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Adoption of Virtual Reality Technology in Learning Elementary of Music Theory to Enhance the Learning Outcomes of Students with Disabilities

Waleed Maqableh
Luminus Technical University College, Amman, Jordan, *w.maqableh@saejordan.com*

Jamal Zraqou
University of Petra, Amman, Jordan, *Jamal.Zraqou@uop.edu.jo*

Abdallah Alnuaimi
Luminus Technical University College, Amman, Jordan, *a.alnuaimi@saejordan.com*

Ali Al-Shurman
Luminus Technical University College, Amman, Jordan, *a.alshurman@saejordan.com*

Advancements in technology have led to the widespread use of modern technologies in education, including the integration of augmented reality (AR) and virtual reality (VR) technologies. During the COVID-19 era, Music learning like other applied educational disciplines, has faced many technical and application problems, especially in finding alternative educational tools that fulfill the learning purpose and preserve the expected learning outcomes. This study came to explore the effectiveness of using Virtual Reality technology in music education and to figure out the students' acceptance and their intention to use the technology. For this purpose, an interactive virtual learning environment was developed to aid students in learning the "principle of music theory", a sample group of 20 students including students with Motor Disabilities from Luminus Technical University College (LTUC) participated in the study experiment.

The results of the study show that the use of virtual reality technology is effective in learning music, and also there is an acceptable degree of intention to use the technology but at a high rate among students with motor disabilities. In addition, the analysis of the results highlights the essential factors that should be considered to improve the VR learning environment and the expected learning outcomes.

Keywords: virtual reality, education technology, immersive learning, music learning, active learning, disabilities learning

INTRODUCTION

Music is a powerful tool that transcends cultural, emotional, and linguistic barriers. It has been integral to human life since immemorial, catalyzing creativity and self-expression. As a result, many educational methods have been developed to teach people

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how to express themselves musically. These methods range from simple exercises like listening to natural pitches to more advanced musical theory and instrument-playing training. In the modern era, technology has revolutionized how we learn music, with specialized applications and online lessons helping individuals develop their technical skills like never before (Haleem et al., 2022).

In 2020, COVID-19 became a pandemic threatening human health and the world's economies. COVID-19 is the virus illness, and it was first noticed in December 2019 in and around Wuhan. Although the long-term consequences of COVID-19 are uncertain, the pandemic is expected to be responsible for the worst global recession since the terrible global economic collapse of the 1930s (Xiaoqian et al., 2021).

The COVID-19 pandemic has presented several challenges to the educational environment, such as the need for direct follow-up of student learning tasks and the lack of face-to-face interaction between students and teachers. These challenges can negatively impact the learning process and hinder students from achieving their desired outcomes (Azis et al., 2023). Despite these difficulties, educational institutions from primary school to higher education have started to adopt virtual classrooms and e-learning as an alternative to traditional classroom methods. As a result, most higher education institutions have revised their curricula to suit the new learning environment and have implemented Blended learning as an alternative to traditional education.

Due to the impact of the COVID-19 pandemic on the education system, this study was conducted at Luminus Technical University College (LTUC). LTUC is recognized as one of Jordan's leading institutions in providing applied education that meets the needs of diverse students and the labor market. The college has several academic departments, including programs that cater to students with physical disabilities, who are integrated into regular classrooms. The university provides various support services to ensure that these students receive the necessary assistance throughout his or her learning times and ensure continuity of their learning.

Due to the challenges posed by the Covid-19 pandemic, the education system is facing difficulties. In this regard, this study explores the potential of virtual reality technology as an educational tool. Specifically, the study seeks to investigate the effectiveness of using virtual reality technology to overcome obstacles faced by students in the "Principles of Music Theory" course. The research hypotheses are designed to verify the effectiveness of integrating virtual reality technology into music learning theory and to identify any differences in the attitudes of students with and without disabilities towards this technology as an educational means. The study sample comprises students enrolled in the "Principles of Music Theory" course, and further details of the study sample will be discussed in the research methodology.

The research objectives are summarized as follows:

Objective 1: Examine the impact of students' attitudes towards using VR technology on their intention to use it in learning the principles of music theory.

Objective 2: Examine the impact of the VR technology's effectiveness on their intention to use it in learning the principles of music theory.

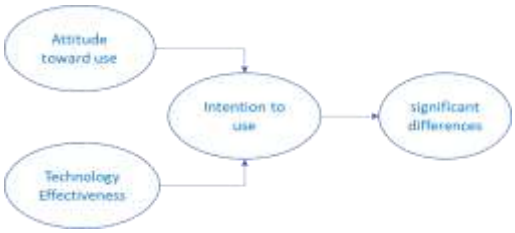

Figure 1
Research objectives map

Literature Review

The past years have witnessed a countable development in the educational technologies and its tools, as many educational institutions start to explore innovative methods of learning and employing the modern technologies in order to enrich the educational process and to be a replacement of the traditional learning and to move away from the classroom. This development in the educational technologies came to ensure the continuity of the educational process and to overcome any challenges it may face.

The COVID-19 pandemic has accelerated the adoption of digital learning, as schools and universities were forced to shut down in many countries due to safety measures and social distancing requirements. This led to a paradigm shift in how educators deliver high-quality instruction using a variety of online platforms. The emergence of online learning, distance learning, and continuing education as a response to the global pandemic has posed numerous challenges for teachers and students. According to (Gurukkal, 2021), moving from traditional face-to-face to online learning can present a completely different learning environment. In addition (Yuosf, R et al., 2022) stated that online distance learning can be successful in improving learning outcomes for students in remote areas who are unable to attend school physically. However, with the lack of other options, students and instructors were forced to accept this shift.

Learning music like other education sectors suffered many challenges during the pandemic, such as the inequities in education systems, the lack of computers needed for online education, the unavailability of digital learning resources, and insufficient computer access for online learning. Some of the music teaching methods during the Corona pandemic, such as using Zoom or Teams applications, revealed their ineffective-ness in learning music because learning music has a different nature than other subjects, and the use of virtual reality (VR) technology in learning '"Music Theory" could be a better fit (Rucsanda et al., 2021).

Music is a multifaceted discipline that encompasses both educational and entertainment aspects and is inextricably linked to the fast-paced advances in technology. This provides ample opportunity for the music industry to leverage the global technological boom and achieve pioneering educational, entertainment, and music production goals. Researchers are actively exploring the wide-ranging possibilities of Technology in Music to enhance the international musical experience for all.

Disability and Education

A disability refers to any condition of the body or mind that makes it more challenging to perform certain activities. Sometimes, a person may have multiple disabilities, which can hinder their ability to see, move, think, learn, or communicate effectively with others.

According to a report by the (Council for the Rights of Persons with Disabilities, 2021), around 11.2% of the Jordanian population, including males and females, have disabilities. Additionally, the (Ababneh & Al-Khamra, 2020) report shows that 33% of students in Jordan have some form of disability. (Table 1) presents the distribution of disabilities across different age groups.

Table 1
Distribution of disabilities

	Total no of students	Those enrolled	Attendance percentage
Primary School	4.958	543	10.9 %
Secondary School	7.668	2.501	32.6 %

Although disability may affect the ability of individuals with disabilities to perform daily activities, it should not deter them from pursuing their lives and education, just like any other person. Students with disabilities in all communities may face similar challenges in pursuing their education, with some variation in the degree of these challenges. However, one of the biggest challenges facing people with disabilities is technological barriers and the lack of assistive specialized tools in education. According to (Rodríguez & Díez, 2019), the Challenges faced by disabilities in their learning process are as follows (difficulty in focus during a lesson, social situations are confusing or difficult for disabled students, Students with ADHD or dyslexia may read or write slower than their peers, The inability to access the classroom, and teacher's awareness of Students with disabilities needs).

In reviewing previous literature, the researchers found that no single technological solution meets the diverse needs of students with special needs due to the diverse range of disabilities. Therefore, it is necessary to find customized solutions that suit the specific requirements of students with special needs in two directions: the direction of educational tools and the direction of the academic environment.

Many studies have been conducted to identify appropriate educational tools for students with special needs. For example (Ismail et al., 2023) Investigate the possible approaches that could help music students avoid the complexity of singing and playing traditional percussion (kompang) simultaneously during school music performances, his study found that Dalcroze’s approach is able to speed up and ease students’ mastery of musical skills compared to the conventional methods used, by adopting this approach, students were able to master singing skills while playing kompang.

According to (Marlina et al., 2023), Assistive Technology is one such tool that can help disabled students continue their education, especially when special education teachers are not available or cannot reach the learning location. Assistive technology refers to devices, tools, and software that enable people with disabilities to access educational

content using computers. These technologies come in various forms, such as screen readers, screen magnifiers, alternative input devices, keyboard enhancements and accelerators, and alternative pointing devices. According to (Bond, E., 2014), digital technologies, such as computers, laptops, and mobile devices, are excellent tools for accessing the curriculum and can significantly impact students' lives. Assistive technologies can enhance students' engagement with educational material and reduce their fear of continuing learning (Asongu & Nting, 2019). To improve the inclusion of students with disabilities in the learning process, the availability and accessibility of assistive technology, low costs of placement of assistive technology, and training on the use of virtual devices and platforms are essential aspects that must be present (Byrd & León, 2017).

Regarding the second direction, the educational environment, several contemporary education organizations employ virtual reality technology to engage students and visually represent the learning material. Many technologies can also assist students with disabilities by generating a simulated environment and providing them with the freedom to learn without the limitations posed by their disabilities.

Many studies have been conducted to explore the impact of the new technologies on the learning environments, were these studies highlighted the positive effects of employing the technologies in the learning environments. For example, Adyrkhaev (2016) indicated that technologies would help in improving the learning process and how the students' may interaction with educational materials.

On the other hand, (Alper & Goggin, 2017) mentioned that students with disabilities are the primary beneficiaries of the "digital revolution". In addition (McClain & Raja, 2021) pointed that students with disabilities can overcome the communication barriers with the help of "online learning" environments.

(Hui et al., 2022) indicated that developing the educational content using VR technology and the use of digital textbooks could help in overcome the restrictions faced by students with disabilities.

Despite the benefits that can be gained from employing VR technologies in the educational process such as its ability to enhance students' attention and moves the learning environment to be more attractive and exciting but there is a lack of the research that discuss the use of virtual reality in music learning for students with disabilities in particular. According to (Innocenti et al., 2019), the field of music education through VR is still in its early stages, and most of the existing VR applications are focused on music performance rather than theoretical aspects. However, as many authors have pointed out, inclusive education aims to improve diversity and ensure equal access to Education, educational programs, and environments. Hence, when modern educational technologies are available, all students, with or without disabilities, should be able to learn together in the same classroom and in the same learning environments. (UNICEF, 2019; Medina et al., 2020).

Virtual Reality (VR) in Education

Virtual reality technology is defined as computer simulation of a 3D image or environment, which can be interacted with in a way that appears natural or physical by a person using special electronic equipment such as a head-mounted display (HMD).

Recently, researchers become interested in researching and developing relevant theories and technologies to virtual reality (VR) and augmented reality (AR) technologies. VR and AR technologies have been widely employed in various industries, including entertainment, travel, medicine, and games, and especially in education, where many studies have been conducted on VR applications and their effectiveness in education and training fields since the 1980s (Bian, 2016).

According to (Hamilton et al., 2020), the interest in employing virtual reality technology in educational environments comes from its capabilities to provide learners with an immersive learning experience at a time when these experiences cannot be obtained in any other way; also, VR can support the interactivity between both of the users and the VR components, and VR technology permits learning to be boosted by the manipulation of the relative size of objects in virtual worlds.

In addition to the capability of VR to provide students with immersive learning experiences, other benefits of virtual reality in education come from its ability to inspire students' creativity, spark their imaginations, enhance their interest in new subjects, and help them acquire modern skills. For example, virtual reality has enabled students to learn complex engineering concepts, conduct difficult chemical experiments, train to use machines, and explore places without needing to move outside the classroom. (Radianti et al., 2020) report that, teaching with AR/VR enabled students to score higher than others. He also mentioned that students who learned in an immersive environment such as virtual reality can retain and recall memory more than other students.

Virtual Reality in Music Learning

Digital technologies in learning and education are increasingly widespread, especially using technologies such as virtual learning environments, which will significantly impact digital education in the coming years.

According to (Zhang, 2021), the development of Music art began at the beginning of the seventh century AD by the Italian Bartolomeo Cristofori; this art emerged as an elegant artistic activity where the learning of this art was limited to the upper class in society, during the time and with the societies progression this art spread to the various categories of society until it arrived in our time to be taught at the level of schools and university colleges. According to (Ismail et al., 2021) music is not only an important subject in general education, but it particularly serves gifted students who face various psychological issues not encountered by their ‘normal’ peers.

Music learning methods have also evolved in harmony with the advances in information technology. Nowadays, music learning methods are used through modern technologies such as AR / VR to enable music theories to be compatible with distance learning

environments. (Platz, & Kopiez, 2012) report that, traditional music teaching methods are weak in distance learning, and the use of Music education resources is poor. On the other hand, other researchers have highlighted the effectiveness of modern technologies in developing theories of music learning (Johnson et al., 2019).

As stated by (Nijs & Leman, 2014), computers are used to learn music effectively in various directions, such as (music basics, musical performance skills, music analysis, and music composition skills). In addition, computer technologies are used as a tool for learning music, as in many other fields, due to their ability of computer technologies to simplify the learning and teaching process, enhance student motivation, provide practical application, and save time, which is crucial not only for the student but also to the lecturer.

Computer-assisted piano instruction can be more effective than the standard curriculum because the activities conducted during the learning process are crucial in cognitive development (Erdogan, 2016). Therefore, the actions performed during the learning process are essential for guaranteeing the longevity of the information acquired. In addition, it is known that learning activities involving multiple sense organs are more permanent. With the aid of computers, educational environments that encourage the active use of these sense organs can be created (KALKANOĞLU, 2020).

Researchers also explored using software and hardware systems to enhance instrument learning. For example, (Liu & Ye, 2023) used AR technology to develop an AR system named PIANO. The design projects color and notes on the physical piano keys to ease the workload and support individual piano playing.

A study by (Wijaya et al., 2020) introduces a virtual reality (VR) piano platform that uses two Leap Motions to capture hand gestures and pressure sensors to determine if a key is depressed to improve the piano playing experience. These two pressure sensor systems aid in piano learning, but their use in piano instruction and collaborative learning remains unknown.

Although the emergence of VR technology could replace traditional music education in colleges and universities, the evaluation of VR technology in music education is very challenging and essential at the same time. The benefits of virtual reality are increasingly apparent; its adoption in learning is rapidly increasing, and more research needs to be conducted to predict better student intention to use virtual reality in learning (Radianti et al., 2020). Many studies have investigated the factors that affect the adaption of VR technology to learn music. (Table 2) shows an overview of the vital research references and their respective outcomes.

Table 2
Summary of findings from related works

Study Title	Year	Aim of the study	Findings
Finding factors influencing classroom acceptance of virtual reality using the TAM (Abd Majid et al., 2019).	2019	The study aims to determine the variables that could influence the respondents' adoption of VR in the classroom.	Revealed that in promoting fruitful VR usage in the classroom
Using the technology acceptability model to investigate student acceptability of e-learning in Jordanian universities. (Altawalbeh, 2023).	2023	Explore the factors that impact the acceptance of e-learning	E-learning advancement and training aided in focusing on how technology can help students enhance their performance and learning effectiveness
Authenticity as well as curiosity in virtual reality: Results of an experiment via educational virtual environments created with 3D modeling and photogrammetry. (Fink et al., 2023).	2023	Investigated authenticity and interest development in a VR educational setting.	Building classrooms with 3D modeling may suffice in many educational contexts where participants are primarily focused on the task and do not need to observe the fine details of enclosed 3D objects.
Assessing the impact of virtual reality-supported instruction on the learning of elementary students. (Sidhu et al., 2016).	2016	Assessing the Impact of Virtual reality-supported instruction on the learning of elementary students	The results confirmed that VR can be a useful learning instrument that provides students with learning opportunities.
Proposal and validation of a questionnaire to assess user experience in immersive virtual environments. (Tcha-Tokey et al., 2016).	2016	Verify that the UX questionnaire for IVEs, was designed using preexisting questionnaire elements and subjects.	The result provides a tool for measurement intended to measure the multiple dimensions of UX in IVE in the edutainment field, to demonstrate the reliability and internal consistency of a questionnaire using Cronbach's alpha.
Exploring the Opportunity to Use Virtual Reality for the Education of Children with Disabilities. (Chițu et al., 2023).	2023	Investigate the Ability of using virtual reality (VR) Technology to enhance the learning process of children with disabilities	VR application is a new experience; users pointed out that this technology could improve the process of educating children with disabilities and VR becomes a useful tool to support education.
Mobile virtual reality for musical genre learning in primary education. (Innocenti et al., 2019).	2019	Investigate the problem of enhancing Music learning in primary education through the use of mobile VR.	Adopting mobile VR technologies in synergy with old teaching methodologies can improve the music learning experience in primary education
Preliminary findings of a virtual reality app for children with special needs. (Laki, 2021).	2022	Discuses how virtual reality can make an impact on the lives of individuals with disabilities.	The study provides a summary of virtual reality applications developed for persons with disabilities.
From Physical to Virtual: A New Learning Norm in Music Education for Gifted Students (Ismail et al., 2022).	2022	Identify the effectiveness of level of music online distance learning among gifted students in terms of empowerment, usefulness, success, interest, and caring;	Results reveal that an online distance learning approach to music classes is significantly effective to enhance gifted students' motivation domains of empowerment, usefulness, success, interest, and caring.
Differentiated Learning Assessment Model to Improve Involvement of Special Needs Students in Inclusive Schools (Marlina et al., 2023).	2023	Measuring the Relationship of Differentiated Learning Assessment with the Involvement of Students with Special Needs in Inclusive Schools.	The study found two types of instruments that were indispensable for differentiated learning in inclusive schools, which consisted of two instruments, namely 1. An assessment instrument for differentiated learning 2. An instrument for assessing 3. Readiness, interest, and learning profile.

METHOD

This study aims to achieve two objectives. Firstly, to investigate the effectiveness of incorporating virtual reality technology in learning the "Principles of Music Theory." Secondly, it aims to investigate any variances in the attitudes of the students, with and without disabilities, towards using this technology as an educational aid.

In this regard, 20 students (10 with disabilities and 10 without disabilities) were selected from the "Principles of Music Theory" course. The students learn music theory using virtual reality applications. The sample consisted of an equal number of male and female students, as shown in (Table 3).

Table 3
Participants' Information

Students participating in the experiment	20
Female without disability	6
Female with disability	4
Male without disability	7
Male with disability	3
Study level	Years 1, 2, 3

This research employs a quantitative design, utilizing a questionnaire to gather data. The questionnaire comprises three main sections, as illustrated before in Figure 1. The first section, encompassing Questions 1 through 15, was employed to collect data on the first objective: "The effectiveness of using virtual reality technology." The second section, covering Questions 16 to 30, was utilized to collect data related to the second objective: "Intention to use virtual reality as an educational tool"

The following section discuss the proposed Technology Acceptance Model (TAM) employed to analyze factors that influence students' intention to use and accept technology.

TAM Model

The Technology Acceptance Model, "TAM," was developed based on Davis architectures; it was specifically designed to measure a user's acceptance of the use of certain types of technology through six factors, as shown in (Table 4), (Liu & Yang, 2018).

Table 4
Factors definitions

Experimental Factors	Factors Definitions
perceived usefulness	Reflects students' perception of whether the technology will enhance their performance.
Perceived ease of use	Refers to students' perception that using technology in learning will require minimal effort.
Enjoyments	Refers to the student's perception of the enjoyment level during the experiment.
Time spends learning	Refers to the daily time a student spends learning using the technology.
Authenticity	It indicates the extent to which the technology can assist in achieving the learning objectives.
Satisfaction	Refers to the quality of information provided by the technology.
Attitude toward use	Refers to student's intention to use technology in learning at present and in the future.
Technology effectiveness	Refers to the improvement of the student's performance in understanding the principles of musical theory.
Intention to use	Refers to the individual's intention to use technology as their commitment toward a technology

Many researchers have used TAM as (TEPE, 2022; Weng et al., 2018; Suad et al., 2023). According to (Chang et al., 2018; Lee et al., 2019) reported that the appropriate approach to examine the students' acceptance of VR technology in the educational setting is to expand the original TAM to include relevant factors to VR technology.

The model employed in this research is Davis's TAM model (Figure 2), expanded with new factors related to the VR/AR technology, i.e. (Time spent learning, Enjoyment, and Satisfaction) to investigate the acceptance and effectiveness of adopting VR technology in music education.

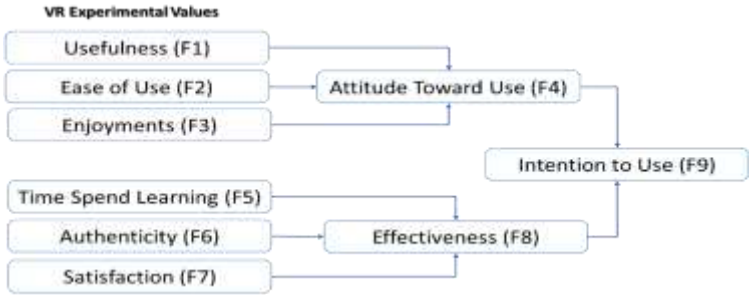

Figure 2
Modified acceptance model of adapting VR for music theory education

Research Hypotheses

Based on the TAM model presented earlier, The study proposes six factors as empirical values of virtual reality to determine the effectiveness and attitude toward the use of VR technology in learning musical theory, as well as whether these two factors lead to acceptance and adoption of the technology in the educational process.

The research proposed the following hypotheses.

H1: The experiential value of virtual reality positively influences attitudes toward technology usage
h1-a: Perceived usefulness positively affects attitude toward the use of the technology.
h1-b: Perceived ease of use positively affects attitude toward the use of the technology.
h1-c: Enjoyments positively affect attitude toward the use of technology.

H2: The experiential values of VR demonstrate a positive correlation with the effectiveness of the technology
h2-a: Time spent learning exerts a positive effect on the effectiveness of the technology.
h2-b: Authenticity exerts a positive effect on the effectiveness of the technology.
h2-c: Satisfaction exerts a positive effect on the effectiveness of the technology.

In addition to the previous considerations, the following additional hypotheses are proposed.

H3: Effectiveness and Attitude towards Use of Technology are positive indicators of Intention to Use

H4: There are no statistically significant differences between the two groups concerning the intention of using virtual reality technology as a supportive learning tool

The Proposed VR Application

The research aims to create a virtual educational platform that offers students an interactive learning experience. The platform has three main goals: to teach the

fundamental concepts of music theory for playing the piano, help students overcome learning difficulties, and improve the overall educational process outcomes.

Several tools are available for developing virtual reality applications, including Unreal Engine, Unity, CryEngine, and 3ds Max. For this study, the educational platform was created using CryEngine and 3ds Max due to the availability of free content suitable for academic environments.

Component of the Proposed VR Application

The proposed VR application aims to introduce the musical principles to the students who participated in the experiment in a way that could assist them in achieving the course's learning outcomes (Figure 7). The application components were designed without any complexity of use in the virtual environment.

Virtual Piano Keyboard

The musical keyboard was designed based on the simulation of the first and second octaves, as they constitute the main musical notes, to keep the learning environment simple and to keep students away from being distracted during the learning process, as shown in (Figure 3).

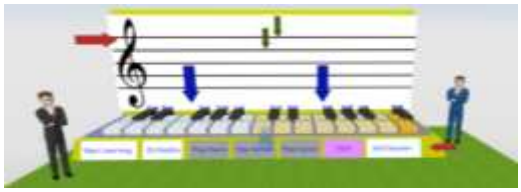

Figure 3
The proposed Virtual Piano Keyboard.

VR Musical staff

The second component is the model of the musical staff, as shown in (Figure 4), which consists of (five lines E, G, B, D, and F, and four spaces appear between these lines. The combination of the lines and spaces forms the musical staff as shown in (Figure 6). The musical staff defines the number of physical vibrations (Pitch) per second emanating from the press of the key over the musical keyboard (Coleman, 2016).

The musical scale was used to represent a series of successive tones forming the nucleus of the musical melody, and by adding the (G clef or Treble clef) the musical scale formed, as shown also in (Figure 4).

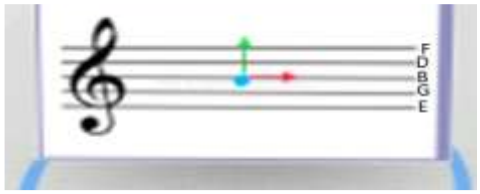

Figure 4
The virtual musical staff

The Virtual Lecturer

During the development process, it was deemed that the educational process should be more interactive to meet student expectations and enrich the educational environment. To this end, a virtual model of the lecturer, as depicted in Figure 6, was developed to present lesson topics and guide students in the virtual environment on what to do during the Learning process.

The Virtual Exam

The use of games during the learning process can help increase the learner's interaction and immersion in the lesson. According to (Aguilera & de Roock, 2022), virtual games can improve the focus and attention of students, and Game-Based Learning can improve students' attitudes toward learning.

Figure 5
The environment of the Virtual Quiz

According to (Agbo et al., 2023), the learning goals were well predicted by learners when educational game-based learning is applied. The research employed the use of virtual games to assess the development of the proposed application components, and for this purpose, a quiz was designed to measure the student's achievement in the subjects they studied, as shown above in (Figure 5). When the test starts, the roller coaster starts to move, and at each roller coaster level, the students have to answer the Quiz questions. At the end of the game, the student's score on the Quiz will be calculated.

Figure 6
Virtual lecturer model

Figure 7
Virtual lecturer mod

FINDINGS

Factors Reliability Test

Before conducting the analysis, the researchers determined the dependability and consistency of the results by conducting a validity and reliability test, which required

calculating the Cronbach's alpha coefficient to evaluate the reliability of the factors and guarantee the consistency of the items used for each factor as reported by (Nunnally & Bernstein, 2010). In Addition, Cronbach's alpha coefficient test results supported the dependability of the factors as shown in (Table 5).

Table 5
The results of Cronbach's alpha coefficient tested

TAM Factors	Result of Alpha Test	Result
Usefulness (F1)	0.865	Good
Ease of Use (F2)	0.888	Good
Enjoyments (F3)	0.909	Excellent
Attitude Toward Use (F4)	0.744	Acceptable
Time Spend (F5)	0.909	Excellent
Authenticity (F6)	0.715	Acceptable
Satisfaction (F7)	0.748	Acceptable
Effectiveness (F8)	0.728	Acceptable
Intention to Use (F9)	0.741	Acceptable

Factors and Hypotheses Analysis

To investigate the research hypotheses, partial least-squares structural equation modelling (PLS-SEM) was employed to examine the correlation between the experimental value and technology acceptance (Figure 8). This specific test was selected due to the ability of PLS-SEM to accommodate deviations from the assumptions of the normal distribution. It is also appropriate for studies with constrained sample sizes and is helpful in situations where the proposed model encompasses reflective and compositional structures (Maqableh et al., 2023; Hwang et al., 2023).

Upon conducting the PLS-SEM analysis, the research derived the path coefficient values and factor correlations to assess the strength and direction of relationships among the experimental variables. The outcomes, as presented in Tables (6 & 7), demonstrate that all path coefficients and correlation values associated with **F1** ($\beta = 0.134$, $R = 0.64$), **F2** ($\beta = 0.413$, $R = 0.72$), and **F3** ($\beta = 0.29$, $R = 0.70$) exhibited positive values, indicating significant positive direct effects on attitude toward use. Additionally, the results reveal that all path coefficients and correlation values corresponding to **F5** ($\beta = 0.349$, $R = 0.26$), **F6** ($\beta = 0.394$, $R = 0.23$), and **F7** ($\beta = 0.193$, $R = 0.46$) also display positive values, suggesting positive direct effects on technology effectiveness.

Table 6
Path coefficient (β)

Factor Paths Coefficient (β) Table			
Factor	Factor	β value	Result
Usefulness (F1)	Attitude Toward Use	0.134	Positive
Ease of Use (F2)		0.413	Positive
Enjoyments (F3)		0.29	Positive
Attitude Toward Use (F4)		0.24	Positive
Time Spend (F5)	Effectiveness	0.349	Positive
Authenticity (F6)		0.394	Positive
Satisfaction (F7)		0.193	Positive
Effectiveness (F8)	Intention To Use	0.733	Positive
Intention to Use (F9)			

Table 7
Correlation Analysis

Factors Correlations (R) Analysis				Result
Factors	F4	F8	F9	
Usefulness (F1)	0.64			Substantial
Ease of Use (F2)	0.72			Substantial
Enjoyments (F3)	0.70			Substantial
Attitude Toward Use (F4)			0.86	Perfect
Time Spend (F5)		0.26		Fair
Authenticity (F6)		0.23		Fair
Satisfaction (F7)		0.46		Moderate
Effectiveness (F8)			0.78	Substantial

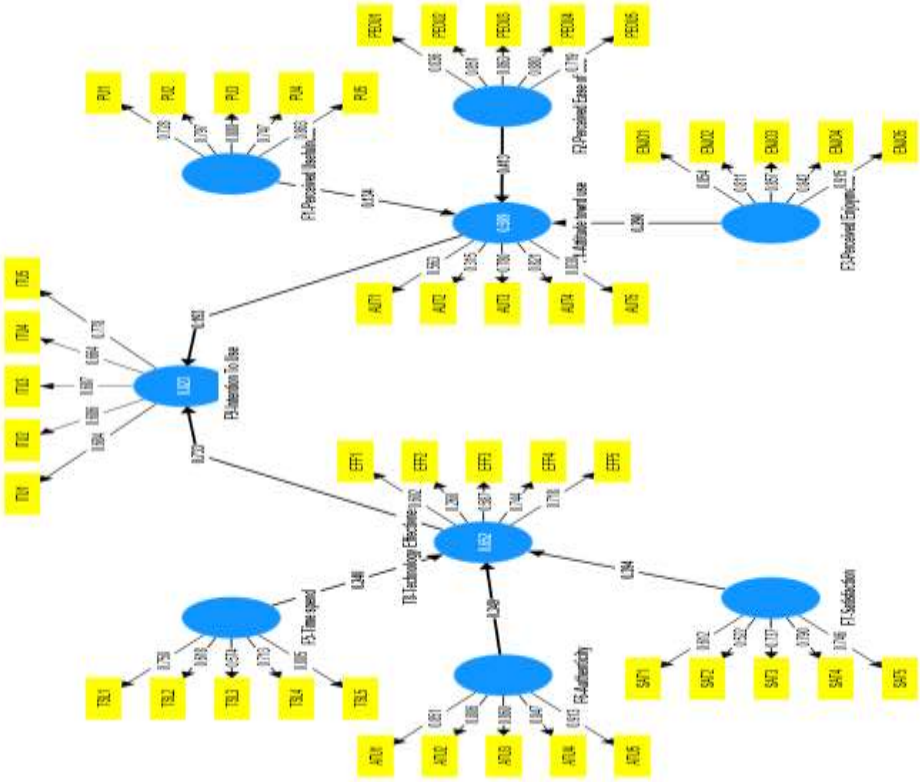

Figure 8
(PLS-SEM) Analysis model

Descriptive Analysis

The results of the descriptive analysis listed in (Table 10) show the most prominent elements that had a clear impact on the experimental factors that the research aims to investigate their impact on the technology success.

In analyzing the elements of Usefulness (F1), the results emphasize the importance of enhancing learning performance and academic productivity in this factor. While in the factor of Ease of Use (F2), there is a need to focus on the interaction methods with the virtual environment, which should be simple and avoid complexity. and related to the third factor, enjoyment (F3), the results showed that the value of enjoyment can be enhanced when the virtual environment is enriched with more of 3D virtual models.

Regarding the time factor (F5), the results showed that it is better for users to feel comfortable when using virtual reality technology in a short time.

In addition, with regard to the Authenticity factor (F6), it is necessary to provide the suitable educational content that serves the learning outcomes and to ensure the success of the educational process.

Finally, the success of the satisfaction factor (F7) depends on the availability of the proper VR devices to gain the maximum degree of immersion in the virtual environment and allow the users to interact with it.

Table 8
Factors descriptive analysis

Item No	Item Statement	Mean score
PU1	After using the VR Application, my learning performance improved.	3.73
PU2	After using the VR Application my academic productivity increased.	3.67
PEOU1	I found the VR Application easy to use.	3.83
PEOU2	I encountered no difficulties while navigating and interacting with the content in the VR environment	3.77
ENJO1	I found learning using virtual reality technology interesting.	3.73
TSL1	I have the intention to regularly utilize the VR application for practicing piano playing.	4.1
TSL5	It doesn't take much time to feel at ease and comfortable using VR technology.	3.93
AUT1	Integrating technology is relevant or applicable to my curriculum.	3.73
AUT2	The integration of VR technology has the potential to enhance learning outcomes.	3.73
SAT1	The utilization of technology simplifies the learning process for course material.	4.1
SAT2	Accessing the available technology in school is convenient for me whenever I require it.	4

Hypotheses Evaluation

Hypotheses H1

The first hypothesis, H1, was based on three sub-hypotheses (h1-a, h1-b, and h1-c), which were proposed to verify the extent to which the experimental factors influence the attitudes toward use.

The results shown in (Table 9) indicate a positive relationship between experimental factors i.e. usefulness (F1), ease of use (F2), and enjoyment (F3) and the attitude toward using technology.

Since (Cronbach's α, B-Value, and R-value) are all verified. We conclude that the hypotheses (h1-a), (h1-b), and (h1-c) have all been met, which indicates that they

positively affect attitudes toward using technology. As a result, hypothesis H1 was accepted.

Table 9
Results of PLS-SEM analysis used to test (h1-a, h1-b, h1-c)

Hypotheses	Cronbach's α	B-Value	R-value	Judgment
h1-a	0.865	0.134	0.64	Accepted
h1-b	0.888	0.413	0.72	Accepted
h1-c	0.909	0.29	0.70	Accepted
H1	Accepted			

Hypotheses H2

The second hypothesis, H2, was also formulated based on three sub-hypotheses (h2-a, h2-b, and h2-c) to investigate the relationship and impact of the experimental factors on technology effectiveness. Through an analysis of the results presented in (Table 10), specifically focusing on the factors of time spent (F5), Authenticity (F6), and Satisfaction (F7), it is evident that there exists a positive correlation between these factors and technology effectiveness. Therefore, we can conclude that hypotheses (h2-a), (h2-b), and (h3-c) are supported, indicating that they exert a positive effect on technology effectiveness. As a result, *hypothesis H2 is accepted*.

Table 10
Results of PLS-SEM analysis used to test (h2-a, h2-b, h2-c)

Hypotheses	Cronbach's α	β value	R-value	Judgment
h2-a	0.909	0.349	0.26	Accepted
h2-b	0.715	0.394	0.23	Accepted
h2-c	0.748	0.193	0.46	Accepted
H2	Accepted			

Hypotheses H3.

The third hypothesis, H3, was formulated to explore the relationship between attitude towards use (F4) and technology effectiveness (F8) and their impact on intention to use, also referred to as technology acceptance. Analyzing the findings presented in (Table 11), confirmed that both variables (F4 and F8) positively impact the intention to use. Consequently, *H3 is supported.*

Table 11
Results of PLS-SEM analysis used to test H3

Hypotheses	Cronbach's α	β value	R-value	Judgment
F4	0.744	0.240	0.86	Accepted
F8	0.728	0.733	0.78	Accepted
H3	Accepted			

Hypotheses H4

H4, as stated in Section 4.2, suggested that there are no significant differences between the two groups regarding the intention to use VR technology as a supportive educational tool. However, upon analyzing the results presented in (Table 12), it is evident that

there are apparent differences between the averages of participants' responses related to their intention to use VR.

For example, among the group of students with disabilities, 70% expressed a desire to use VR technology in the future, compared to 55% among students without disabilities. Similarly, 80% of students with disabilities exhibited a positive attitude towards VR technology, whereas only 55% of students without disabilities did so. Additionally, 85% of students with disabilities believed VR technology could enhance their engagement with the learning experience, compared to 60% of students without disabilities. Furthermore, 80% of students with disabilities felt a strong sense of presence in the virtual world, while 70% of students without disabilities reported the same experience. Also, 85% of students with disabilities believed that VR technology could enhance their understanding of the learning content, whereas 70% of students without disabilities shared this belief.

In conclusion, while the results demonstrate that both groups are attentive to VR technology, there is a notable disparity in the percentage of intention to use between these two groups. Students with disabilities scored (80%), whereas students without disabilities scored (60%). Consequently, *H4 is rejected.*

Table 12
Average of participants' responses on items related to intention to use

	Planning to use VR	Attitude towards AR	VR Improve engagement	Presence in the Virtual world	better enhance	Intention to use
Disability	70%	80%	85%	80%	85%	80%
With No Disability	55%	55%	60%	70%	70%	60%

Research Limitations

This study aimed to analyze the effectiveness of using virtual reality technology in music education. The research conducted during the COVID-19 pandemic presented some challenges to optimally conducting the research.

In the first aspect, the challenges primarily related to the participants' fear of interacting with others, which led to the limited number of participants in the experiment, as we mentioned previously in (Table 3).

As for the second challenge, student participation was limited to students with disabilities, such as mobility impairment, and those with other disabilities did not participate due to the restrictions imposed during the COVID-19 pandemic. Finally, due to the challenges, the study sample consisted of only 20 students, who were divided into small groups and conducted experiments at different time intervals.

DISCUSSION

Based on the study results, the use of Virtual Reality (VR) technology in teaching the "principles of music theory" has been successful in improving students' learning outcomes. This success was attributed to the verification of all the factors specified in the Technology Acceptance Model (TAM), which include usefulness, ease of use, enjoyment, attitude toward use, time spent, authenticity, satisfaction, and effectiveness,

this is also supported by (Fussell et al., 2019) he states that the original TAM factors showed strong relationships with factors used to measure VR technology in learning.

In the first hypothesis, the research suggested that there is a relationship between the experimental factors i.e. (usefulness, ease of use, and enjoyment) and the student's attitudes toward use. By analyzing the results of the path coefficient for each of the sub-hypotheses (h1-a, h1-b, h1-c) as shown in Table (6), the research found that the students found VR technology useful, easy to use, and enjoyable during the learning process. Consequently, the experimental factors have a positive impact on attitudes toward using virtual reality technology. Therefore, the first hypothesis is accepted.

The second hypothesis came to examine the effectiveness of using VR technology. The hypothesis suggested that Time spent (F5), Authenticity (F6), and Satisfaction (7) are experimental factors. The Path coefficient results in Table 6 show a positive relationship between the experimental factors and the effectiveness of the technology. Consequently, each of the sub-hypotheses (H2-a, H2-b, and H2-c) was accepted. This suggests that students found the use of VR technology will not take much time, the technology has no impact on their health, and it can help to achieve the learning objectives. As a result, these three factors have a positive impact on the effectiveness of the technology. Therefore, the second hypothesis is accepted.

The third hypothesis came to evaluate whether the effectiveness and attitude towards technology use are having positive indicators of the intention to use VR technology. The hypothesis proposed that both effectiveness (F8) and attitude towards use (F4) are experimental factors that positively influence the intention to use. The path coefficient results (β) in Table 6 indicate a positive relationship between the experimental factors and the intention to use VR technology. As a result, H3 was accepted, suggesting that students have a positive attitude towards using VR technology and found it effective in learning music principles. Therefore, the students have a positive intention to use VR technology.

The fourth and final hypothesis aimed to verify the intention of using virtual reality technology among students with disabilities and other students. The hypothesis suggested that there are no statistical differences in the intention to use between the two groups. However, based on the results presented in Table (12), the research found that there are statistically significant differences between the two groups. The results confirmed that students with disabilities have a greater intention to use the technology. This can be explained by the fact that students with disabilities found that virtual reality technology helps them overcome the physical disability that they suffer from, this is supported by (Sohrabei and Atashi, 2021) as they indicate that the use of virtual reality in mobile health can be effective for educating patients and reducing fear and anxiety, especially for the disabled.

CONCLUSIONS

The lockdowns and associated closures of schools implemented in response to the arrival of the COVID-19 pandemic represented a sudden and unprecedented event for which the education sector was unprepared to face its consequences. However, online

and distance learning arrangements were put in place at short notice in emergency circumstances. Although it was not an ideal replacement for face-to-face classes, it allowed most teachers to continue teaching and most students to continue learning.

This study demonstrates that integrating virtual reality technology with information technology can create a realistic educational environment, enhancing self-directed learning motivation among students. The study also showed that using virtual reality technology as an alternative to traditional methods can be used to overcome obstacles to learning music. This study presented an innovative virtual reality (VR) approach to teaching/learning the principal theory of music.

As part of the research, a virtual reality (VR) application was created to teach elementary music theory effectively. The study found that the approach and application were successful in participation and learning outcomes. It is worth noting that both disabled and non-disabled students showed high levels of acceptance towards using VR in music education. In addition, the study shows that using virtual reality technology in music learning allows teachers to conduct assessments in an enjoyable environment while allowing students to practice music during lectures or on their own time. As a result, students participating in the experiment showed an improvement in their intention to use this technology, and it's worth noting that students with disabilities expressed a higher intention to use virtual reality technology for learning music than other students.

In the future, the research will aim to broaden its scope by including a more significant number of students with disabilities. This will enable us to understand their learning needs better and identify more tools that can be used to enhance the learning outcomes. Additionally, the research intends to explore the feasibility of applying virtual reality technology in other educational subjects that cater to the needs of this category of students.

SUGGESTION

As discussed in the descriptive analysis section (4.3), Table 8 summarizes the key elements that positively impact the success of VR technology as an educational tool. Therefore, these elements must be considered when developing similar educational tools.

According to the research, to achieve the best degree of Attitude toward use, we need to focus on enhancing learning performance and academic productivity. Additionally, we need to focus on simple methods of interaction with the virtual environment. The virtual reality environment should be enhanced with attractive 3D models to increase user enjoyment.

Regarding the effectiveness factor, attention must be paid to ensuring that users feel comfortable during shorter periods of using virtual reality technology. The content provided must suit the curriculum to ensure the achievement of learning outcomes. It is also essential to ensure the availability of necessary devices for virtual reality technology.

These factors significantly influence users' attitudes, enjoyment, and perceived effectiveness of virtual reality technology.

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