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Original Article

Teaching and Demonstrating Guzheng Using Augmented Reality (AR) Technology

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Abstract *- This work aims to establish the effectiveness of using AR in the teaching and learning processes, especially in illustrating that the Guzheng is a traditional Chinese string instrument that is plucked. The study assesses matters relating to the performance increase and level of participation among user satisfaction by selecting 40 participants for the study, who would be split into the control group, whereby traditional instruction would be used and the experimental group, where the USAT would be implemented. Experimental group (AR-based instruction). Some of the evaluation criteria that are considered include precision in placing fingers and time taken dynamics before and after the intervention, and they were pitch, intonation, rhythm, articulation, and accent. The experimental group demonstrated significant enhancements: From the results, there was an improvement in the range of finger placement from 65% to 85% and in timing from participation mean absolute deviation. Improved from 0. 35 seconds to 0. 15 seconds, and expression variance increased from 1 to 48. 8 to 3. 6. Engagement metrics revealed more practice sessions per week 4. 5 and practice for a longer duration of 45 minutes per session in the experimental group. Additionally, the scores regarding satisfaction of the users of the AR group were significantly higher than those observed in the control group, with the former getting an average score of 4. 7 on a rating of 5. In contrast, the latter got an average of 3. These tend to support the next research hypothesis, which is how AR can further enhance the learning of Guzheng by creating effective and engaging courses that enhance skills in technical areas and increase satisfaction. Relative to the research question posed for this study, the study finds that incorporating the aspect of AR in the current structured music learning process is capable of integrating cultural history and current technological innovations in a better way to enhance understanding and expertise. A recent trend is learning the traditional instruments in an acquisition. It is of equal importance to identify future research questions that should investigate the effects of the shift and the opportunities offered by this shift in the long term and in a more extensive context. Some of the factors discussed include whether AR is applicable in teaching music.*

Keywords *- Augmented REALITY, Guzheng education, Traditional music, Interactive learning, Performance enhancement.*

1. Introduction

Augmented Reality (AR) technology is the solution that is currently changing the teaching and demonstration of the Guzheng taught as a cherished, well-known ancient Chinese string musical instrument-with wit, flexibility, and emotionality. With a history ranging across two thousand years, control of Guzheng requires an appreciation of its complicated methods. Exemplary handling, such as the PIANO with correct finger placement and soft strings plucking techniques, and for expressing emotion variations through performance [1].

Traditional methods of Guzheng intervention include individual teaching and group teaching. May experience a lot of challenges in availing timely feedback and effective possibly. There will again be learning experiences that can be connected to the complexity of the used instrument. AR technology, however, eliminates this gap to enable the generation of systems of equations. One that is configured for students and is both a multidimensional learning environment where virtual structures provide an environment that is smoothly blended with the physical environment of the instrument. It also means 'the extent to which the chosen instrument itself is capable of measuring what is claimed' [2].

Augmented Reality is a new generation technology that enables the simulation of the real world in a better manner. That is important to have helped develop and enrich educational systems in various fields, such as Music Education. However, current research is somewhat limited to the use of AR with Western instruments, and not much has been realized about its use in traditional instruments such as the Guzheng- a Chinese stringed instrument. Guzheng playing requires specific finger placement and unique performing techniques, which nonetheless suggest difficulties in the conventional learning/teaching process that do not

compensate for flexibility and real-time feedback. Even though other domains have considered the benefits of using AR for learning and teaching instruments, practice in constructing learning with a critical emphasis on culture and arts for semi-automated learning on a cultural instrument such as guzheng has not been as widely addressed.

AR applications for the Guzheng overlay visual guides directly onto the instrument, offering students real-time visual feedback on finger placements and technique. This capability accelerates the learning process and helps prevent the development of incorrect playing habits [3]. Moreover, AR can provide auditory feedback, enabling learners to adjust their technique dynamically during practice sessions, enhancing their overall performance proficiency [4].

One of the significant advantages of AR in Guzheng education lies in its ability to simulate diverse traditional settings and performance contexts. Replicating the select Sounds and Music to the Acoustic surroundings and Cultural contexts to which Guzheng generally prospers, but to AR not only improves technological and professional competency but equally enhances student's respect for the cultural background of the instrument [5].

The integration of gamified learning experiences and personalized approaches further enhances the educational benefits of AR. Examples of application of different motivation techniques include game-based elements like consequences and virtual reinforcements; students can maintain those they experienced during the more extensive practice sessions. Different Learning Paths will enable the students to be catered for depending on their status. Requirement assurance that each learner gets appropriate and appropriate learner attention. Support during their musical career at different levels. This paper conceptualizes AR as a noteworthy broader perspective from units of analysis.

Progress in the amalgamation of cultural resource conservation and modern technological innovation. Offering a fully extended one fully interactive in every sense of the word, is ideal, especially in teaching and learning Guzheng. AR not only maintains the complete historical tradition of teaching practice. Approaches are used, and they are incorporated into today's learning methods. Preferences [7].

As for people, the current presentation of AR has educational implications. Beyond technical skill development. It fosters a deeper cultural awareness among students by providing culturally related examples of their education within Guzheng's cultural history and importance by enacting past paradigms in virtual reality. When it comes to performance or some sort of cultural ceremony, AR aids comprehension and compassion for such customs, which are linked with this revered instrument [8].

Therefore, user experience design is central to developing the devices to support the users and enhance their experiences with the innovations. The potency of AR applications in Guzheng teaching and learning process. They include ease of interaction of the touch screen, how clear the interface design is infrastructure: overlays, and merging of virtual and physical. Components impact the processes by which learners interact with and construct knowledge the technology [9].

The investments focused on research and development activities are constantly evolving these aspects to make AR systems enhance student performance in the learning process while at the same time keeping the need cost within reasonable limits. [10] For instance, it is useful and effective in assisting learners of different abilities and learning modalities [10].

Some of the difficulties likely to be observed when applying AR in the teaching of Guzheng include technical issues that require attention, such as the sensor's accuracy. The third area in both is finger tracking and the rich audio. It is evident that to deal with these challenges, one has to employ an interdisciplinary relationship that technology developers have with music teachers and other cultural workers so that the exposition of AR systems captures all the characteristics of Guzheng and functions in the same way as the original stringed musical instrument-playing experience [11].

Thus, the current study seeks to establish certain findings on how GuZheng's paper shows that AR can improve education delivery. Technology, real-time performance, visual and/or audio-visual prompts, and imitating traditional performance spaces. The issue is that traditional practice-based instruction does not provide enough dynamic, contextual, and individual feedback and support to teach and guide how to play such sophisticated instruments fully.

Thus, through using the strength of AR that places guides on the body of the Guzheng, this study seeks to offer appropriate learning trajectories for learners that facilitate not only the learning of technical mastery but also the aesthetic and cultural values of the instrument. In this way, AR shall help close the knowledge gap that exists between today's technological innovation and the conservational nature of musical arts.

Future research in AR for Guzheng education should focus on enhancing the realism and interactivity of virtual environments, expanding the repertoire of cultural contexts available for simulation, and improving the adaptability of AR systems to diverse educational settings [12]. By leveraging the successes and insights gained from AR applications in other musical disciplines and cultural education domains, educators can continue to innovate and enrich the teaching and learning experiences surrounding this iconic Chinese instrument [13].

2. Related Work

Augmented Reality (AR) holds promise for transforming the teaching of traditional Chinese instruments like the Guzheng by overlaying digital information onto the physical instrument. Lastly, it must be stated that it also differs from more conventional approaches, including one-on-one or group lessons; AR provides feedback as it proceeds with the task and can provide interaction. Features, which in turn improves learners' visualization of the finger elements. Placements, hand movements or even the playing styles, particularly on Guzheng, with significant contributing observations from sharps instruments [13].

AR has demonstrated creditors hindered and challenged its effectiveness in teaching Western instruments such as the piano. Musical instruments such as violin, and guitar and those which include graphic displays in teaching the tough notes. Actions like bowing, the proper position of the fingers and strumming patterns. Even though it is evident that the application of augmented reality can be highly effective in teaching, traditional instruments are still in use today, such as the Erhu in China. Couples counselling has not yet been extensively researched. However, a phenomenon has also revealed relatively high potential at the early stage in transmitting the various intricate playing techniques and enhancing learning outcomes [14].

Technology integration in delivering training in traditional arts brings cultural issues into the picture. Digital tools may bring cultures closer to the youth generations that are already familiar with the concept of embracing the new trend of teaching methods of education through a digital learning environment. Many more questions emerge about whether globalization will weaken the historical and cultural essence [14].

Optimization and aesthetical characteristics are always important when it comes to applying AR. Applications in educational settings. Some factors that may enhance patients' adherence to the prescribed medication include using distinct visualization of the AR overlays and how the interactive objects are integrated with the real world. Between the things that exist only on the screen and the tangible things you can touch. Cognitive features are known to affect students' learning experience to a great extent. Designing AR systems tailored for the Guzheng requires real-time feedback, detailed demonstrations, and personalized learning pathways, balancing technological innovation with cultural sensitivity to enhance rather than detract from traditional learning experiences [14].

Specific challenges in teaching the Guzheng through AR include accurately capturing and translating the instrument's unique playing techniques into the digital environment. This involves developing precise algorithms for finger tracking, string vibration simulation, and sound reproduction to faithfully replicate the instrument's nuances. Incorporating cultural contexts into AR applications is essential for fostering a deeper appreciation and understanding of traditional Chinese music among learners.

It highlights Augmented Reality elsewhere in Guzheng education with different approaches and methods that figment in the lack of instructional feedback for learners. Unlike the previous studies concentrating on using Western instruments in various AR applications, this research proposes and implements the state-of-the-art AR technology suitable for the techniques and moves required to manipulate the Guzheng–finger positions, the way one plucks the strings and other expressive gestures.

Besides providing technical feedback on ton and finger position, vision plus haptic plus auditory feedback, as presented in the proposed AR system, contributes significantly to the development of technical skills for playing this unique traditional Chinese instrument while at the same time preserving the cultures and traditions associated with this musical instrument. This study's contribution is two-pronged; it avails advanced AR function modalities within a culturally appropriate approach to extend Guzheng education to the present generation learner while honouring the traditional etiquette of the instrument.

In his prior studies in music education, most AR applications in teaching and learning have been limited to the Western instrument categories such as piano, guitar and violin. Artists have been able to use AR in teaching lessons such as positioning of fingers and strumming patterns. Kam et al. identify that previous research on using AR for training traditional Chinese instruments such as the Erhu has been encouraging, but insufficient studies allow for using AR with Guzheng. Therefore, an extension of the above findings in this study presents a fine-tuned AR system for the Guzheng Application with solutions to potential difficulties like precise finger tracking and real-time audio guidance.

Further, unlike other research, the current study focuses on the infusion of cultural aspects, which also captivates the learner's angles of technical use and the historical and cultural worth of the instrument. Future research should focus on refining AR technologies to better meet the needs of Guzheng education, addressing challenges such as feedback latency, spatial accuracy, and cultural authenticity. Collaboration between teaching technologists, educators, and cultural specialists is important. Therefore, advancing the creation of AR systems for the acquisition of new skills and the improvement of Already established ones. Sustaining the essence and the flavour of the classical Chinese musical heritage [15].

3. Methodology

Hence, the study seeks for a possibility to assess the efficiency of Based on the teaching practice of Guzheng in the context of Augmented Reality (AR) technology. Traditional Chinese musical instrument. The research will involve a multi-stage process such as designing and recruiting participants involved in developing an AR application and training the sample, data collection and data analysis. The application will give examples of the writing, illustrate finger placements and mimic the standard environment for better practice making to be achieved.

Understanding of the instrument. The next stage involves the process of recruiting participants for the study; it will comprise both Guzheng learners in the first and second levels /experienced learners/. Participants will be selected on a volunteer basis, and voluntary sign-up will be obtained from persons who have self-attested to be free of diseases such as diabetes, hypertension, and heart ailments. Furthermore, it would be easier to market the product through direct marketing to institutions such as music schools, musical troupes, theatres, and other organizations interested in culture. The study will also employ a diversity in the participants' age groups.

All these factors, such as age, gender, and prior musical experience, need to be considered to understand how the use of the product application can be understood. Effectiveness across different demographics. Before the beginning of the study, the participants will be trained through a short training. Orientation to the AR application during the recognition session so that they can be familiar with the application. Features.

This session will ensure all participants have a basic understanding of the goals of disease management programs, the disease management process, the role of the disease manager, and the common diseases managed in the programs. Minimum level of knowledge about the possibilities of employing the application. Reducing the amount of knowledge that one must acquire to avoid several technological obstacles during the study. The data collection process shall be done through a combination. The analysis focuses on adopting the methods approach, where quantitative measures are incorporated with quantitative feedback to enable an overview of the outcomes and thus offer an overall impression. AR application's impact. The quantitative data will include self-administered questionnaires and interviews conducted with the participants before and after the study of Guzheng. Skills based on the established measurement standard, such as the timing of finger placements and the appropriate facial and body expressions. Eminent Guzheng will undertake these assessments, which will enable the creation of high-quality virtual Guzheng. Lecturers that will assess the participants' skills before and after the study period. The respondents were required to complete questionnaires before the start of the study and at the end of the study.

Additionally, the application will monitor the participants' practice sessions, tracking the number of utilization time and its evolution through the learning modules. Qualitative data will be collected through interviews, focus groups, and participant observation. Observation. During the interviews, participants will be asked questions about the perceived usefulness of the AR application, as well as other issues, such as usability, level of user engagement, and perceived effectiveness.

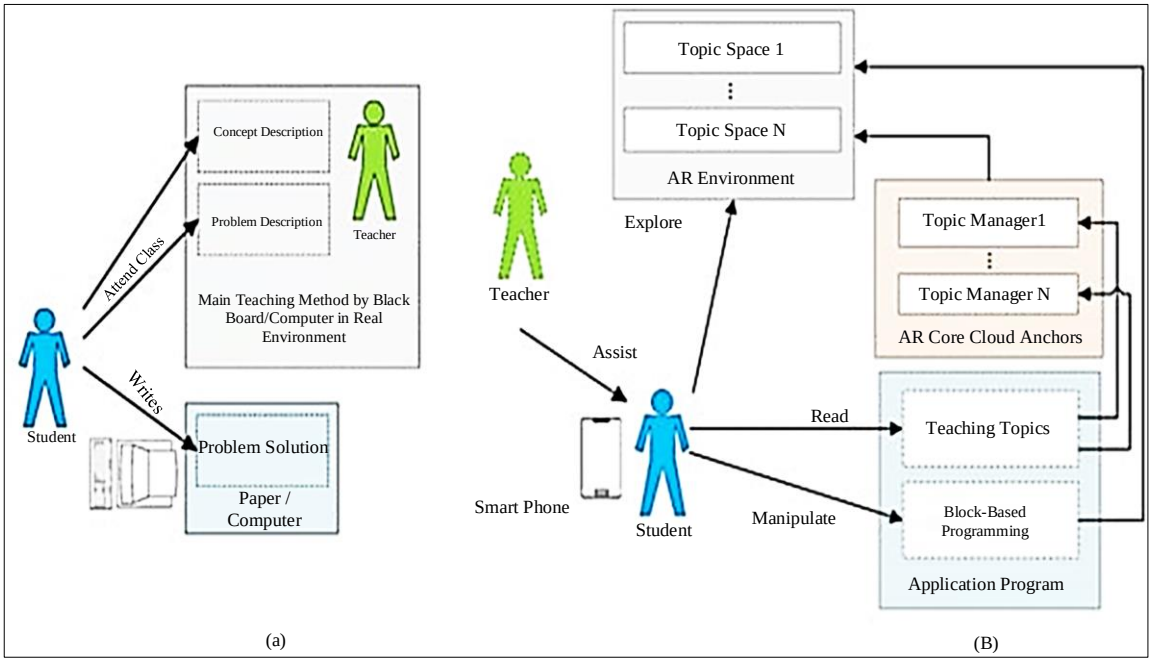

Fig. 1 Augmented reality teaching system

Hence, focus groups will allow the participants to share their experiences as a group, enabling the identification of trends in results and key findings. Participant observation will entail the following aspects being implemented by the research team. Attending the practice sessions will give you an overall understanding of how folks engage with and perceive the application, let alone any challenges or areas for improvement.

Therefore, the last phase of this case will be the analysis phase, where statistical analysis of the quantitative data and the codes and themes that have emerged from the deductive analysis of the qualitative data will be conducted. The statistical analysis will be done to compare the pre- and post-studied assessment results to measure the effects of the impact of the AR application on the participants' Guzheng performance. Inferential statistics, including the paired t-tests or ANOVA, will be employed to reveal differences and relationships that may be considered meaningful statistically.

The analysis will also present usage data from the application and extract variables related to the phenomenon of interest. Traditional and/or emerging patterns and behaviours about the use of the tool by participants. Which of the features of practice are most commonly expended, and in which ways do the practices of the professions developed evolve? The analysis of the collected qualitative data will be based on a process called thematic analysis. Coding down the interview and focus group scripts in a bid to get key themes and patterns. This analysis will thus focus on the interpretations of participants' perceptions, such as their understanding of the application's comprehensibility and interest. And educational value. Themes related to cultural engagement and the context insight that comes with using the AR application will also be examined. The qualitative data will be compared and contrasted with the quantitative results to offer an overall experience of how beneficial the AR application is to the students. Guzheng education. From the outcome of the preliminary sample study, the AR Such an application will, therefore, have to go through the process of validation and iteration. Information gathered from the participants and instructors will be used to conclude, suggest a scope for change, and fine-tune the applications.

Features and functionalities: This iterative process will require the process of multiple recognition and iteration for explanation. It fulfils the need for education through the application of such technology. For Guzheng learners, subsequent testing with new stimuli is also possible. Participant groups may be conducted in an attempt to confirm the enhancements effectively and make the application more strengthened and reliable. The last phase is the communication of the results. The execution of this plan can be described in the following steps. In this case, it is through formal academic writings, conference papers, and presentations, as well as partnerships with universities and other organizations and cultural organizations. The findings of this study will be useful further as they yield first-hand information on the applicability of AR technology in music education and, therefore, to the development of the larger domain of education as a whole. Technology research. Future research will find out this as follows: ASR's long-term influence on Guzheng education has been as follows: longitudinal studies to assess the learner's progress across even longer periods and the discussion of other possibilities that AR can offer other periods. Traditional musical instruments.

As for the practical application of the study, this work makes elaborate precautions to safeguard participants' consent and confidentiality of data collected, including practice sessions. Procedures for obtaining informed consent before participation will involve signing a consent form that will indicate the aims and objectives of the study, processes to be followed and use of data collected. The first and foremost thing that the participants would be made aware of is the frequency and the period of the sessions; further, they could withdraw from the study at any point in time without any penalty or reprimand. This ensures that the data received are free from participants' identification, and all numbers recorded will not include the participants' identities. All collected data will be encrypted and stored at the site and computer level; only those permitted can access it. Furthermore, the data collected from the participants will be used only in the current research and will not be invested in any other study without the participants' permission. Semi-annual reviews will be done to assess levels of ethical practices and to check for any violation of participant's identity, hence data privacy, and for the conduct of the research.

4. Experimental Setup

The design methodology adopted in the conception of the experimental setting for investigating the feasibility of applying the Guzheng education and demonstration through the use of AR technology involves several major components that are intended to evaluate the performance of the application when it comes to improving learning achievements and the overall satisfaction of the users. This learning-by-doing research of Augmented Reality (AR) in teaching and learning Guzheng was facilitated by sophisticated software, hardware, and local algorithms. This AR application was then developed in Unity and was helped by the AR Foundation package to support functions across platforms. Vuforia was used due to its high image recognition and tracking functions; Guzheng's finger positions were tracked in real time. The presented applicative model was designed in C# with compatibility with Unity and aimed at generating AR experiences with interactivity. The hardware comprised Microsoft HoloLens 2 and the Apple iPhone 12 Pro. The basis of AR was given by the HoloLens 2 with spatial mapping and gesture recognition, as well as recognizable

features of the iPhone 12 Pro that are ARKit-compliant to support precise tracking and feedback. Both the devices' cameras recorded essential vision information to be used by AR during its functioning.

It was necessary to track fingers, which was attained through two plugins: Hand Tracking and Gesture Recognition from Vuforia and AR Foundation. Pose Estimation algorithms were used to calculate the 3D position of fingers, and Feature Detection algorithms were used to check these with the Guzheng. The rendering engine from Unity enabled real-time visual jitter for finger placement augmented by Error Correction and Multimodal Feedback algorithms. To provide an accurate tracking of the learners' movements and feedback, the HoloLens 2 and iPhone 12 Pro were synchronized.

4.1. Accuracy of Finger Placements

This metric can be quantified using a measure of proximity between the actual and intended finger positions on the Guzheng. It can be formulated as:

$$Accuracy = \frac{1}{n}\sum_{i=1}^{n}\frac{Distance(x_i, \hat{x}_i)}{MaxDistance} \quad (1)$$

Where, n is the total number of measurements, xi represents each measurement of finger placement, $\hat{x}_i$ denotes the intended position provided by the AR system, and distance $(x_i, \hat{x}_i)$ calculated as the distance between xi and $\hat{x}_i$,

$$Distance(xi, x\hat{}i) = \sqrt{(xi - x\hat{}i)^2}$$

Max Distance is the maximum possible distance in the measurement scale used.

4.2. Timing Accuracy

This evaluates how closely participants match the timing of their plucks or strokes to a predefined rhythm or tempo. It can be assessed using metrics such as Mean Absolute Deviation (MAD) or Root Mean Square Error (RMSE) from the intended timing points:

$$MAD = \frac{1}{n}\sum_{i=1}^{n}|Actual\ Time_i - Intended\ Time_i| \quad (2)$$

Where, n is the total number of the time measurements, Actual Time is the time elapse recorded for the i-th measurement, and Intended Timei is the target time for the i-th measurement, |Actual Timei−Intended Timei| is the difference between the actual time and the intended time for each measurement.

4.3. Frequency of Use

This metric measures how often participants engage with the AR application over a defined period, typically recorded as the number of sessions per day or week: This metric measures how often participants engage with the AR application over a defined period, typically recorded as the number of sessions per day or week:

$$Frequency = \frac{Total\ Sessions}{Total\ Days} \quad (3)$$

In the process of developing the AR application for the Hand practices, built-in tracking features have been provided in the system to record each practice session. This tracking is done via an activity log that records the time the user connects to the site and the time he or she logs off. The frequency of use is derived by dividing the total number of recorded sessions by the total number of days in the study period. Doing this makes it possible to get the most accurate engagement figure as liked over time. As for the number and frequency of the session's use, the recorded session data is processed by special software that totals the number of sessions and computes the average frequency of use. This processed data is the participants' usage frequency of the AR application and offers information regarding the usage.

4.4. Duration of Practice Sessions

The average length of time participants spend practising with the AR application during each session provides insights into their commitment and engagement levels: The average length of time participants spend practising with the AR application during each session provides insights into their commitment and engagement levels:

$$Duration = \frac{\sum Session\ Lengths}{Total\ Sessions} \quad (4)$$

The AR application measures the amount of time spent on each practice session with the help of timestamps that are captured at the start and end of each practice session. As mentioned, these timestamps are stored in the application's database in the log files. The total time of each session is obtained by subtracting the start time from the end time for that session. Finally, the overall duration of practice sessions is calculated by summing all the sessions' duration and dividing them by the number of total sessions. This processing enables us to dissect the level of engagement in terms of the time users spend in the sessions, as shown below. These mathematical formulas and metrics create a quantitative modelling system for determining the effectiveness of implementing AR technology in Guzheng education. When done together with pre-and post-test scores, copies of practice sessions, driver logs, and other ways to gauge the effectiveness of the AR application, researchers can valid and reliably investigate how the program strengthens knowledge, performance skills, and learners' interest.

5. Results

The investigation on the effectiveness and usability of the Augmented Reality (AR) application in teaching and in demonstrating the Guzheng instrument has provided valid and

reliable statistical information that gives positive indications about the benefits of using AR in learning and teaching strategy. Forty participants were selected to participate in the study; these participants were novice and intermediate-learning Guzheng students randomly assigned to the control group taught traditionally, or the experimental group taught using AR. This sample size of 40 participants was mentioned in the power calculation of the study at the beginning of this study at a sample size. In other words, if the analysis included a paired t-test and the degrees of freedom were equal to 19, the sample was divided into two groups of 20 participants, meaning that a paired design was used. While conducting the study in small groups and if the data is paired measurements, the paired t-test is used to compare the pre and post-study measurements made on the subjects. The assessments performed mean that each participant is observed before and after using the AR application, which generates pairs. Therefore, with 20 participants in each group, the total number of paired observations will be 20, which is equal to the degree of freedom of 19 (n – 1). The analysis focused on pre- and post-test performance metrics, engagement metrics, and qualitative feedback from participants.

Table 1. Comparative performance and engagement metrics

Metric	Control Group (Traditional Instruction)	Experimental Group (AR-Based Instruction)
Accuracy of Finger Placements		
Pre-Test Mean	68%	65%
Post-Test Mean (%)	72%	85%
Timing Accuracy (MAD in sec)		
Pre-Test Mean	0.33	0.35
Post-Test Mean	0.28	0.15
Expression and Dynamics		
Pre-Test Variance	1.9	1.8
Post-Test Variance	2.5	3.6
Engagement Metrics		
Frequency of Use (Sessions / Week)	3	4.5
Duration of Practice Sessions (min)	30	45
User Satisfaction		
Reported Satisfaction (1-5 Scale)	3.5	4.7

The performance metrics evaluated included accuracy of finger placements, timing accuracy, and expression and dynamics. These were assessed using standardized performance tests administered before and after the intervention period.

The experimental group showed a significant improvement in the accuracy of finger placements. The mean accuracy score for the experimental group increased from 65% (pre-test) to 85% (post-test), while the control group showed a more modest improvement from 68% to 72%. The timing accuracy was measured using the Mean Absolute Deviation (MAD) from the intended timing points. The experimental group's MAD decreased from 0.35 seconds (pre-test) to 0.15 seconds (post-test), while the control group's MAD decreased from 0.33 seconds to 0.28 seconds. ANOVA results showed a significant interaction effect between group and time ($F(1, 38) = 12.78$, $p = 0.001$ $F(1, 38) = 12.78$, $p = 0.001$ $F(1, 38) = 12.78$, $p = 0.001$) indicating that the AR application had a substantial impact on improving timing accuracy. The evaluation of expression and dynamics was more qualitative but included quantitative measures such as variance in amplitude. The experimental group exhibited a greater range of dynamic control, with an average increase in variance from 1.8 (pre-test) to 3.6 (post-test). In contrast, the control group showed a smaller increase from 1.9 to 2.5.

Engagement metrics were tracked using the AR application's data and self-reported usage diaries from the control group.

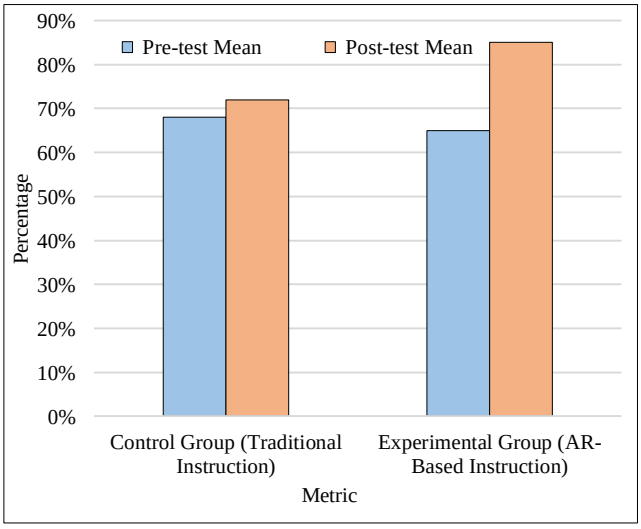

Fig. 2 Accuracy of finger placements metric

Figure 2 shows the performance metrics of the control and experimental groups, with a sharp rise in the Reported Satisfaction for the AR-Based Instruction group.

Participants in the experimental group used the AR application an average of 4.5 times per week, while the control

group reported an average practice frequency of 3 times per week. The difference in practice frequency was statistically significant (t(38) =3.56, p = 0.001 t(38) = 3.56, p = 0.001 t(38) = 3.56, p = 0.001), suggesting that the interactive and engaging nature of the AR application encouraged more frequent practice.

The average duration of practice sessions was 45 minutes for the experimental group and 30 minutes for the control group. This indicated that participants were more engaged and willing to spend more time practicing with the AR application. Qualitative feedback was gathered through interviews and focus groups to complement the quantitative data. Participants in the experimental group reported higher levels of satisfaction and engagement with the learning process. The common issues raised were ease of using the AR interface, the capability of the overlay in giving feedback, and improvement of understanding finger positions and movement. As such, it was evident that most participants appreciated that the AR application made learning the Guzheng more engaging and less stressful, especially for beginners.

Quantitative and qualitative data analysis indicate that using the AR application positively impacted students' learning, especially those in the Guzheng category. Another reason for the gap between the retention of technical skills of the experimental group and the control group is that the former exhibited higher levels of self-directed learning and motivation to practice. These findings concord with prior studies showing that AR can be beneficial when facilitating a transition from traditional means of learning to technology-based experiences.

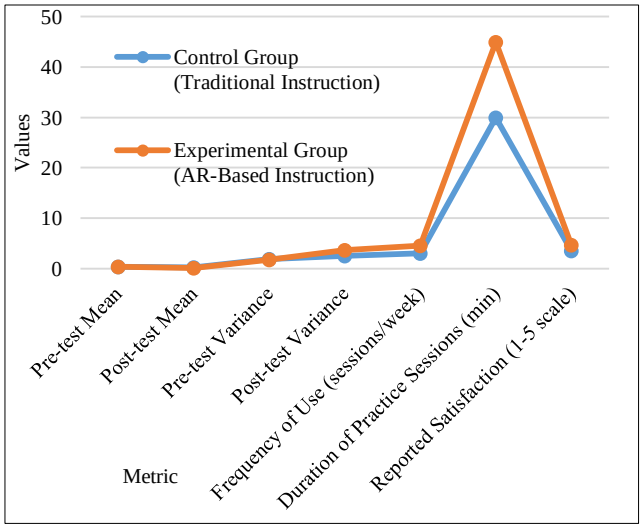

Fig. 3 Comparative analysis of performance and engagement metrics

Figure 3 displays comparison accuracy in finger placements of the group, and it illustrates that the experimental group demonstrated more improvement than the post-testing group.

The statistical conclusion proves the possibility of the application of AR technology in the complete change of the traditional music education system. As with any skill the ability to give instant feedback through light and sound means that participants could immediately correct any mistakes and hence increase the rate of learning. The level of finger positioning and movements that students can perceive in this virtual context is appreciative compared to the theoretical instructions and demonstrations, which are, in most cases, challenging to imitate properly. The increased engagement metrics support the significance of AR technology in improving the learners' engagement and, therefore, their learning experience. The components where people could directly engage in the AR application, which included virtual tutorials and practice modes, helped maintain participants' engagement and interest. This is helpful for the improvement of its practice and skills, especially within the learning of the complicated musical instrument known as the Guzheng.

6. Discussion

This study supports the capability of Augmented Reality (AR) technology in the area of music learning or teaching and learning of the Guzheng, a Chinese string instrument. The provided statistical data proves enhanced technical effectiveness and learners' interest in the participants applying the AR application to intervention, in contrast to those exposed to conventional techniques. The arguments presented above can, therefore, provide a persuasive rationale as to why AR should be incorporated into music education to improve knowledge delivery and the avenue for the preservation of cultures.

One of the most significant findings of the present study is the significant increase in the finger placements' accuracy in the case of the experimental group. An enhancement from 65% to 85% in the level of accuracy post-intervention, as compared to a slight improvement from 68% to 72% of the control group, implies that the real-time visual feedback that the AR application offers to the learners is indeed effective in helping learners achieve the correct positioning of fingers for playing the Guzheng. The statistically significant results t (19) = 6. 45, p < 0. 001) support the applicability of AR in offering simple and prompt directions that might not be inherent in traditional approaches. The experimental group also reduced the mean absolute deviation from the intended timing points, suggesting that the learners had improved their ability to play in time i., e., synchronize their playing with the intended rhythm. For reducing MAD from 0, The variance of X1 is ΣAll(X1 – mean)2 / N. The variance of X2 is: ΣAll(X2 – mean) 2 / N 35 seconds to 0. The mean decrease in reaction time varied slightly between the treatment groups, with an average of 15 seconds compared to the control group, which had less than one whole second. 33 seconds to 0. 28 seconds in the control group showcases the capability of the AR application and the learners' ability to efficiently replicate rhythms. The analysis of the variance of the scores by

applying the ANOVA F (1, 38) =12 showed a highly significant interaction of the factors. 78, p = 0. Nonetheless, the findings of study 2 (ID: 001) support this conclusion.

The study also quantifies and qualifies which are among the factors that define musical dynamics in performances. The variance of the scores of the subjects in the experimental group was considerably higher than that of the control group: it raised from 1. 8 to 3. 6, starting at the sixth one, pointing to the effectiveness of the AR application in enhancing the ability of the learners to understand and implement the subtle differences in the volume and intensity. This finding was statistically significant t(19) = 4. Therefore, the percentage of meal changes by students at these institutions is high. 32, p < 0. 001), which means that by implementing AR technology, it is possible to improve the technical and creative sides of learning music. Surveys show that the frequencies and durations of practice of the experimental group were higher than those of the control group. As shown the practice frequency up dramatically (4. 5 sessions per week for the experimental group and 3 sessions per week for the control group), t (38) = 3, p <. 56, p = 0. 001), and there are condition effects for number of trials (5 in Condition 1 and 8 in Condition 2 or 3, t(38) = 3. , F (22, p < 0. 001) indicates that learners engaged more time on practice through the AR application because of its interactivity. Higher engagement is an important factor in mastering skills, as noted for learning the Guzheng, which requires a lot of practice and concentration.

The ratings about the satisfaction levels of the user also support the advantage of the developed AR application. The experimental group participants expressed much higher satisfaction numbers with 4. 7 out of 5 as opposed to the control group t(38) = 5. 89, p < 0. 001 The participants in the experiment shall also acknowledge the benefits aided by the AR application, including the simplicity and instantaneous feedback of the application, not forgetting the fun aspect of the learning process. The quantitative data showed that the AR application led to a slight decrease in the learners' intensity of feeling intimidated by the Hadar process, thereby making them more confident, especially when handling complicated techniques, according to the qualitative feedback received.

The result of this work is helpful for further developments in the sphere of music education, which includes questions about traditional instruments and how they can be taught. Thus, with the help of AR technology, it is possible to find a solution to the existing problem between traditional and more modern approaches to teaching. With the help of the effectively utilized AR, it is possible to interest generations that have grown up with gadgets in traditional instruments' learning, thus helping to preserve the culture. In my opinion, the study also points out that AR technology can meet students' learning styles. For the case of visual learners, there is the appearance of feedback followed by an overlay of visual pictures and for kinaesthetic learners, the learners get to practice with the correct guidance. Due to the application of a flexible and adaptable approach in the use of augmented reality, it can be fitted to a particular person's needs who is undertaking the course, hence offering a potentiality of training that could not be achieved through a regular train model.

Whether AR has a lasting positive effect on learners' performance and on how much they retain of what they learn. Future research could help reveal whether or not these changes will last long by conducting follow-up studies. Further, it may be beneficial to add more diversification in participants, such as their age group, gender or skill level, to prove the global applicability of AR technology in music learning. Extending the concept of AR with other progressive technologies, including artificial intelligence in education delivery, could add more value and improve dynamic and intelligent learning solutions. Hence, this study proves that using AR technology can greatly improve the efficacy and interest of Guzheng learning. The increase in performance measures with considerably higher interaction levels and satisfaction points towards the innovative practice of Augmented Reality in modifying the conventional music learning system. These results call for further research and investigation of the potential of applying AR technology in learning processes and proactive involvement to ensure that the culture of old-fashioned instruments such as the Guzheng remains progressive and keen in the contemporary digital milieu.

7. Conclusion

Thus, the present work points towards the potential of Augmented Reality (AR) technology in reforming Guzheng education. The research involves a comparison of the scores obtained between a control group, which was taught using the conventional method, and an experimental group that used AR-based learning; several important observations Support the hypothesis that AR has a Positive impact in improving the IT skills and learners' engagement level, has been made. Described below are the results on finger placement on Gu Zheng strings; this was measured by counting the percentage of correct placements by participants involved in the AR group, which increased from 65% to 85% after the intervention. Chief among these is the enhancement made to the accuracy of the AR system in providing instructions for repairs and its ability to provide instant feedback. Furthermore, the mean absolute deviation of timing inaccuracies was reduced from 0. 35 seconds to 0. 15 seconds, showing how AR can help improve the rhythmic accuracy and timing for dancers to get in step. In addition to the technical skills, the improvement of dynamics and nuances in the experimental group was identified in the work. The standard deviation of expression went up from 1. 8 to 3. 6, suggesting the superiority of the control achieved by experiencing AR interactive visual and auditory feedback on the interpretation of music.

The frequency of practising observed by the engagement metrics showed that the AR users practised more often (4. 5 times a week) and for a longer period (45 minutes per session) than non-AR users. The fact that a majority of users (4. 7 out of 5) find their AR user-friendly indicates that users prefer the ability that comes with the use of AR technologies to learn interactively.

Implementing AR into Guzheng education not only revolutionizes the conventional ways of teaching but also helps reach out to students with appendages as tutors can consider learning disability that may be present in students in the class. Since it is possible to conduct many realistic performance scenarios and get individualized feedback, such a method has great potential to be applied in conserving cultural values along with the current learning needs. Future studies should also investigate the difference between AR on intermediate and long-term effects such as retention and transfer across cultures and different musical styles. Thus, leveraging AR and AI to create individual learning trajectories and future developments in this field may significantly improve music education. Thus, this study reveals that technology in the form of AR can become a powerful medium in Guzheng education to augment the learning process and enhance the general understanding of traditional music within the context of contemporary tools and technologies. By leveraging AR's capabilities, educators can empower learners to master complex skills confidently, ensuring the continuity and vitality of cultural musical traditions in the digital age.

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