



Studies on the Use of Augmented Reality in Music Education in Türkiye

Köksal Apaydın* and Merve Şentürk
Ordu University, Türkiye

Abstract

Augmented reality (AR) is one of the latest technologies enabling interaction by merging virtual 3D images with the real world through mobile devices, such as smartphones and tablets. As it is frequently used in medicine, engineering, military, and architecture, it has also been applied in various fields of education in recent years. One of these field is music education, and while the number is limited, studies on augmented reality in Türkiye are being conducted. In this context, this research aimed to reveal the current status and trends of music education studies using AR technology in Türkiye. For this descriptive research, the Council of Turkish Higher Education Thesis Center, TR Index, DergiPark, and Google Scholar databases were used, and four master's theses, two doctoral dissertations, three articles, one conference proceeding, and a book chapter were found. In addition to these studies, a master's thesis that examines the effect of AR technology used in music courses on the achievements of high school students is being conducted under the author's supervision. The data obtained from the publications were classified into five categories: years, publication types, study groups, subjects, and outcomes, and were analyzed using content analysis method. The findings showed that the highest number of publications belonged to 2023. This study indicated that 3D visuals created with this technology enhanced students' interest and motivation in the classroom, facilitated learning due to attractive and entertaining applications, and that mobile devices (such as smartphones and tablets) used in AR applications were more advantageous than virtual reality headsets. However, limitations in this study include technical issues caused by outdated mobile devices and synchronization problems between audio and visuals. Based on the results, guiding recommendations were developed for researchers interested in conducting studies related to the use of AR in music education.

Keywords: digitalization, augmented reality, education, music, technology

1. Introduction

Augmented reality (AR) is one of the latest technologies enabling interaction by merging virtual 3D images with the real world through mobile devices, such as smartphones and tablets.

This technology enriches knowledge in the fields where it is used, concretizes abstract concepts, and facilitates the learning of complex ideas and subjects (Azuma, 1997). Initially, AR technology, with these advantages, was predominantly employed in military applications and space research. However, over time, it has evolved to be used in medicine, engineering, architecture, commerce, tourism, and entertainment (Feiner, 2002; Van Krevelen & Poelman, 2010; Somyürek, 2014; Altınpulluk, 2018; Kuzgun, 2019). With its accessibility, AR technology has become a part of daily life and is utilized in almost every field. It is also frequently applied in the field of education, such as natural sciences (physics, chemistry and biology), mathematics, computer and instructional technologies, history, geography, and language teaching (Altınpulluk, 2018; Sırakaya & Alsancak Sırakaya, 2018). A literature review reveals that music education has also been integrated into this list, with studies combining this technology with music education. In this context, Yang (2020) introduced the features of several AR applications (e.g., Vicon Mx 3D project, AR piano system, Keynvision, Andantino) among the modern technologies utilized in piano education. The study further explored the effectiveness and limitations of these applications in the context of music education and instrumental training. Serafin et al. (2017) observed that AR applications in music education were predominantly used for learning instruments such as the piano and the guitar. Similarly, Turchet et al. (2021) highlighted that the piano is the most extensively examined instrument in research involving AR technology. Additionally Lu (2024) investigated the impact of AR technology on the development of left-hand piano playing skills among piano students. The study utilized the AR Piano application, which generates three-dimensional, intuitively comprehensible visualizations designed to facilitate the piano learning process and minimize students' cognitive load. The findings indicated that AR-based instruction had a positive effect on the development of motor skills in the experimental group, demonstrating the potential of AR technology to enhance piano education.

Apart from these studies, Apaydınlı (2023) examined research indexed in the Web of Science (WoS) and Scopus databases, focusing on the use of AR technology in music education. The findings revealed that the first study in this field was conducted in 2006, with study groups ranging from kindergarten to undergraduate-level students. Moreover, the studies originated from various countries, including Austria, Belgium, Brazil, China, Colombia, Germany, Greece, Indonesia, Japan, Malaysia, New Zealand, Portugal, Taiwan, and the USA. This broad geographical distribution underscores the global relevance of AR in music education. A significant majority of these studies focused on prototype development in instrumental education, especially concerning piano and guitar instruction aimed at beginner-level students. The reviewed studies emphasized the effectiveness of AR applications in music education in enhancing cognitive skills and facilitating learning (Martin-Gutierrez et al., 2020; Rogers et al., 2014; Sun & Chiang, 2018). Additionally, these applications were found to engage and entertain students (Cai et al., 2019; Li, 2018; Martins et al., 2015; Molloy et al., 2019; Zhang et al., 2015) while also increasing motivation and success in instrumental training (Preka & Rangoussi, 2019; Rio-Guerra et al., 2019; Zhang et al., 2015). However, alongside with these advantages, certain limitations were noted, including difficulties in accurate marker recognition and technical issues such as lagging and freezing during application use (Sun & Chiang, 2018; Tan & Lim, 2019).

In addition to these academic studies, major educational organizations have recognized the potential of AR in enhancing music education. For instance, the European Commission's Apollo project employs state-of-the-art AR and VR technologies to preserve and promote Berlin's classical heritage, thereby bringing it into the digital age. This project enhances music education by providing immersive experiences that allow learners to engage with classical music in innovative ways (European Commission, 2019). Furthermore, in collaboration with

the Republic of Korea, UNESCO has launched the "Digital Creativity Lab" project, which aims to empower youth with digital skills, including AR applications. This project fosters innovation and cultural growth, providing young professionals with essential digital competencies that can be applied in various fields, including music education (UNESCO, 2025).

In Türkiye, however, research on the use of AR technology in music education is still in its early stages. Although limited in number, studies in this field have begun to emerge.

1.1 Aim of the research

This research aimed to reveal the current status and trends of music education studies using augmented reality technology in Türkiye. The research questions are given below:

1.1.1 Research questions

- a. What is the distribution of the studies on augmented reality in music education in Türkiye
 - by years?
 - by publication types?
 - by study groups?
 - by subjects?
- b. What are the outcomes of the studies on augmented reality in music education in Türkiye?

2. Method

This research was a qualitative study conducted using a descriptive survey model. It is a research approach that aims to present the subject of study as it exists, portraying the current situation and thereby seeking to understand the problem through depiction (Karasar, 2014; Arıkan, 2021). In descriptive survey studies, the literature related to the identified research topic is systematically reviewed, and the data can be analyzed based on their frequency and prevalence (frequency distribution). Frequency distribution enables the data to be expressed in terms of numbers or percentages (Büyüköztürk, 2008). In this study, the descriptive survey model was used, as the current state of studies on the use of AR technology in music education in Türkiye was depicted.

The data were obtained from the Council of Turkish Higher Education Thesis Center, TR Index, DergiPark, and Google Scholar databases using the keywords “augmented reality” and “music education”, without any year limitations, and were classified into five categories: years, publication types, study groups, subjects and outcomes. To identify trends in the studies, the data were systematically organized into frequency tables and charts for clarity and were presented in the results section for better comprehension. Outcomes were analyzed using the content analysis method, a systematic approach for classifying and interpreting scientific data by organizing it into predefined or emerging themes and categories, allowing for synthesis and the development of theoretical insights (Cohen, Manion, & Morrison, 2018; Finfgeld-Connett, 2014).

3. Results

The studies conducted in Türkiye on music education using AR technology, as identified through a literature review, are shown in detail in Table 1.

Table 1: The studies conducted in Türkiye on music education using AR technology

#	Publication Type	Title	Author(s)	Year	Department	Subject	Study Group
1	Master's Thesis	An Augmented Reality Application for Virtual Instrument Playing	Onur AGBULUT	2017	Computer Engineering	Development of AR Application for Musical Instruments	Volunteer players
2	Book Chapter	A Review of Mobile Applications Designed with Augmented Reality for Music Education: An IOS Operating System Example.	Burcu KALKANOGLU	2020	Musicology	Other	AR apps: Piano 3D-AR, Guitar 3D, Tonic-AR, Note Blast, Music.iLuv.
3	Master's Thesis	Augmented Reality Technology in Music Education and Sample Application	Hatice GUCLU	2021	Computer Engineering	Development of an AR Application in Instrument Education	Primary school students
4	Proceeding*	Application of Augmented Reality in Music Education	Hatice GUCLU Sabri KOCER Ozgur DUNDAR	2021	Computer Engineering	Development of an AR Application in Instrument Education	Primary school students
5	Master's Thesis	Piano Teaching Mobile Application with Augmented Reality	Ismail Mohammed JAMAL	2022	Computer Engineering	Development of AR Application for Musical Instruments	Volunteer participants
6	Article*	A New Approach in Turkish Music Instrument Training: Augmented Reality Technology	Ersin ORHAN Levent DEGIRMENCI OGLU	2022	Music	Development of an AR Application in Instrument Education	-
7	Doctoral Dissertation	Augmented Reality Based Digital Material Design in Musical Instrument Education	Ersin ORHAN	2023	Music	Development of an AR Application in Instrument Education	Undergraduate students of Music Department
8	Doctoral Dissertation	The Effect of Augmented Reality Based Applications on Performance in Piano Education	Kenan TUFEKCI	2023	Music Education	Development of an AR Application in Instrument Education	Undergraduate students of Music Department
9	Article*	Student Opinions on Augmented Reality Applications in Piano Education	Kenan TUFEKCI Sadik OZCELIK	2023	Music Education	Development of an AR Application in Instrument Education	Undergraduate students of Music Department
10	Article	Augmented Reality and Music Education	Ismet ARICI	2023	Music Education	Other	AR apps: Piano Vision, Groove Reality, SoundStage AR, Chordana Play

* The studies derived from theses in collaboration with supervisors.

11	Master's Thesis	The Effect of an Augmented Reality Application For Beginner Piano Training On Students' Sight-Reading Skills	Volkan BATU	2023	Music Education	Instrument Education with Existing AR Application (Simply Piano)	High school students
-	Master's Thesis	An Investigation into the Impact of Augmented Reality Application Developed for Music Courses on High School Students' Academic Achievement.	Merve SENTURK	Continued	Music	Development of an AR Application in Music Education	High school students

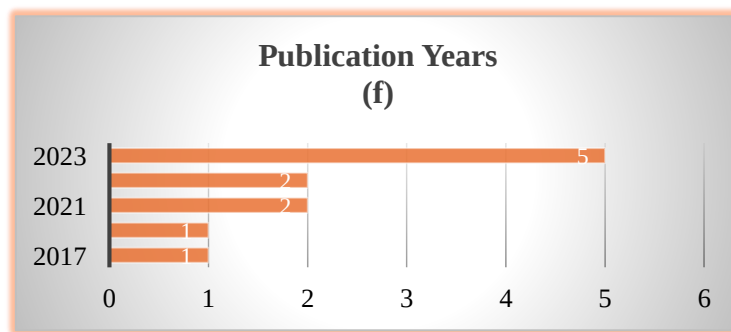
As shown in Table 1, eleven studies-including master's theses and doctoral dissertations, articles, conference proceeding and a book chapter-were conducted in Türkiye between 2017 and 2023. In addition to these studies, a master's thesis examining the effect of AR technology used in music courses on high school students' achievements is being conducted under the author's supervision.

3.1. Findings related to the first research question

The studies were categorized by years, publication types, study groups, and subjects, and were presented using the figures below.

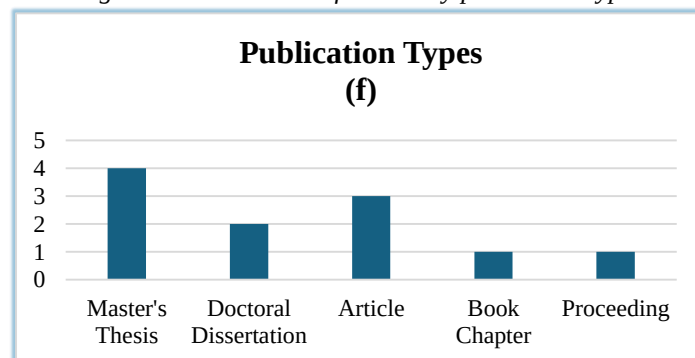
As shown in Figure 1, the first study utilizing AR technology in music education was conducted in 2017, with no studies undertaken between 2018 and 2020. Starting in 2021, the number of studies began to rise, reaching its peak in 2023 with a total of five studies conducted.

Figure 1: Distribution of the studies by years



According to Figure 2, four master's theses, two doctoral dissertations, three articles, one book chapter and one conference proceeding were found.

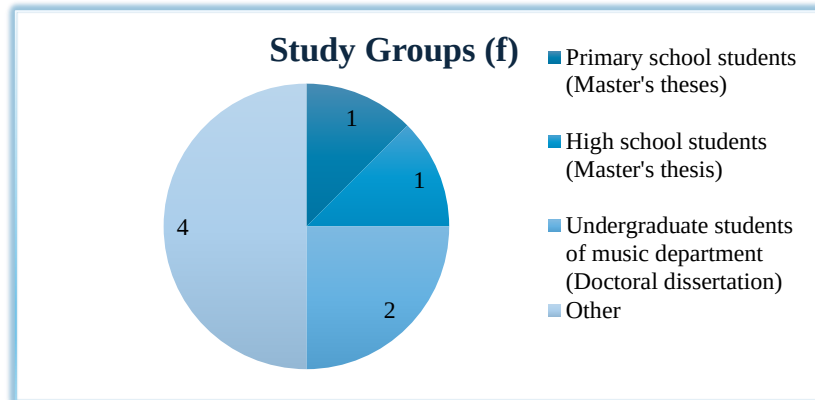
Figure 2: Distribution of studies by publication types



A review of the publications showed that two articles (Orhan and Değirmencioglu, 2022; Tufekçi and Özçelik, 2023) and one proceeding (Güçlü, Koçer, and Dündar, 2021) were derived from theses in collaboration with supervisors. Three of the master's theses belonged to the department of computer engineering, while remaining studies were from departments related to the field of music.

As shown in Figure 3, the studies were conducted with primary school, high school, and undergraduate students. The study groups from articles based on theses were not included in this dataset.

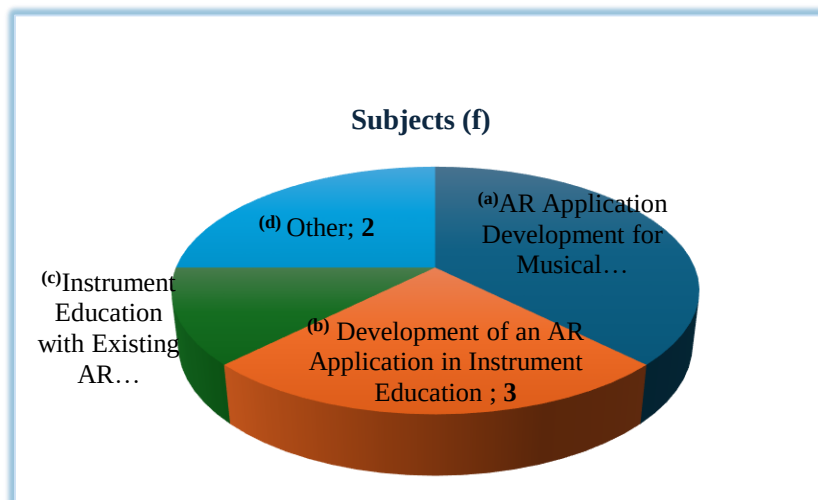
Figure 3: Distribution of studies by study groups



According to Figure 3, a total of two master's theses were conducted—one with primary and one with high school students—while two doctoral dissertations were conducted with undergraduate music students. Half of the research sample (n=4) belonged to the “other” category, consisting of applications available in app stores and feedback from volunteer participants regarding the developed applications.

According to Figure 4, two studies were related to AR application development for musical instruments^(a), while three studies focus on the use of developed AR applications in instrument education^(b). Additionally, one study was concerned with the use of an existing AR application in instrument education^(c).

Figure 4: Distribution of studies by subjects



Studies in the “Other” category involved the overview of certain augmented reality applications in the music field available on the application store^(d). The subjects of the studies derived from theses were not included in this dataset.

The contents of the studies concerned with the subjects in Figure 4 were detailed in Table 2 below.

Table 2: Contents of the studies

#	Publication Type	Title	Author(s)	Year	Content
1	Master's Thesis	An Augmented Reality Application for Virtual Instrument Playing	Onur AGBULUT	2017	To create a virtual drum utilizing the technologies of augmented reality and motion capturing (Microsoft Kinect) in the comfort of user's home ^(a) .
2	Book Chapter	A Review of Mobile Applications Designed with Augmented Reality for Music Education: An IOS Operating System Example.	Burcu KALKANOGLU	2020	A presentation of five augmented reality applications designed for music education on the IOS operating system, including an assessment of their strengths and limitations ^(d) .
3	Master's Thesis	Augmented Reality Technology in Music Education and Sample Application	Hatice GUCLU	2021	Teaching of simple school songs composed of basic notes through the developed AR-Recorder app ^(b) .
4	Proceeding*	Application of Augmented Reality in Music Education	Hatice GUCLU Sabri KOCER Ozgur DUNDAR	2021	Teaching of simple school songs composed of basic notes through the developed AR-Recorder app.
5	Master's Thesis	Piano Teaching Mobile Application with Augmented Reality	Ismail Mohammed JAMAL	2022	To create an affordable, simple, easy-to-set-up, and accessible piano teaching mobile AR application, named EasyARPiano ^(a) .
6	Article*	A New Approach in Turkish Music Instrument Training: Augmented Reality Technology.	Ersin ORHAN Levent DEGIRMENCI OGLU	2022	The development of a prototype that enables self-guided learning in Turkish music instrument education using augmented reality technology.
7	Doctoral Dissertation	Augmented Reality Based Digital Material Design in Musical Instrument Education	Ersin ORHAN	2023	The development of a digital design utilizing AR technology for Turkish music instruments, ud and baglama, featuring content, such as sheet explanations (with avatars), reference performances (from different performers), educator performances, sight-reading exercises, cursor-guided sheets, accompaniment with qanun and kaval, and 3D concert hall ^(b) .
8	Doctoral Dissertation	The Effect of Augmented Reality Based Applications on Performance in Piano Education	Kenan TUFEKCI	2023	The effect of animation-supported AR applications, designed for legato, staccato, and non-legato techniques, on students' piano-playing skills ^(b) .
9	Article*	Student Opinions on Augmented Reality Applications in Piano Education	Kenan TUFEKCI Sadik OZCELIK	2023	Student perspectives on the effect of AR applications, created for legato, staccato, and non-legato techniques, on piano-playing skills.
10	Article	Augmented Reality and Music Education	Ismet ARICI	2023	A presentation of several existing mobile AR applications and their contributions to music education ^(d) .

11	Master's Thesis	The Effect of an Augmented Reality Application For Beginner Piano Training On Students' Sight-Reading Skills	Volkan BATU	2023	The effect of an existing augmented reality application (Simply Piano) designed for beginners in piano education on students' sight-reading skills ^(c) .
----	-----------------	--	-------------	------	---

*The studies derived from theses in collaboration with supervisors.

3.2. Findings related to the second research question

The conducted studies revealed that AR technology had positive contributions to music education. The 3D visuals created with this technology increased interest and motivation towards lessons, and due to the engaging nature of its applications, it notably facilitated learning for beginners in instrument training. Students demonstrated increased awareness of the subject and a better understanding of topics. Additionally, mobile devices (smartphones and tablets) used in AR applications were considered more advantageous than virtual headsets. However, alongside these positive outcomes, certain limitations emerged, such as technical issues due to outdated mobile devices, synchronization problems between visuals and audio, the inability of videos in the applications to work offline, and the weight of smart glasses causing fatigue during long-term use.

4. Conclusion

This study focuses on music education research in Türkiye that utilizes AR technology. The results revealed 11 publications: four master's theses, two doctoral dissertations, three articles, one conference proceeding and a book chapter. Additionally, there is an ongoing master's thesis related to AR and music education under the author's supervision. However, it has not been completed and has not been included in the quantitative data of this research.

The first study in this field in Türkiye, a master's thesis in computer engineering aimed at developing an AR-based drum, was completed in 2017. This was followed by another master's thesis in 2021, also in computer engineering, focused on developing an AR-Recorder. However, it appears that these studies did not employ any assessment tools to measure the impact of AR technology in music education on students' achievement or motivation. The effect of this technology on instrumental courses is observed in master's and doctoral theses in music from 2023, with the highest number of studies in this field.

Upon examining all the studies conducted, it is understood that AR technology offers advantages such as increasing interest and motivation towards lessons and facilitating learning. However, it also presents certain limitations, including device overheating, synchronization issues between visuals and audio, and problems with image-based recognition. In today's rapidly advancing technological landscape, it is believed that these technical challenges can be resolved over time.

In Türkiye, the use of AR in music education remains a new research area with a limited number of studies. To promote the broader application of this technology in music education—already utilized in many fields of education today—it is recommended to provide teachers and academics with training on AR technology and encourage academics interested in this field. Since the existing studies have primarily focused on instrument training, future research could explore the impact of AR technology on students' achievement and motivation in music history, music theory, choir, and orchestra. In addition to these, interdisciplinary studies involving music educators could be conducted, and collaborative European Union projects could be developed between universities in Turkey and those abroad.

Acknowledgment

This study was supported by the Ordu University Scientific Research Projects Committee under the project code B-2415.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

References

- Ağbulut, O. (2017). An augmented reality application for virtual instrument playing. Unpublished Master's Thesis, Yaşar University, Graduate School of Natural and Applied Sciences, Department of Computer Engineering, Istanbul, Türkiye.
- Altınpulluk, H. (2018). Examination of theses on augmented reality in Turkey through bibliometric analysis method. *Educational Technology Theory and Practice*, vol. 8, issue 1, pp. 248-272.
- Apaydınlı, K. (2023). Content analysis of music education studies related to augmented reality technology. *Journal of Educational Technology & Online Learning*, [Online]. Vol. 6, issue.2, pp. 447-481. Available: <https://doi.org/10.31681/jetol.1243501>
- Arıcı, İ. (2023). Augmented reality and music education. *Journal of Current Researches on Social Sciences*, [Online]. Vol. 13 issue 4, pp. 355-362. Available: <https://doi.org/10.26579/jocress.13.4.2>
- Arıkan, R. (2021). *Research Methods and Techniques*, 4 th ed. Ankara: Nobel Academic Publications.
- Azuma, R. T. (1997). A survey of augmented reality. Presence: *Teleoperators and Virtual Environments*, [Online]. Vol. 6 issue 4, pp. 355-385. Available: <https://doi.org/10.1162/pres.1997.6.4.355>
- Batu, V. (2023). The effect of an augmented reality application for beginner piano training on students' sight-reading skills, Unpublished Master's Thesis, Gazi University, Institute of Educational Sciences, Department of Music Education, Ankara, Türkiye.
- Büyüköztürk, Ş. (2018). *Handbook of Data Analysis for Social Sciences*. Ankara: Pegem Academic Publications.
- Cai, M., Amrizal, M. A., Abe, T., & Suganuma, T. (2019). Design of an AR-Based System for Group Piano Learning. *IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, 20-21. <https://doi.org/10.1109/ISMAR-Adjunct.2019.00020>
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed). Routledge. <https://doi.org/10.4324/9781315456539>
- European Commission, (22 November 2019). Preserving Berlin's musical treasures with augmented reality and virtual reality. Available: https://ec.europa.eu/regional_policy/en/projects/Germany/preserving-berlins-musical-treasures-with-augmented-and-virtual-reality

- Finfgeld-Connett, D. (2014) Use of content analysis to conduct knowledge-building and theory-generating qualitative systematic reviews. *Qualitative Research*, 14 (3), pp. 341–52. <https://doi.org/10.4324/9781315456539>
- Feiner, S. (2002). Augmented reality: A new way of seeing. *Scientific American*, vol. 286, issue 4, pp. 48–55. <https://doi.org/10.1038/scientificamerican0402-48>
- Güçlü, H. (2021). Augmented reality technology in music education and sample application Unpublished Master's Thesis, Necmettin Erbakan University, Institute of Science, Department of Computer Engineering, Konya, Türkiye. <https://doi.org/10.55549/epstem.1050174>
- Güçlü, H., Koçer, S. and DüNDAR, O. (2021). Application of augmented reality in music education. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)*, vol. 14, Antalya, Türkiye, pp. 45-56.
- Jamal, I. M. (2022). Piano teaching mobile application with augmented reality. Unpublished Master's Thesis. Ondokuz Mayıs University, Graduate School, Department of Computer Engineering, Samsun, Türkiye.
- Kalkanoğlu, B. (2020). *A review of mobile applications designed with augmented reality for music education: An iOS operating system example*. In Academic Researches in Educational Sciences, (Ed. Gülnaz Kurt), pp. 7-35. İzmir: Duvar Publishing.
- Karasar, N. (2014). *Scientific Research Methods: Concepts, Principles, Techniques*. Ankara: Nobel Academic Publications.,
- Kuzgun, H. (2019). Utilization of augmented reality in early childhood: A case study. Unpublished Master's Thesis, Afyon Kocatepe University, Institute of Science, Afyonkarahisar, Türkiye.
- Li, L. (2018). Application of Augmented Reality Technology in Piano Teaching System Design. *Educational Sciences: Theory & Practice*, 18(5), 1712-1721. <https://doi.org/10.12738/estp.2018.5.070>
- Lu, D. (2024). The Impact of Augmented Reality on Motor Skills in Piano Education: Improving the Left-Hand Technique with AR Piano. *International Journal of Human-Computer Interaction*, 1–11. <https://doi.org/10.1080/10447318.2024.2408627>
- Martin-Gutierrez, J., Del Rio Guerra, M. S., Lopez-Chao, V., Soto Gastelum, R. H., & Valenzuela Bojórquez, J. F. (2020). Augmented Reality to Facilitate Learning of the Acoustic Guitar. *Applied Sciences*, 10(7), 1-14. <https://doi.org/10.3390/app10072425>
- Martins, V. F., Gomes, L., & Guimarães, M. (2015). Challenges and Possibilities of Use of Augmented Reality in Education. *Proceedings of 15th International Conference on Computational Science and Its Applications (ICCSA)*, 9159, 223-233. https://doi.org/10.1007/978-3-319-21413-9_16
- Molloy, W., Huang, E., & Wunsche, B. C. (2019). Mixed Reality Piano Tutor: A Gamified Piano Practice Environment. *Proceedings of International Conference on Electronics, Information, and Communication (ICEIC)*, 1-7. <https://doi.org/10.23919/ELINFOCOM.2019.8706474>
- Orhan, E. (2023). Augmented reality based digital material design in musical instrument education. Unpublished Doctoral Dissertation, Erciyes University, Institute of Fine Arts, Department of Music, Kayseri, Türkiye.

- Orhan, E. and Değirmencioğlu, L. (2022). A new approach in Turkish music instrument training: Augmented reality technology. *International Journal of Eurasian Education and Culture*, [Online]. Vol. 7 issue 18, pp. 1917-1967. Available: <https://doi.org/10.35826/ijoecc.601>
- Preka, G., & Rangoussi, M. (2019). Augmented Reality and QR Codes for Teaching Music to Preschoolers and Kindergarteners: Educational Intervention and Evaluation. *Proceedings of the 11th International Conference on Computer Supported Education*, 113-123. <https://doi.org/10.5220/0007682301130123>
- Rio-Guerra, M. S., Martin-Gutierrez, J., Lopez-Chao, V. A., Flores Parra, R., & Ramirez Sosa, M. A. (2019). AR Graphic Representation of Musical Notes for Self-Learning on Guitar. *Applied Sciences*, 9(21), 1-14. <https://doi.org/10.3390/app9214527>
- Rogers, K., Weber, M., Röhligh, A., Weing, M., Gugenheimer, J., Könings, B., Klepsch, M., Schaub, F., Rukzio, E., & Seufert, T. (2014). P.I.A.N.O.: Faster Piano Learning with Interactive Projection. *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces - ITS '14*, 149-158. <https://doi.org/10.1145/2669485.2669514>
- Serafin, S., Adjorlu, A., Nilsson, N., Thomsen, L., & Nordahl, R. (2017). Considerations on the use of virtual and augmented reality technologies in music education. *Virtual Reality Workshop on K-12 Embodied Learning through Virtual Augmented Reality (KELVAR)*, 1-4. <https://doi.org/10.1109/KELVAR.2017.7961562>
- Sırakaya, M. and Alsancak Sirakaya, D. (2018). Trends in educational augmented reality studies: A systematic review. *Malaysian Online Journal of Educational Technology*, [Online]. Vol. 6 issue 2, pp. 60-74. Available: <https://doi.org/10.17220/mojet.2018.02.005>
- Somyürek, S. (2014). Gaining the attention of generation z in learning process: Augmented reality. *Educational Technology Theory and Practice*, [Online]. Vol. 4 issue 1, pp. 63-80. Available: <https://doi.org/10.17943/etku.88319>
- Sun, C.-H., & Chiang, P.-Y. (2018). Mr. Piano: A Portable Piano Tutoring System. *Proceedings of IEEE XXV International Conference on Electronics, Electrical Engineering and Computing (INTERCON)*, 1-4. <https://doi.org/10.1109/INTERCON.2018.8526423>
- Tan, K., & Lim, C. (2019). Malaysian Music Augmented Reality (MMAR): Development of Traditional Musical Instruments Using Augmented Reality. *International Journal of Innovative Technology and Exploring Engineering*, 8(4S), 340-345.
- Turchet, L., Hamilton, R., & Camci, A. (2021). Music in Extended Realities. *IEEE Access*, 9, 15810-15832. <https://doi.org/10.1109/ACCESS.2021.3052931>
- Tüfekci, K. (2023). The effect of augmented reality based applications on performance in piano education, Unpublished Doctoral Dissertation, Gazi University, Institute of Educational Sciences, Department of Music Education, Ankara, Türkiye.
- Tüfekci, K. and Özçelik, S. (2023). Student opinions on augmented reality applications in piano education. *Journal of Kırşehir Education Faculty*, [Online]. Vol. 24 issue 1, pp. 547–569. Available: <http://kefad.ahievran.edu.tr>
- UNESCO, (13 January 2025). UNESCO and Republic of Korea upskill youth through a creativity lab. Available: <https://www.unesco.org/en/articles/unesco-and-republic-korea-upskill-youth-through-creativity-lab>

- Van Krevelen, R. and Poelman, R. (2010). A survey of augmented reality technologies, applications, and limitations. *International Journal of Virtual Reality*, [Online]. Vol. 9 issue 2, pp. 1-20. Available: <https://doi.org/10.20870/IJVR.2010.9.2.2767>
- Yang, Z. Y. (2020). Modern piano teaching technologies: Accessibility, effectiveness, the need for pedagogues. *İlköğretim Online*, 19(3), 1812-1819. <https://doi.org/10.17051/ilkonline.2020.735171>.
- Zhang, Y., Liu, S., Tao, L., Yu, C., Shi, Y., & Xu, Y. (2015). ChinAR: Facilitating Chinese Guqin Learning through Interactive Projected Augmentation. *Proceedings of the Third International Symposium of Chinese CHI*, 23-31. <https://doi.org/10.1145/2739999.2740003>