, significantly surpassing the performance of the control group, which improved results by only 10 %. This may be associated with VR technologies providing deeper immersion in the material and interactive learning, which contributes to better assimilation of theoretical knowledge.

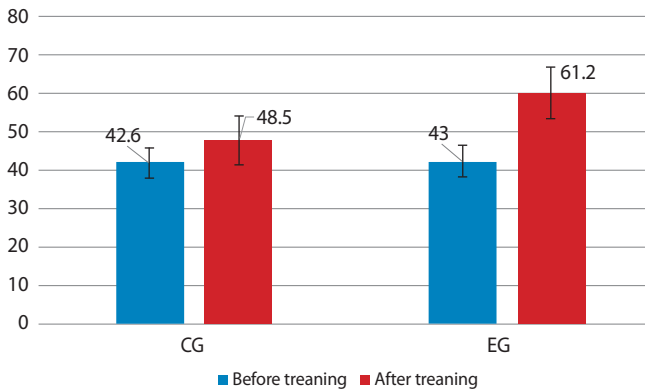


Figure 3. Dynamics of knowledge of music theory (M and SD) in A) the control group and B) the experimental group

Figure 4 depicts changes in the interpretation of musical compositions. Students in the experimental group showed an improvement of 47 %, while the control group improved their results by only 16 %. This indicates that VR technologies assist students in better understanding and feeling music, which enables them to interpret musical

compositions more accurately. Interactive lessons using VR may include simulations of various emotional states and performance styles, which contributes to a more in-depth comprehension of musical compositions.

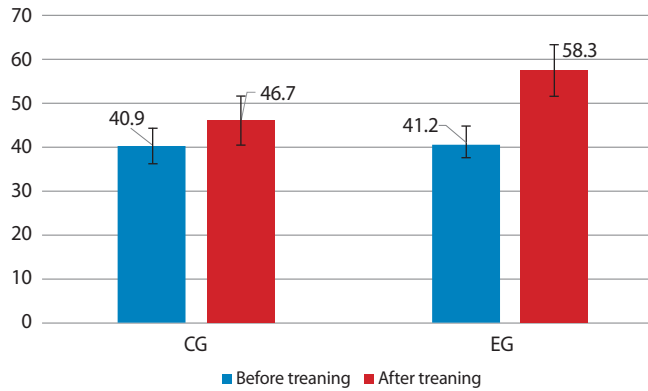


Figure 4. Dynamics of musical interpretation (M and SD) in A) the control group and B) the experimental group

Table 2 demonstrates the results of statistical tests which were used to assess the impact of VR technologies on cello-playing education. The values of the paired t-test (< 0.001) and independent t-test (< 0.001) confirmed a statistically significant difference between the groups.

Table 2

Results of Statistical Tests on the Impact of VR Technologies on Cello Playing Education

Indicator	p-value (paired t-test/ independent t-test)	F-value/p-value (ANOVA)	F-value/p-value (MANOVA)
Technical skills	$< 0.001 / < 0.001$	22.4 / < 0.001	19.3 / < 0.001
Knowledge of music theory	$< 0.001 / < 0.001$	19.8 / < 0.001	16.7 / < 0.001
Interpretation of musical works	$< 0.001 / < 0.001$	21.5 / < 0.001	18.1 / < 0.001

The results of ANOVA and MANOVA also confirmed a significant positive impact of VR technologies on overall student performance. The p-values for all indicators were less than 0.001, which indicated a high level of statistical significance.

Discussion

The study's results indicate that using VR technology in cello training significantly enhances technical skills. Additionally, this approach helps students acquire theoretical knowledge and develop interpretative abilities more effectively. These benefits may be attributed to the interactivity and engagement provided by innovative technologies. VR can create more realistic and emotionally immersive learning environments, thereby facilitating a better understanding of musical compositions.

Cello-playing approaches were identified based on available literature. Playing the cello should involve sight-reading technique, because it provides ear training, which develops the speed of thinking and improvisation skills. The sight-reading skills while playing the cello can be determined by identifying errors in the pitch and fluency used in short pieces of music. Knowing the location of the notes can have a negative correlation between the location of the notes and sight-reading performance. Yet, an increased musical complexity leads to more performance errors and more pauses. Such deficiencies can only be corrected through regular exercises that increase technical difficulty (Wolfs et al., 2020).

Timbre is one of the main parameters for the emotionality of perceived melodies – angry, happy, kind and sad. The musical instrument's timbre is associated with different variations and dynamic range, so playing the cello requires learning the instrument's parameters and the sound features first. To do this, the bow should be perpendicular to the string. Light touching of the string with the bow gives the sound special colouring. The proper ratio of the bow's pace to pressure should be identified when touching the string (Wang et al., 2021). This part is based on approaches to cello instruction that rely on common parameters, which eliminate the technical components of specific elements. This causes a gap in the presented research as it emphasizes contemporary cello techniques that have value for national orchestras because they contribute to the vividness and expressiveness of the cello's sound.

Self-regulation of improvised sounds is one of the main approaches used to play the cello because it promotes the naturalness of performance. This approach improves playing skills by making them more sophisticated. The first performances of musical compositions may be associated with slipping bow and out-of-tune sounds, but regular lessons level out the sounds. Learning should start from a one-octave scale and expand to a two-octave scale (Casas-Mas et al., 2019).

Traditional cello learning approaches (lessons with instructors, studying information in books) have been transformed, which makes it possible to use digital tools. Such digital tools may be used to identify the bow movements and correct inaccuracies during performance. Cameras track movements at specific points, which helps to correct play with prompts (Lu et al., 2020). Playing in an orchestra requires a musician's expertise, the ability to coordinate movements and expressive rhythm. When playing in an orchestra, a harmonious combination of all musical instruments is required. Quality cello playing requires daily practice that focuses on fingers, bow strokes and scales. Watching other experts' recitals helps correct mistakes and get their technique right (Ponchione-Bailey & Clarke, 2021).

Regarding VR in cello playing education, one study explored the issue of improving music learning in elementary education through mobile VR (Degli Innocenti et al., 2019). Students immersed themselves in musical performances of various genres (e.g., classical, country, jazz, swing) as they navigated through several music rooms. Evaluation of the didactic protocol revealed statistically significant improvements in

genre learning characteristics (i.e., typical instruments and their spatial placement on stage) compared to traditional lessons with printed materials and passive listening. These results indicate that the use of mobile VR technologies in conjunction with traditional teaching methodologies can enhance the music learning experience in elementary school. This approach is effective in terms of active listening, attention and engagement. Our study results align with previous findings, as VR-based learning showed significantly better outcomes compared to the traditional method. The experimental group demonstrated significantly higher scores across all measured parameters compared to the control group.

In another study, authors assessed the feasibility of conducting virtual music education programs with an automated assessment system for children with autism (Shahab et al., 2022). Over 20 weeks, intervention sessions were conducted for five children with high-functioning autism aged 6 to 8 years, which included a baseline session, pre-test, instructional sessions, post-test and control test. Each music education session involved teaching various notes and musical compositions according to the child's cooperation, accuracy and skill level. The sessions entailed using virtual reality robots and virtual musical instruments. The effectiveness of the proposed method was demonstrated through statistical analysis of child performance data during music education sessions. The data were obtained through both video coding and the proposed automated assessment system.

Another study compared the learning outcomes of a group of students using VR with the VR4EDU virtual reality programme to those of a control group attending traditional online music lessons (Sai, 2024). The sample consisted of 96 students from Shandong University of Management in China. Researchers identified statistically significant improvements in music learning through virtual reality in the few areas. For Exercise 1, improvements ranged from M:30 % to M:45 %; for Exercise 2, improvements ranged from M:32 % to M:54 %; and for Exercise 3, improvements ranged from M:57 % to M:83 %. The study highlighted the technical features of the virtual reality environment in music education. The features can assist developers and designers in creating effective educational programmes for students. The results of our study showed that the use of VR technologies in cello-playing education had a significant positive impact on the development of students' technical skills. VR technologies also had positive impact on the students' knowledge of music theory and the ability to interpret musical compositions. For example, the experimental group using VR technologies demonstrated a significant improvement in technical skills by 25 %, while the control group improved their results by only 5 %. Thus, the application of VR technologies in cello playing education has demonstrated its effectiveness, which is also supported by statistical indicators.

As can be seen from the discussion, the use of VR tools in music education extends far beyond Chinese context. The results obtained in this study are in line with studies outside China which suggest that the positive impact of VR is independent of the

country's context and that the results can be extrapolated to other countries and educational systems (Waddell & Williamon, 2019; Wang et al., 2021; Xiaolin, 2021).

The study's results demonstrate the high effectiveness of using VR in cello teaching. Substantial improvements in technical skills, knowledge of music theory and the ability to interpret musical works confirm the feasibility of implementing innovative technologies in music education. These data can be used to devise educational programs and integrate VR into the music learning process. The results underscore the importance of VR in music education and necessitate further research in this field.

Conclusions

The results of the study have demonstrated that the utilization of VR technologies in cello-playing education significantly enhances the development of technical skills, knowledge of music theory and proficiency in interpreting musical compositions. Students in the experimental group exhibited substantial improvements across all aspects. This indicated the effectiveness of interactive and immersive teaching methods facilitated by VR technologies. In contrast, the control group, instructed through conventional methods, exhibited considerably less progress.

The scientific value of this research lies in confirming the efficacy of VR technologies in music education. Furthermore, the study has provided new insights into the impact of interactive and immersive learning on the development of musical skills. The obtained results can serve as a foundation for further scholarly endeavors in this field and contribute to the development of novel teaching methodologies and technologies.

The practical significance of the study lies in the integration of state-of-the-art technologies into music education processes. The use of VR enables the creation of more engaging and effective learning environments, which fosters improved material assimilation and skills development among students. This may prove beneficial for music educational institutions that strive to enhance educational quality and student motivation.

The potential application domains of the research results encompass music schools, conservatories, private music studios and even distance learning platforms. The utilization of VR technologies can prove effective for educating both beginners and experienced musicians. Moreover, such technologies can be beneficial for inclusive education, which may facilitate the creation of adaptive learning environments for students with special needs. Prospects for further research include investigating the long-term effects of VR technology usage in music education. They also include exploring opportunities for VR's integration with other innovative technologies, such as artificial intelligence. It is also important to continue studying the economic feasibility of implementing such technologies in educational institutions to ensure their accessibility to a wide range of students. Thus, the results of this research open new horizons for enhancing music teaching methodologies and may contribute to further development of innovative approaches in music education.

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Qiong Wu

Harbin Conservatory of Music
Department of Vocal Opera
Harbin, Heilongjiang Province, China
2016400045@stu.hrbcu.edu.cn

Appendix A

The test designed to measure the initial and final assessment of cello playing skills.

Indicator	Task	Instruction	Assessment Criteria
Technical Skills	Scales and Arpeggios	Perform scales and arpeggios in major and minor keys (C, G, D, A, E, F, B). Accuracy, speed, and smoothness of execution are assessed.	Accuracy (correctness of notes): 10 points Speed (execution time): 5 points Smoothness (consistency and equality of sound): 5 points Maximum score: 20 points
Technical Exercises		Perform selected technical exercises, focusing on position changes, strokes, and techniques (e.g., legato, staccato, pizzicato).	Position change technique: 5 points Execution of various strokes: 5 points Instrument control: 10 points Maximum score: 20 points
Knowledge of Music Theory	Testing	Answer questions regarding music notation, intervals, chords, modes, musical forms, and structure.	Accuracy of answers: 20 points
Interpretation of Musical Piece	Score Analysis	Analyze the score of a short piece, identifying key musical elements (melody, harmony, rhythm, structure).	Understanding of melodic lines: 10 points Understanding of harmonic structure: 10 points Understanding of rhythmic features: 10 points Analysis of musical form: 10 points Maximum score: 40 points

Korištenje tehnologija virtualne stvarnosti u nastavi violončela u Kini

Sažetak

Posljednjih godina, pristupi nastavi violončela u Kini doživjeli su značajne promjene zbog primjene inovativnih tehnoloških metoda. Ove nove metodologije ne samo da poboljšavaju tehničke vještine učenika, već i doprinose očuvanju i razvoju nacionalne orkestralne tradicije. Cilj je ove studije analizirati učinkovitost korištenja tehnologija virtualne stvarnosti u nastavi violončela u Kini. U proučavanje pristupa izvedbi violončela uključeno je 215 učenika koji su učili svirati glazbeni instrument. Ova studija koristila je eksperimentalni pristup, koristeći metodu testiranja. Učenici su podijeljeni u dvije skupine: eksperimentalnu skupinu, koja je poučavana korištenjem VR tehnologija i kontrolnu skupinu, koja je poučavana na tradicionalan način. Rezultati su pokazali da su se prosječne tehničke vještine eksperimentalne skupine značajno poboljšale za 25 %, dok se kontrolna skupina poboljšala samo za 5 %. U teorijskom testiranju, eksperimentalna skupina pokazala je povećanje znanja od 34 %, što značajno nadmašuje poboljšanje kontrolne skupine od 10 %. Eksperimentalna skupina također je pokazala poboljšanje od 47 % u interpretaciji glazbenih djela, u usporedbi s poboljšanjem od 16 % u kontrolnoj skupini. Primjena VR tehnologija u nastavi violončela pokazala se učinkovitom, što potvrđuju statistički pokazatelji. Nalazi studije pokazuju da VR tehnologije pomažu učenicima da bolje razumiju i osjećaju glazbu, omogućujući točnije interpretacije glazbenih djela. Praktična vrijednost ovoga istraživanja leži u integraciji najsuvremenijih tehnologija u proces glazbenoga obrazovanja jer korištenje VR-a stvara zanimljivije i učinkovitije okruženje za učenje, pomažući učenicima da bolje usvoje gradivo i poboljšaju svoje vještine.

Ključne riječi: inovativna nastava; melodijska linija; računalne tehnologije; tehnika gitare; tehnika kružnoga gudanja; play point; VR

Uvod

Izražajnost glazbenih skladbi stvara se glasom i pratnjom glazbenih instrumenata (Kielian-Gilbert, 2020). Korištenje tehnika sviranja gudačkih instrumenata s istovremenim tapkanjem proizvodi zvukove i raznolikost zvukova (Zhao i sur., 2021). Violončelo se koristi za pratnju falseta (Kruger i Jacobs, 2020). Violončelo se koristi u kineskom

orkestru, doprinoseći improvizaciji zvukova i slika prirode, zvuku narodnih instrumenata i izražavanju (Xiaolin, 2021). Kineski orkestar značajan je element glazbene kulture jer prenosi nacionalne elemente prikazane na tradicionalnim glazbenim instrumentima (Leung i Cheung, 2020). Kineski nacionalni orkestri koriste razne glazbene instrumente za stvaranje novih melodija. Ove melodije bogate su obnovljenim ritmovima i tembrima koji prenose nacionalni identitet temeljen na narodnoj glazbi (Corbalán i sur., 2019). U kineskoj orkestralnoj kreativnosti razlikuju se sljedeće faze (Fung, 2018):

- 1900. – 1949.: razdoblje interakcije između kineske i zapadne kulture
- 1949. – 1976.: razdoblje Kulturne revolucije
- 1976. do danas: širenje kineske glazbe u svijetu.

Razdoblja razvoja nacionalnih orkestara utjecala su na korištenje europskih tehnika za izvođenje kineske glazbe. To se odnosi na nove pristupe izvedbi. Sviranje i učenje sviranja violončela važan je dio akademske kineske glazbe koja je uobičajena i u kineskoj orkestralnoj glazbi, kao i na lokalnim i međunarodnim glazbenim natjecanjima (Zhang i Fyr, 2021). Wang Jian, koji je slijedio J. Bacha (Lu i sur., 2020), jedan je od najpoznatijih kineskih violončelista. Njegova glazba je jedinstvena i preklapa se s klasičnom glazbom. Wang Jianova glazba putovala je daleko izvan Kine i bila je predstavljena u Berlinskoj filharmoniji, Čikaškom simfonijskom orkestru i Londonskom simfonijskom orkestru (Lu i sur., 2020).

Kineska tradicija poučavanja violončela potječe iz metoda poučavanja europske glazbene kulture. Istraživači primjećuju da kineske povijesne karakteristike imaju mali utjecaj u ovom kontekstu (Gudozhnikova, 2019; Leung i Cheung, 2020). Tradicionalno glazbeno obrazovanje uglavnom se manifestiralo samo u pristupima poučavanju sličnim onima koji se koriste za poučavanje gudačkih instrumenata (Kielian-Gilbert, 2020). Kineske glazbenike karakterizira upornost koju predvodi učitelj, predanost i velika konkurencija s visokokvalitetnim stranim izvođačima (Wang i sur., 2021; Wei i sur., 2022).

Jednostavne vježbe u početku se koriste za razvoj refleksa za složenije pokrete (Johnson, 2021) kako bi se izgradile vještine sviranja violončela. Među njima je i tehnika pizzicato u kojoj gudalo svira na otvorenim žicama i koja pomaže u učenju pravilnoga položaja gudala. Za koordinaciju pokreta koristi se tehnika swinga, s prvim i četvrtim prstom u igri, a glavna os violončela prolazi između palčeva (Lin i sur., 2021). Kako bi se olakšao proces učenja, treba koristiti dosljedan pristup. Nastoji se primijeniti poboljšane tehnike koje će identificirati nove pristupe sviranju violončela (Yantian i sur., 2021.).

Violončelo prenosi jedinstvenu melodiju koju stvara tembar zvuka prilikom sviranja. Imajući to na umu, prilikom sviranja violončela treba staviti veći naglasak na proučavanje tembra. Doprinosi netradicionalnoj interpretaciji instrumenta, oblikovanju tonaliteta i forme. To uključuje istraživanje širine zvuka violončela, što se postiže proučavanjem gudačkih instrumenata, kao i improvizacijskim i virtuoznim izvođenjem (Beavers, 2019.). Dizajn i materijal glazbenih instrumenata određuju njihova akustična svojstva.

Struktura drvenih ćelija pomaže u stvaranju niskih zvukova, dok prirodno drvo daje življe zvukove.

Prilikom sviranja violončela treba primijeniti akordično sviranje figurativnoga basa temeljeno na tradicionalnoj baroknoj izvedbi. Za postizanje akordičnoga basa treba postići skladnu kombinaciju akorda jednih s drugima. To zahtijeva izgradnju bas-linije i dodjeljivanje brojeva notama, što olakšava sviranje violončela. Figurativni bas postiže se improvizacijom (Whittaker, 2021). Sviranje melodija na violončelu zahtijeva izvedbu raznih sonata, kategoriziranih po žanru i izričaju. To je zato što svaki od skladatelja prenosi proširena umjetnička rješenja, učenje sviranja koje pomaže u poboljšanju tehnike violončelista. Ovaj pristup doprinosi razumijevanju tehnika prožimanja tembra, ekvivalencije instrumentalnih dionica i dijaloškoga tipa međuigre između glazbenih elemenata. Analiza repertoara za violončelo pokazala je korištenje tema, intonacijskih formula narodne glazbe i originalnih tembrova (Gudozhnikova, 2019). Sviranje violončela treba biti izgrađeno na logičkom razmišljanju, omogućujući prepoznavanje elemenata koji nedostaju za sviranje melodije. Primjena principa prisilnih vibracija temeljenih na spiccato pomaže u učenju osnova glazbene kompozicije i tehnike sviranja gudalom s ukrštenim žicama. U orkestralnim skladbama, violončelo omogućuje sviranje ekspresivnoga sola. Violončelo se može koristiti na koncertima, kao pojedinačne skladbe, kao solo i prateći instrument.

Za samostalno sviranje violončela napisane su posebne skladbe. Koriste transkripcije i adaptacije djela napisanih za druge instrumente, poput violine. Tijekom sviranja violončela treba proučavati repertoar, identificirajući njegove jake i slabe elemente. Prilikom sviranja violončela treba odabrati skladbe koje otkrivaju živahnu melodiju te gladak i virtuozan tembar (Bekenova i sur., 2020). Međutim, poučavanje violončela u Kini doživjelo je značajne promjene tijekom posljednjih desetljeća zbog primjene inovativnih tehnoloških metoda. Ove metode ne samo da transformiraju obrazovne pristupe, već utječu i na nacionalnu orkestralnu tradiciju. Integracija vrhunskih tehnologija, poput virtualne stvarnosti (VR), umjetne inteligencije (AI) i *online* platformi, stvara nove mogućnosti za glazbeno obrazovanje i osposobljavanje visokokvalificiranih glazbenika (Hamilton, 2019a; Hosek, 2023; Rutkowski i sur., 2021; Wei i sur., 2022).

Posljednjih godina značajno se povećao interes za inovativne metode poučavanja glazbenih instrumenata, posebno violončela. Istraživanja pokazuju da integracija novih tehnologija u glazbeno obrazovanje poboljšava ishode učenja i potiče motivaciju učenika (Vasil, 2019; Waddell i Williamon, 2019). Razne zemlje široko koriste VR i AI tehnologije za stvaranje interaktivnih okruženja za učenje koja omogućuju učenicima da poboljšaju svoje vještine na zanimljiviji i učinkovitiji način (Dai, 2021; Hamilton, 2019a; Rutkowski i sur., 2021; Wei i sur., 2022). Vodeće zemlje aktivno implementiraju *online* platforme za glazbeno obrazovanje. Ove platforme omogućuju učenicima pristup nastavnim materijalima bilo kada i s bilo kojeg mjesta (Park, 2019). Često uključuju videolekcije, interaktivne vježbe i mogućnosti za povratne informacije instruktora (Hamilton, 2019b).

Međutim, ne podržavaju sve studije jednoglasno učinkovitost inovativnih tehnologija u glazbenom obrazovanju. Na primjer, neki istraživači tvrde da korištenje VR-a može odvratiti učenike od tradicionalnih metoda poučavanja i ne razvija adekvatno glazbene vještine (Kamińska i sur., 2019). Također utječe na njihovo emocionalno stanje (Gómez-Rios i sur., 2023.). Drugi ističu probleme s dostupnošću i cijenom takvih tehnologija, što može ograničiti njihovu primjenu u obrazovnim ustanovama s ograničenim resursima (Marougkas i sur., 2023.).

Ipak, inovacije također predstavljaju nekoliko izazova i problema. Tradicionalne metode poučavanja, temeljene na dugogodišnjem iskustvu i kulturnim specifičnostima, zahtijevaju prilagodbu novim tehnologijama. To postavlja pitanje: kako se mogu očuvati nacionalne tradicije sviranja violončela, a istovremeno iskoristiti prednosti inovativnih tehnologija? Ovo pitanje posebno je relevantno u kontekstu globalizacije pri čemu kulturne granice postaju sve transparentnije, a razmjena informacija trenutačna. Relevantnost ove teme potaknuta je brzim razvojem tehnologija i njihovim utjecajem na sve aspekte života, uključujući umjetnost i obrazovanje.

Motivacija za pisanje ovoga članka proizlazi iz potrebe za istraživanjem učinkovitosti i utjecaja novih tehnologija na obrazovanje violončelista u Kini, posebno uz primjenu tehnologija virtualne stvarnosti. Pažnja se posvećuje tome kako se te inovacije mogu integrirati u obrazovni proces uz očuvanje jedinstvenih karakteristika kineske glazbene tradicije. Članak ima za cilj naglasiti važnost primjene modernih tehnologija u glazbenom obrazovanju. Otkriva se kako virtualna stvarnost omogućuje stvaranje interaktivnih okružja za učenje u kojima učenici mogu vježbati u realnim uvjetima i primiti povratne informacije u stvarnom vremenu (Hosek, 2023; Park, 2019).

Novost ove studije jest u njezinom fokusu na nastavu violončela u kontekstu kineske glazbene tradicije. U usporedbi s prethodnim istraživanjima, ovaj rad pruža detaljnu analizu kako se inovativne tehnologije mogu integrirati u obrazovni proces, uzimajući u obzir kulturne karakteristike i specifičnosti nacionalne orkestralne tradicije. Dobiveni rezultati mogu se koristiti za razvoj novih pristupa poučavanju koji uključuju i moderne tehnološke mogućnosti i tradicionalne glazbene prakse. To će poboljšati kvalitetu glazbenoga obrazovanja i očuvati nacionalnu glazbenu baštinu u kontekstu globalizacije.

Hipoteza studije je da će korištenje tehnologija virtualne stvarnosti (VR) u nastavi violončela pozitivno utjecati na tehničke vještine, znanje glazbene teorije i glazbenu interpretaciju.

Cilj studije bio je analizirati učinkovitost korištenja VR tehnologija u nastavi violončela u Kini.

Ciljevi istraživanja:

1. Analizirati potencijal virtualne stvarnosti u nastavi violončela ispitivanjem njezinih prednosti i ograničenja.
2. Provesti eksperiment korištenjem virtualne stvarnosti tijekom nastave violončela i prikupiti podatke o njezinom utjecaju na ishode učenja učenika.

3. Procijeniti učinkovitost VR tehnologija, donijeti zaključke o njihovom utjecaju na kvalitetu nastave i njihovom doprinosu očuvanju nacionalnih orkestralnih tradicija.

Metodologija

Dizajn istraživanja

U ovoj studiji korišten je eksperimentalni pristup koji omogućuje detaljnu procjenu utjecaja tehnologija virtualne stvarnosti (VR) na proces poučavanja violončela u kineskom kontekstu. Eksperimentalni pristup odabran je zbog svoje sposobnosti da pruži jasnu usporedbu između različitih skupina sudionika. Studija je provedena u obliku kvaziekperimenta, a sudionici su podijeljeni u dvije skupine. U istraživanju je korištena metoda testiranja.

Uzorak

Kako bi se proučili pristupi sviranju violončela, sudjelovalo je 215 studenata koji su učili svirati ovaj glazbeni instrument. Ispitanici su bili s Glazbenog konzervatorija u Xi'anu, Sveučilišta Lishui. Za sudjelovanje u studiji, ispitanici su morali studirati violončelo u 3., 4. i 5. godini. Uzorak studenata sastojao se od studenata završnih godina jer su već upoznati s različitim načinima sviranja violončela i razumiju teorijske aspekte, što potvrđuje i istraživački program koji je osigurao dekanat sveučilišta. Ispitanici su odabrani među predstavljenim institucijama jer su se prvi prijavili nakon objave među sveučilištima u Kini. U skladu s etičkim standardima, ispitanici su dali privolu za sudjelovanje u studiji. Studenti su nasumično raspoređeni u grupe pomoću programa za randomizaciju. Tablica 1 pruža sveobuhvatniji opis uzorka.

Tablica 1

Postupak

Na početku studije, svi sudionici su prošli početnu procjenu koja je obuhvaćala testove tehničkih vještina, glazbene teorije i glazbene interpretacije (vidi Dodatak 1). Tijekom tri mjeseca, studenti iz obiju skupina prošli su pouku koristeći odgovarajuće metodologije. U eksperimentalnoj skupini, VR aplikacije korištene su u svakoj sesiji kako bi se pružila interaktivna i impresivna iskustva učenja. Kontrolna skupina pridržavala se tradicionalnih metoda poučavanja. Nakon završetka tromjesečne nastave, svi sudionici su prošli naknadnu procjenu, sličnu početnoj procjeni, kako bi se usporedili rezultati i utvrdile promjene u vještinama i znanju.

Eksperimentalna skupina sastojala se od 108 pojedinaca. Studenti u ovoj skupini dobili su upute za korištenje VR tehnologija. Korištene su specijalizirane VR aplikacije koje omogućuju stvaranje interaktivnih obrazovnih okružja. Korišten je program *Cello Simulator: Play & Learn* (Slika 1). Tijekom obuke, sudionici su koristili dostupan i jeftin, ali funkcionalno prikladan *Generic Smartphone VR Viewer* kao preglednik virtualne stvarnosti. Studenti su mogli vježbati u virtualnom okružju, primajući povratne informacije u stvarnom vremenu od softvera. Lekcije su uključivale vježbe o tehnicima sviranja, glazbenoj teoriji i glazbenoj interpretaciji.

Slika 1

Kontrolna skupina sastojala se od 107 pojedinaca. Učenici u ovoj skupini primali su nastavu tradicionalnim metodama bez korištenja VR tehnologija. Nastava je uključivala individualne i grupne sesije s nastavnikom, korištenje tiskanih nota, audiosnimaka i videolekcija. Nastava je također uključivala vježbe iz tehnike sviranja, glazbene teorije i glazbene interpretacije.

Prikupljanje podataka

Kako bi se procijenila učinkovitost novoga programa poučavanja violončela korištenjem VR tehnologija, odabrano je nekoliko metričkih instrumenata za sveobuhvatnu procjenu akademskoga uspjeha studenata. Ključni pokazatelji korišteni za mjerenje ishoda uključivali su tehničke vještine, glazbenu teoriju i glazbenu interpretaciju.

Test tehničkih vještina sviranja violončela uključivao je vježbe zagrijavanja prstiju (ljestvice i arpeggi), izvođenje etuda koje pokrivaju različite tehničke aspekte (legato, staccato, dvostruki rezon) i izvođenje glazbenih ulomaka iz različitih glazbenih razdoblja (barok, klasika, romantika, suvremena glazba). Ovaj test razvijen je na temelju postojećih programa glazbenih akademija i validiran je u konzultaciji s konzultantskim instruktorima. Pokazao je visoku valjanost, mjerenu koeficijentom konkordancije, koji je dao vrijednosti ne niže od 0,64. Ovi rezultati ukazuju na dobru razinu metodološke valjanosti jer pokriva sve glavne tehničke aspekte sviranja violončela. Pouzdanost testa potvrđena je Cronbachovim alfa koeficijentom koji je iznosio 0,96.

Test znanja glazbene teorije obuhvaćao je identificiranje nota na glazbenoj partituri, prepoznavanje intervala i akorda po sluhu te analizu glazbenih skladbi (harmonija, oblik, melodija). Ovaj test temelji se na standardiziranom nastavnom planu i programu glazbene škole. Njegova valjanost potvrđena je procjenom koeficijenta konkordancije koji je dao vrijednost od 0,67. Pouzdanost testa osigurana je Cronbachovim alfa koeficijentom koji iznosi 0,98.

Test glazbene interpretacije uključivao je izvođenje dviju odabranih glazbenih skladbi iz različitih razdoblja. Procijenio je interpretaciju u smislu ekspresivnosti, dinamike, artikulacije i stilske prikladnosti. Glazbena interpretacija služi kao značajan pokazatelj glazbenoga razvoja učenika, odražavajući njihovu sposobnost umjetničkoga samoizražavanja. Test je razvijen u suradnji s vodećim konzultantskim instruktorima i usklađen s međunarodnim natjecateljskim programima. Njegova valjanost potkrijepljena je koeficijentom konkordancije koji je dao vrijednosti ne niže od 0,65. Osim toga, pouzdanost testa potvrđena je Cronbachovim alfa koeficijentom koji iznosi 0,94.

Analiza videozapisa lekcija obuhvatila je snimke sesija korištenjem VR i tradicionalnih metoda, procjenu interakcije učenika i nastavnika te korištenje tehnologije te praćenje napretka učenika tijekom nastave. Videosnimke omogućuju detaljan pregled nastavnoga procesa i napretka učenika, olakšavajući objektivnu procjenu učinkovitosti VR tehnologija. Korištenje specifičnih instrumenata za testiranje i metoda evaluacije omogućuje sveobuhvatnu procjenu utjecaja VR tehnologija na nastavu violončela.

Statistička obrada

Prije provođenja parametarskih testova, normalnost distribucije provjerena je Kolmogorov-Smirnovljevim testom. Za svaki pokazatelj, p-vrijednost premašila je razinu značajnosti od 0,05 (tehničke vještine – 0,73; glazbena teorija – 0,69; glazbena interpretacija – 0,81). Ovi rezultati potvrdili su nultu hipotezu da su podatci normalno distribuirani. Stoga je bilo optimalno koristiti parametarske testove.

F-test je korišten za procjenu jednakosti varijanci. Utvrđeno je da su sve tri F-vrijednosti manje od kritične F vrijednosti na razini značajnosti od 0,05 (tehničke vještine – 0,87; glazbena teorija – 0,94; glazbena interpretacija – 0,91). Posljedično, hipoteza da su varijance jednake ne može se odbaciti jer ne postoji značajna razlika u varijancama.

Kako bi se uzeli u obzir outlieri, z-vrijednost je izračunata pomoću sljedeće formule:

$$(z\text{-score}) = \frac{\chi - \mu}{\sigma}$$

Izračuni su pokazali da nijedna vrijednost nije imala apsolutnu vrijednost veću od 3 te stoga nisu otkrivene abnormalne vrijednosti. Analiza podataka u ovom istraživanju provedena je korištenjem SPSS-a (Statistical Package for the Social Sciences) verzije 26. Ovaj softver je odabran zbog svojih opsežnih mogućnosti u provođenju statističkih testova i analize podataka u društvenim i bihevioralnim znanostima. Osim toga, SPSS olakšava jednostavnu obradu velikih skupova podataka i pruža korisničko sučelje za vizualizaciju rezultata. Studentov t-test (t-test) korišten je za usporedbu srednjih vrijednosti pokazatelja prije i nakon implementacije tradicionalnih i inovativnih metoda poučavanja violončela. Ovaj test omogućuje utvrđivanje postoje li značajne razlike između dva uzorka, što je ključno za procjenu učinkovitosti inovativne metodologije. Provedene su dvije vrste t-testova: Parni t-test korišten je za usporedbu srednjih vrijednosti pokazatelja tehničkih vještina, glazbene teorije i interpretacije prije i nakon implementacije VR tehnologija unutar svake skupine (eksperimentalne i kontrolne). Neovisni t-test: za usporedbu rezultata između eksperimentalne i kontrolne skupine nakon završetka poduke. Analiza varijance (ANOVA) korištena je za utvrđivanje prisutnosti statistički značajnih razlika među više skupina. U našoj studiji, ANOVA je pomogla u procjeni utjecaja različitih čimbenika, poput metodologije poučavanja (tradicionalne ili VR-bazirane), na ukupne pokazatelje uspješnosti učenika. To je omogućilo uzimanje u obzir varijabilnosti podataka i utvrđivanje jesu li razlike između skupina statistički značajne.

Multivarijantna analiza varijance (MANOVA) korištena je za simultanu analizu nekoliko zavisnih varijabli. U našem slučaju, te varijable uključivale su tehničke vještine, znanje glazbene teorije i interpretaciju glazbenih skladbi. MANOVA omogućuje određivanje ukupnoga učinka metodologije poučavanja na više zavisnih varijabli, pružajući sveobuhvatniji pristup analizi podataka.

Etička pitanja

Etička pitanja istražena su korištenjem kriterija ESOMAR-a (2016.) temeljenih na povjerljivosti i pouzdanosti pruženih podataka, kao i pravima i odgovornostima ispitanika.

Ograničenja istraživanja

Iako korišteni instrumenti osiguravaju visokokvalitetne podatke, postoje određena ograničenja, uključujući subjektivnost procjena glazbene interpretacije, što može utjecati na rezultate. Treba napomenuti i moguće tehničke poteškoće i izazove u prilagodbi studenata novim tehnologijama. Vrijedi spomenuti da i ova studija ima svoja ograničenja, uključujući potrebu za skupom opremom i specijaliziranim znanjem za njezino korištenje. Iako je eksperiment proveden u skladu sa standardima povjerljivosti i etičkim razmatranjima, ova studija nije uspjela uzeti u obzir utjecaj očekivanja na ishode. Nalazi su prikazani što je moguće objektivnije. Međutim, ovaj fenomen možda zaslužuje daljnje istraživanje u budućim istraživanjima. Također nismo uzeli u obzir nikakve potencijalne promjene u ponašanju sudionika na koje je mogla utjecati želja da se pokažu u najboljem mogućem svjetlu kako bi se poboljšali ishodi eksperimenta. Umjesto toga, naša analiza temeljila se na pretpostavci o kreposnom ponašanju sudionika.

Rezultati

Prije početka istraživanja, eksperimentalna i kontrolna skupina uspoređene su prema tri pokazatelja. Prema p-vrijednostima (tehničke vještine – 0,068; glazbena teorija – 0,071; glazbena interpretacija – 0,066), bilo je nemoguće odbaciti nultu hipotezu o razlikama između dviju skupine na temelju pretestova. Stoga nisu pronađene značajne razlike.

U ovom odjeljku prikazani su rezultati istraživanja o učinkovitosti korištenja VR tehnologija u obrazovanju sviranja violončela. Rezultati su prikazani u obliku tablica i njihovih opisa, što omogućuje bolje razumijevanje utjecaja inovativne metodologije na proces učenja. Slika 2 prikazuje srednje vrijednosti tehničkih vještina učenika prije i nakon treninga. Eksperimentalna skupina, koja je koristila VR tehnologije, pokazala je značajno poboljšanje od 25 %, dok je kontrolna skupina poboljšala svoje rezultate za samo 5 %. Ovi nalazi ukazuju na to da VR tehnologije učinkovitije doprinose razvoju tehničkih vještina u sviranju violončela zbog interaktivnosti i mogućnosti vizualnoga praćenja u stvarnom vremenu i ispravljanja pogrešaka.

Slika 2

Slika 3 prikazuje rezultate testova o znanju glazbene teorije. Eksperimentalna skupina pokazala je povećanje znanja od 34 %, značajno nadmašujući učinak kontrolne skupine koja je poboljšala rezultate za samo 10 %. To se može povezati s VR tehnologijama koje omogućuju dublje uranjanje u gradivo i interaktivno učenje, što doprinosi boljoj apsorpciji teorijskoga znanja.

Slika 3

Slika 4 prikazuje promjene u interpretaciji glazbenih skladbi. Učenici u eksperimentalnoj skupini pokazali su poboljšanje od 47c %, dok je kontrolna skupina poboljšala svoje

rezultate za samo 16 %. To ukazuje na to da VR tehnologije pomažu učenicima u boljem razumijevanju i osjećanju glazbe, omogućujući im da točnije interpretiraju glazbene skladbe. Interaktivne lekcije korištenjem VR-a mogu uključivati simulacije različitih emocionalnih stanja i stilova izvedbe, doprinoseći dubljem razumijevanju glazbenih skladbi.

Slika 4

Tablica 2 prikazuje rezultate statističkih testova koji procjenjuju utjecaj VR tehnologija na nastavu sviranja violončela. Vrijednosti parnoga t-testa ($< 0,001$) i neovisnoga t-testa ($< 0,001$) potvrđuju statistički značajnu razliku između skupina.

Tablica 2

Rezultati ANOVA i MANOVA također su potvrdili značajan pozitivan utjecaj VR tehnologija na ukupni uspjeh učenika. P-vrijednosti za sve pokazatelje bile su manje od 0,001, što ukazuje na visoku razinu statističke značajnosti.

Diskusija

Nalazi studije pokazuju da korištenje VR tehnologije u obuci za sviranje violončela značajno poboljšava tehničke vještine. Osim toga, ovaj pristup pomaže studentima da učinkovitije steknu teorijsko znanje i razviju interpretativne sposobnosti. Ove se prednosti mogu pripisati interaktivnosti i angažmanu koje pružaju inovativne tehnologije. VR može stvoriti realističnija i emocionalno impresivnija okružja za učenje, čime se olakšava bolje razumijevanje glazbenih skladbi.

Pristupi sviranju violončela identificirani su na temelju dostupne literature. Sviranje violončela trebalo bi uključivati tehniku čitanja s lista jer pruža trening sluha, razvija brzinu razmišljanja i vještine improvizacije. Vještine čitanja s lista tijekom sviranja violončela mogu se utvrditi identificiranjem pogrešaka u visini tona i tečnosti korištenih u kratkim glazbenim komadima. Poznavanje položaja nota u slučaju čitanja s lista može imati negativnu korelaciju. Ipak, povećana glazbena složenost dovodi do više pogrešaka u izvedbi i više pauza. Takvi se nedostaci mogu ispraviti samo redovitim vježbama koje povećavaju tehničku težinu (Wolfs i sur., 2020). Boja tona jedan je od glavnih parametara emocionalnosti percipiranja melodija - ljutite, sretne, ljubazne i tužne. Boja glazbenoga instrumenta povezana je s različitim varijacijama i dinamičkim rasponom, stoga sviranje violončela prvo zahtijeva učenje parametara instrumenta i zvučnih karakteristika. Da bi se to postiglo, gudalo treba biti okomito na žicu. Lagani dodir žice gudalom daje zvuku posebnu boju. Pravilan omjer tempa gudala i pritiska treba odrediti pri dodirivanju žice (Wang i sur., 2021). Ovaj dio pisanja temelji se na pristupima poučavanju violončela koji se oslanjaju na uobičajene parametre, eliminirajući tehničke komponente specifičnih elemenata, što uzrokuje prazninu u predstavljenom istraživanju. Predstavljeni rad naglašava suvremene tehnike violončela koje imaju vrijednost za nacionalne orkestre jer doprinose živopisnosti i izražajnosti zvuka violončela.

Samoregulacija improviziranih zvukova jedan je od glavnih pristupa koji se koriste za sviranje violončela jer potiče prirodnost izvedbe. Ovaj pristup poboljšava vještine sviranja čineći ih sofisticiranijima. Prve izvedbe glazbenih skladbi mogu biti povezane s klizanjem gudala i neusklađenim zvukovima, ali redovito poučavanje izravna zvukove. Učenje bi trebalo započeti s ljestvicom od jedne oktave i proširiti se na ljestvicu od dvije oktave (Casas-Mas i sur., 2019).

Tradicionalni pristupi učenju violončela (sati s instruktorima, proučavanje informacija u knjigama) transformirani su, što omogućuje korištenje digitalnih alata. Takvi digitalni alati mogu se koristiti za identifikaciju pokreta gudalom i ispravljanje netočnosti tijekom izvedbe. Kamere prate pokrete u određenim točkama, pomažući u ispravljanju sviranja pomoću uputa (Lu i sur., 2020). Sviranje u orkestru zahtijeva stručnost glazbenika, sposobnost koordinacije pokreta i ekspresivni ritam. Prilikom sviranja u orkestru potrebna je skladna kombinacija svih glazbenih instrumenata. Kvalitetno sviranje violončela zahtijeva svakodnevnu vježbu, fokusiranje na prste, udarce gudalom i ljestvice. Gledanje recitala drugih stručnjaka pomoći će u ispravljanju pogrešaka i usavršavanju njihove tehnike (Ponchione-Bailey i Clarke, 2021).

Što se tiče virtualne stvarnosti (VR) u obrazovanju sviranja violončela, jedna studija istražuje pitanje poboljšanja učenja glazbe u osnovnoškolskom obrazovanju putem mobilne virtualne stvarnosti (Degli Innocenti i sur., 2019). Učenici su uronili u glazbene izvedbe različitih žanrova (npr. klasika, country, jazz, swing). Kretali su se kroz nekoliko glazbenih soba. Evaluacija didaktičkoga protokola otkriva statistički značajna poboljšanja u karakteristikama učenja žanrova (tj. tipični instrumenti i njihov prostorni smještaj na pozornici) u usporedbi s tradicionalnim satima s tiskanim materijalima i pasivnim slušanjem. Ovi rezultati ukazuju na to da korištenje mobilnih VR tehnologija u kombinaciji s tradicionalnim metodologijama poučavanja može poboljšati iskustvo učenja glazbe u osnovnoj školi. Ovaj pristup je učinkovit u smislu aktivnoga slušanja, pažnje i angažmana. Rezultati naše studije podudaraju se s prethodnim nalazima jer je učenje temeljeno na VR-u pokazalo značajno bolje rezultate u usporedbi s tradicionalnom metodom. Eksperimentalna skupina pokazala je značajno više rezultate u svim izmjerenim parametrima u usporedbi s kontrolnom skupinom.

U drugoj studiji, autori su procijenili izvedivost provođenja virtualnih programa glazbenoga obrazovanja s automatiziranim sustavom procjene za djecu s autizmom (Shahab i sur., 2022). Tijekom 20 tjedana provedene su intervencijske sesije za petero djece s visokofunkcionalnim autizmom u dobi od 6 do 8 godina koje su uključivale početnu sesiju, pretest, instrukcijske sesije, posttest i kontrolni test. Svaka sesija glazbenoga obrazovanja uključivala je poučavanje različitih nota i glazbenih skladbi prema djetetovoj suradnji, točnosti i razini vještina. Sesije su koristile robote virtualne stvarnosti i virtualne glazbene instrumente. Učinkovitost predložene metode dokazana je statističkom analizom podataka o dječjoj izvedbi tijekom sati glazbene edukacije. Podatci su dobiveni i videokodiranjem i predloženim automatiziranim sustavom procjene.

Druga studija uspoređuje ishode učenja skupine studenata koji koriste VR s programom virtualne stvarnosti VR4EDU s onima kontrolne skupine koja pohađa tradicionalne *online* sate glazbe (Sai, 2024.). Uzorak se sastojao od 96 studenata sa Sveučilišta za menadžment Shandong u Kini. Istraživači su utvrdili statistički značajna poboljšanja u učenju glazbe putem virtualne stvarnosti u nekoliko područja. Za vježbu 1, poboljšanja su se kretala od M:30 % do M:45 %; za vježbu 2, poboljšanja su se kretala od M:32 % do M:54 %; a za vježbu 3 poboljšanja su se kretala od M:57 % do M:83 %. Studija ističe tehničke značajke okruženja virtualne stvarnosti u glazbenom obrazovanju. Značajke mogu pomoći programerima i dizajnerima u stvaranju učinkovitih obrazovnih programa za studente. Rezultati naše studije pokazali su da korištenje VR tehnologija u eksperimentalnoj skupini studenata u obrazovanju violončela ima značajan pozitivan utjecaj na razvoj tehničkih vještina. VR tehnologije imaju pozitivan utjecaj i na znanje glazbene teorije i sposobnost interpretacije glazbenih skladbi u usporedbi s kontrolnom skupinom. Na primjer, eksperimentalna skupina koja se koristila VR tehnologijom pokazala je značajno poboljšanje tehničkih vještina za 25 %, dok je kontrolna skupina poboljšala svoje rezultate za samo 5 %. Dakle, primjena VR tehnologija u obrazovanju sviranja violončela pokazala je svoju učinkovitost, što potvrđuju i statistički pokazatelji.

Kao što se može vidjeti iz diskusije, korištenje VR alata za glazbeno obrazovanje proteže se daleko izvan kineskoga glazbenog obrazovanja. Rezultati dobiveni u ovoj studiji dobro se slažu sa studijama izvan Kine, što sugerira da je pozitivan utjecaj VR-a neovisan o kontekstu zemlje i rezultati se mogu ekstrapolirati na druge zemlje i obrazovne sustave (Waddell i Williamon, 2019; Wang i sur., 2021; Xiaolin, 2021).

Rezultati studije pokazuju visoku učinkovitost korištenja VR-a u nastavi violončela. Značajna poboljšanja u tehničkim vještinama, poznavanju glazbene teorije i sposobnosti interpretacije glazbenih djela potvrđuju izvedivost primjene inovativnih tehnologija u glazbenom obrazovanju. Ovi podaci mogu se koristiti za osmišljavanje obrazovnih programa i integraciju VR-a u proces učenja glazbe. Nalazi naglašavaju važnost virtualne stvarnosti u glazbenom obrazovanju i zahtijevaju daljnja istraživanja u ovom području.

Zaključak

Rezultati studije pokazali su da korištenje VR tehnologija u obrazovanju sviranja violončela značajno poboljšava razvoj tehničkih vještina, znanja glazbene teorije i vještinu interpretacije glazbenih skladbi. Studenti u eksperimentalnoj skupini pokazali su značajna poboljšanja u svim aspektima. To je ukazivalo na učinkovitost interaktivnih i imerzivnih metoda poučavanja koje omogućuju VR tehnologije. Nasuprot tome, kontrolna skupina koja je poučavana konvencionalnim metodama, pokazala je znatno manji napredak.

Znanstvena vrijednost ovoga istraživanja leži u potvrđivanju učinkovitosti VR tehnologija u glazbenom obrazovanju. Nadalje, studija je pružila nove uvide u utjecaj interaktivnoga i imerzivnoga učenja na razvoj glazbenih vještina. Dobiveni rezultati mogu poslužiti kao temelj za daljnja znanstvena istraživanja u ovom području i doprinijeti razvoju novih metodologija i tehnologija poučavanja.

Praktična vrijednost studije leži u integraciji najsuvremenijih tehnologija u procese glazbenoga obrazovanja. Korištenje VR-a omogućuje stvaranje privlačnijih i učinkovitijih okružja za učenje, potičući poboljšanu asimilaciju gradiva i razvoj vještina među studentima. To može biti korisno za glazbene obrazovne ustanove koje nastoje poboljšati kvalitetu obrazovanja i motivaciju studenata.

Potencijalna područja primjene istraživačkih nalaza obuhvaćaju glazbene škole, konzervatorije, privatne glazbene studije, pa čak i platforme za učenje na daljinu. Korištenje VR tehnologija može se pokazati učinkovitim u obrazovanju i početnika i iskusnih glazbenika. Štoviše, takve tehnologije mogu biti korisne za inkluzivno obrazovanje, olakšavajući stvaranje adaptivnih okružja za učenike s posebnim potrebama. Izgledi za daljnja istraživanja uključuju istraživanje dugoročnih učinaka korištenja VR tehnologije u glazbenom obrazovanju. Oni također uključuju istraživanje mogućnosti za njezinu integraciju s drugim inovativnim tehnologijama, poput umjetne inteligencije. Također je važno nastaviti proučavati ekonomsku isplativost implementacije takvih tehnologija u obrazovnim ustanovama kako bi se osigurala njihova dostupnost širokom rasponu učenika. Dakle, rezultati ovoga istraživanja otvaraju nove horizonte za poboljšanje metodologija poučavanja glazbe i mogu doprinijeti daljnjem razvoju inovativnih pristupa u glazbenom obrazovanju.

Dodatak 1*Test osmišljen za mjerenje početne i konačne procjene vještina sviranja violončela.*

Pokazatelj	Zadatak	Uputa	Kriteriji procjene
Tehničke vještine	Ljestvice i arpeggiji	Izvodite ljestvice i arpeggije u duru i molu (C, G, D, A, E, F, H). Procjenjuje se točnost, brzina i glatkoća izvedbe.	Točnost (ispravnost nota): 10 bodova Brzina (vrijeme izvršenja): 5 bodova Glatkoća (konzistentnost i jednakost zvuka): 5 bodova Maksimalni rezultat: 20 bodova
Tehničke vježbe		Izvedite odabrane tehničke vježbe s naglaskom na promjene položaja, udarce i tehnike (npr. legato, staccato, pizzicato).	Tehnika promjene položaja: 5 bodova Izvođenje različitih zaveslaja: 5 bodova Kontrola instrumenta: 10 bodova Maksimalni rezultat: 20 bodova
Poznavanje glazbene teorije	Testiranje	Odgovorite na pitanja u vezi s notnim zapisom, intervalima, akordima, modusima, glazbenim oblicima i strukturom.	Točnost odgovora: 20 bodova
Interpretacija glazbenoga djela	Analiza partitura	Analizirajte partituru kratkoga djela, identificirajući ključne glazbene elemente (melodiju, harmoniju, ritam, strukturu).	Razumijevanje melodijske linije: 10 bodova Razumijevanje harmonijske strukture: 10 bodova Razumijevanje ritmičkih značajki: 10 bodova Analiza glazbenoga oblika: 10 bodova Maksimalni rezultat: 40 bodova