Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index

Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

Development of Augmented Reality Learning Media to Introduce Musical Instruments for Deaf Elementary School Student

Dian Syafitri Chani Saputri, Anthony Anggrawan, Dyah Susilowati, Rahmat Maulana
Universitas Bumigora, Indonesia.
*Corresponding Author. Email: dian_syafitri@universitasbumigora.ac.id

Abstract: This research aims to develop Augmented Reality learning media for deaf children at the elementary school level in recognizing musical instruments and measuring their effectiveness on learning outcomes. The research method used is research and development (R&D) and uses the Multimedia Development Life Cycle development method. The effectiveness of the media was tested using pretest-posttest. Data analysis techniques use the parametric statistical test. The results of testing by media and content experts concluded that the application was declared suitable for use as a learning medium. From the beta test, it was discovered by 33 deaf students that Augmented Reality learning media was well received. The t-test comparison test shows that there is a difference, which means that the use of Augmented Reality learning media as a medium for introducing musical instruments to deaf students has a positive impact on learning outcomes.

Article History
Received: 21-06-2024
Revised: 27-07-2024
Accepted: 22-08-2024
Published: 18-09-2024

Key Words:
Augmented Reality; Learning Media; Deaf Student; Musical Instrument; Multimedia Development.

How to Cite: Saputri, D. (2024). Development of Augmented Reality Learning Media to Introduce Musical Instruments for Deaf Elementary School Student. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran, 10*(3), 1001-1011. doi:https://doi.org/10.33394/jk.v10i3.12034

https://doi.org/10.33394/jk.v10i3.12034

Introduction

Teaching students in the classroom with a real-world learning environment has become the attention of teachers in recent years (Hwang et al., 2016). Besides that, technology has emerged as part of education and positively impacts achieving educational outcomes (Anggrawan, Hairani, et al., 2023). At the same time, augmented reality (AR) is a digital technology that can improve real-world learning well equipped with sound effects, graphics, text and animation (Kairu, 2021); and AR technology is able to realize the absorption of a real-world learning environment beyond human perception (Ke et al., 2019). System AR helps everyone's perception by more easily understanding the information contained in it (Anggrawan, Saputri, et al., 2023). Therefore, it is not surprising that AR learning media is gaining attention in the world of education, and it has been an effective medium in learning activities (Ke et al., 2019). Apart from that, more and more research institutions are currently conducting scientific research related to AR (Chen et al., 2019). Unfortunately, although there has been a lot of research on AR, there is only a little research in the field of education (Saidin et al., 2015). That is why, this study researches the application of AR in learning.

Moreover, the use of technology is also a concern for academic researchers to apply it in education (Nickl et al., 2022) (Anggrawan et al., 2018). In the meantime, educators have long also emphasized that it is important and necessary to apply appropriate learning media to support student learning (Hwang et al., 2011). Meanwhile, AR-based learning is able to realize effective interaction between the real world and the virtual environment (Javornik, 2016) (Saidin et al., 2015) and presents a real interface for an object (Saidin et al., 2015). This means in other words; AR learning is a learning media that is suitable for students to

learn or get to know something as real physical objects. It is another reason AR was chosen as a learning medium for deaf children in getting to understand musical instruments in this study.

Previous researchers found that introducing musical instruments and learning music had a fairly consistent emotional influence on students, for example, happiness, however, students with hearing impairments have difficulty understanding music (Alice-Ann Darrow, 2016). Other researchers say that even though there are deaf individuals who are successful in getting to know musical instruments, many parties are reluctant to involve deaf students in learning about musical instruments because of the lack of ability of deaf students to learn (Hash, 2013). Remember that effective, active, and innovative learning is mandatory for all students (Alkhattabi, 2017; Bahl, 2020). Likewise, it must apply to deaf students as well as other students, even if learning is disrupted by hearing loss.

This educational outcome is essential for the academic progress of deaf students, especially in learning musical instruments. This research is unique compared to previous related research or has novelty because the research conducted in this study has never been undertaken by other researchers, including related research conducted by Bahl (2020), Brétéché (2021), da Silva et al. (2020), Schmitz et al. (2020), Torppa & Huotilainen (2019), Torres (2019), and Churchill (2015) even if the same article is related to deaf students or deaf and hard of hearing students. Likewise, this study differs in purpose and research object compared to several previous studies that similarly examined the use of augmented reality technology, including related research conducted by Adel (2024) and Anggrawan et al. (2023). This research is also different in research methods, topics and research focus from previous studies conducted by Kairu (2021), Chen et al. (2019), and Wang et al. (2018). Essentially, this study result has the implication of solving the problem of deaf student learning.

There are several recent works that compare with this research. Sylvain Brétéché (2021) investigated the body's sensitivity to sound and the visual dimension of music for the deaf. Whereas Bahl (2020) qualitatively reviewed how deaf students participate in music and education at a school. In the same year, da Silva et al (2020) conducted a literature study to map scientific works on music education or music notation for the deaf, including analyzing the obstacles or successes of education for people who are deaf or hard of hearing. In the meantime, Schmitz et al (2020) researched by quantitatively analyzing the usefulness of audio feedback technology for deaf people in experiencing music. In the previous year, R. Torppa and M. Huotilainen (2019) examined the relationship between speech skills and musical activities in children and adolescents with hearing loss.

Meanwhile, Torres (2019) reviews deaf people's perceptions of music. Previously, Churchill (2015) offered a post-structural narrative approach to understanding music-making by utilizing Foucault's power theory. Although previous research and the research in this article both focus on deaf people, the difference lies in the research objectives and research methods used. The methods of these previous studies are not design research and are also not experimental research like the research in this article. However, the previous studies were studies using qualitative, quantitative and literature review research methods. Apart from that, previous studies did not build an AR system or observe the effect of learning by applying AR technology to the learning of deaf students. In other words, although there are some related studies on deaf people, none of them is the same as the research in this work.

Abdel (2024) systematically reviews previous AR research to synthesize themes related to business management science that have been published. This previous research is different in its research objectives, methods, and objects compared to the research in this

Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

article. Previous research was literature review research on research objects regarding the themes of AR articles that have been published. Meanwhile, the research in this article combines development research (design) and experiments with the research object of deaf students. Anggrawan et al (2023) built mobile-based AR learning and examined the effect of AR learning on independent learning outcomes. This previous research was a combination of design and experimental research methods. This previous research method is the same as the research method in this article, but the aims and research objects are different. The purpose and object of prior research was to build an AR system as a learning medium for car engine lubrication and cooling systems and review its effect on students' independent learning. In contrast to the research in this article is building an AR system as a medium for learning musical instruments for deaf students and the influence of AR on face-to-face learning outcomes for deaf students.

Kairu (2021) conducted a literature study reviewing the benefits and challenges of using web-based AR in educational environments. In contrast, Y. Chen et al., (2019) reviewed the progress of augmented reality and described augmented reality technologies and applications in several fields. Whereas previously, Wang et al (2018) observed the potential for using AR to enhance the five senses in capturing information. The difference in AR research conducted by previous researchers is that the method, topic and focus of the research are different compared to the research in this article. The research methods of previous studies were review and observation studies or not design and experimental research as in the research in this article. Likewise, the previous studies' topics and focus were not on learning musical instruments and not on learning deaf students as in the articles in this research. It means that no previous research on AR has investigated the effect of applying AR technology on deaf students' learning outcomes in recognizing musical instruments, as in the research in this article. Therefore, this research developed Augmented Reality learning media for deaf children at the elementary school level in recognizing musical instruments and measuring their effectiveness.

Research Method

This research uses a Research and Development (R&D) method. R&D is a strategy used to implement beneficial innovations and products aimed at promoting applied knowledge and research-based creative practices (Ramota & Bialik, 2023). The R&D product developed is an AR learning media to introduce musical instruments to deaf students at elementary school level. Learning media is built using the Multimedia Development Life Cycle (MDLC) stages, as presented in Figure 1. The MDLC process includes stages: concept, design, materials collection, assembly, testing, and distribution (Anggrawan, Saputri, et al., 2023). MDLC plays a role in the development of the designed model (Al-Jabari et al., 2019; Aleem et al., 2016; Anggrawan, Saputri, et al., 2023). At the trial or testing stage, the validity of the content and media is tested by experts, then is continued with surveying user satisfaction and testing the effectiveness of AR learning media. Before conducting a satisfaction survey and effectiveness test, the AR learning media that had been developed was first implemented in face-to-face classes.

Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

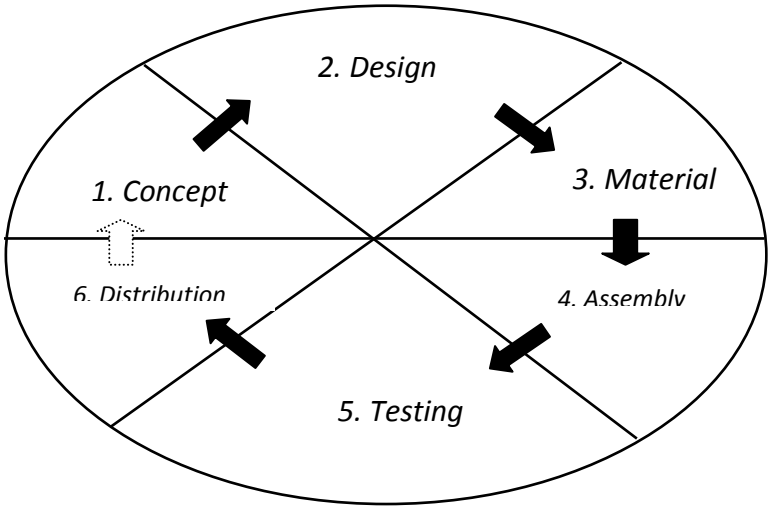

Figure 1. MDLC process sequence

The technique for selecting samples uses accidental sampling. The sample group used for the satisfaction survey and testing the effectiveness of AR learning media consisted of 33 elementary school students at 2 (two) special schools in West Lombok district and Mataram City, West Nusa Tenggara Indonesia who could communicate via sign language (with the help of the teacher). The survey instrument in this study used a Likert measurement scale consisting of 4 answer choices, namely strongly agree, agree, disagree, and strongly disagree. The effectiveness instrument used a pretest and posttest instruments. Data analysis techniques use the parametric statistical test (t-test).

Results and Discussion

Concept

At the concept stage, the aims and objectives of creating the application are determined, including who will use it and the benefits obtained from the application. The aim of designing this application is to design a musical instrument recognition application using Augmented Reality technology which will be applied to Android-based smartphones. Users of this Augmented Reality application are Deaf Students and Deaf Teachers at the Special Elementary School level in Indonesia. Deaf students who use the application have low hearing levels or mild hearing loss but can still use it as the main modality for listening to someone's speech sounds and developing speaking abilities.

Mobile-based learning media for introducing musical instruments using AR technology running on the Android platform. The Augmented Reality method used is marker-based AR. The application introduces 6 musical instruments, namely guitar, violin, organ, drum, trumpet, and cassette. Musical instruments are introduced in the form of 3D animation which are equipped with musical instrument sound features to help users understand the sounds in the surrounding environment (Ridha & Shehieb, 2021). According to the characteristics of deaf students, the menu in the application is equipped with sign language.

Design

At the design stage, the navigation structure, storyboard application, interface design, 3D objects, and AR marker are designed, as shown in figure 2.

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index
Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

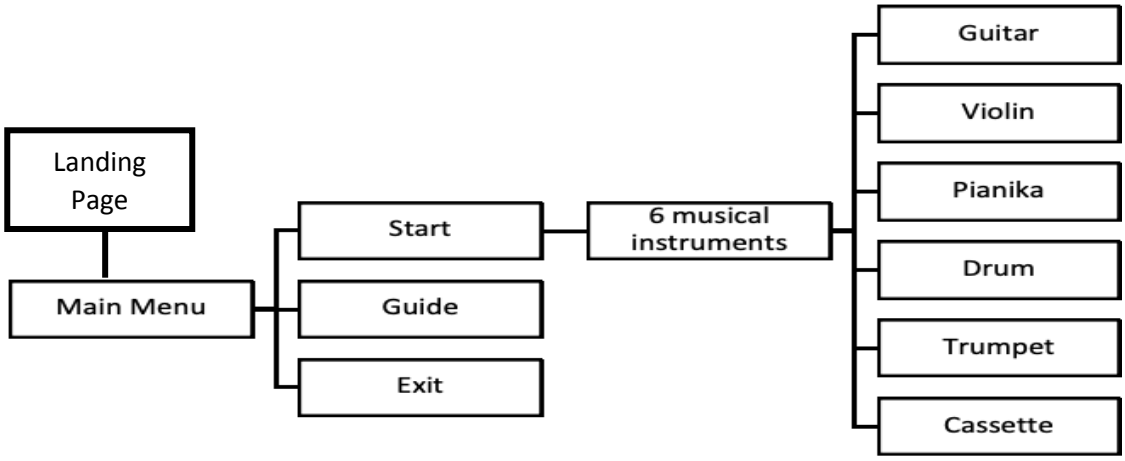

Figure 2. Navigation structure for AR learning media

Material Collecting

This stage includes creating the components needed for application design according to the materials that have been designed in the design stage. These materials are 3-dimensional animation, audio, and graphic design. The 3D animation was built using Blender and interface material using Adobe Illustrator.

Assembly

This stage includes creating an application according to the design that was planned at the design stage. All materials and materials that have been created in the previous stage are authored using Unity software. The results of assembling the Augmented Reality Media application for Introduction to Musical Instruments for Deaf Elementary School Students are shown in figure 3. The Landing page will appear first when entering the application. The application title is equipped with sign language so that it is easy for students to read. On this page, there is a button in the form of a logo to enter the main menu page.

Figure 3. Landing page

Figure 4 shows the main menu page which has three menus, namely "Mulai", "Panduan" and "Keluar". Menu labels are equipped with sign language. The "Mulai" menu functions to open learning features with Augmented Reality. The "Panduan" menu contains information about how to use the application. The "Keluar" menu functions to close the application.

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index
Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

Figure 4. Main menu page

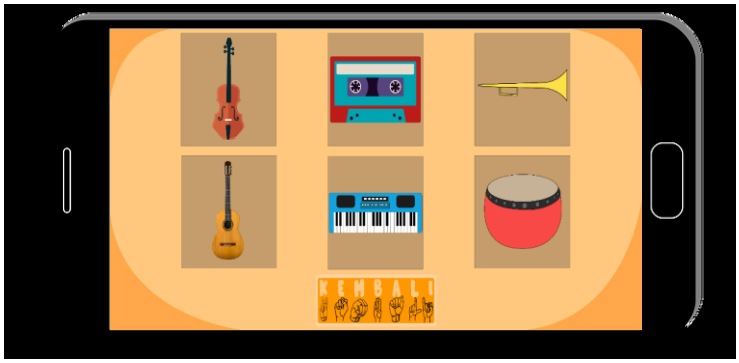

Figure 5. Musical instrument list page

The "Mulai" menu will direct users to a menu page containing a selection of musical instrument images, as shown in figure 5. There are 6 pictures of musical instruments that students can choose to open the camera scan feature to display animated 3D objects, namely guitar, violin, organ, drum, trumpet, and cassette.

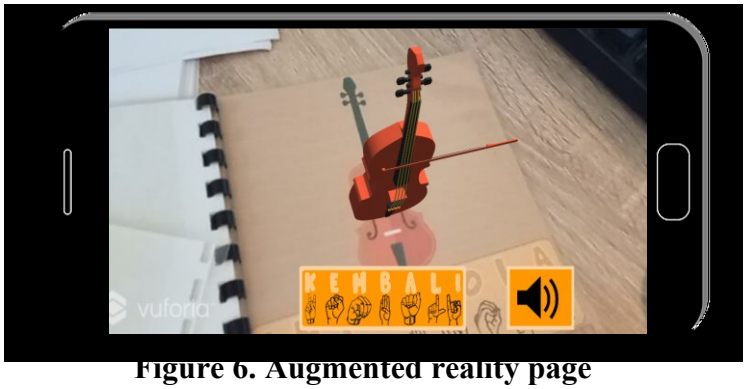

Figure 6. Augmented reality page

After pressing one of the selected musical instrument images, the user will be directed to the camera scan page used to detect markers. Figure 6 shows, if the marker is successfully recognized by the camera, the musical instrument will appear in the form of an animated 3D object. On this page, there is a sound button to listen to the sound of the musical instrument currently displayed. The "back" menu functions to return to the main menu page.

Testing

Testing aims to ensure that the application that has been created will carry out the correct process and produce output that matches the application design. Apart from that, it finds out if there are any errors that might exist in the application. There are two testing methods carried out, namely alpha testing and beta testing. Alpha testing is carried out by researchers or developers using the white box method and carried out by media experts and

subject experts using the black box method. Beta testing was carried out on several deaf student respondents from special schools in West Lombok district and Mataram city. The methods used are user acceptance tests and experiments.

Alpha Testing

Alpha testing is a test carried out by looking for errors in the system to produce functional requirements for the device being built before the product is released to users (Kaplesh & Pang, 2020). Researchers conducted trials on the application by following the test list. Based on the test results, it was found that all application functions ran according to the scenario and no bugs were found.

Table 2. The result of expert validation

No	Aspect	ΣScore	Σ Max Score	Percent (%)	Eligibility Level
Media Expert					
1	Software engineering	16	16	100	Very Worth It
2	Visual Communication	39	44	88,63	Very Worth It
		55	60	91,67	Very Worth It
Subject Matter Expert					
1	Learning Material	21	24	87,5	Very Worth It
2	Delivery of Materials	20	20	100	Very Worth It
		41	44	93,18	Very Worth It

The next alpha testing was carried out by media experts and subject experts. Media experts test application functionality based on software engineering principles and compliance with principles in learning media and visual communication. Meanwhile, material experts test the validity of the material and the accuracy of the methods used in presenting the material. Table 2 shows the results of testing by experts which can be concluded that the application is declared suitable for use as learning media.

Beta Testing

At the Beta testing stage, a user acceptance test is carried out by 33 elementary school level respondents from special schools in West Lombok district and Mataram city. Respondents are given the opportunity to use the application for 15 minutes and then provide an assessment on the questionnaire that has been prepared with the help of the teacher. There are 7 questions filled in by respondents with Likert scale answers consisting of 4 answer choices, namely strongly agree (4), agree (3), disagree (2), and strongly disagree (1). Based on the results of the user acceptance test shown in Table 3, it can be concluded that the application was well received by respondents.

Table 3. User Acceptance Test for AR Learning Media

No	Statement	ΣScore	ΣMax Score	Percent (%)
1	The application is easy for students to use	130	130	100
2	Students love the app	115	130	88,46
3	The 3-dimensional shape is clear	109	130	83,84
4	Good 3D movement	100	130	76,92
5	3D sound is heard	33	130	25,38
6	Nice app button.	124	130	93,38
7	Fun to play with class friends	127	130	97,69
Total		738	910	81,09

The beta testing results show that 100% of students think that the AR application is easy to use, 88.46% of students like the AR application, and 83.84% of students think that 3D objects are clearly recognized. Apart from that, 97.69% of students agree AR applications are fun to

play with classmates, this shows that AR applications can create collaboration in learning for students. This finding is in accordance with a review conducted on AR research (Basumatary & Maity, 2023), that AR can increase engagement and collaboration. Unfortunately, only 25% of students stated that 3D sound was audible.

Learning outcomes are evaluated using the pretest and posttest methods. The pretest and posttest instruments consist of 6 questions in essay form. The instrument was tested for validity and reliability. The results of the instrument validity test (as shown in Table 4) were that all questions were valid with significance below 0.01. Based on the reliability test results as shown in Table 5, the resulting Guttman Split-Half value is 0.753, where this value is greater than 0.6, so it can be said that the questionnaire items are reliable.

Table 4. Result of Validity Test

	Guitar	Violin	Pianica	Cassette	Trumpet	Tambur	Total Score
Pearson Correlation							
Sig. (2-tailed)	,686	,538	,727	,480	,640	,802	1
N	,000	,001	,000	,004	,000	,000	
	35	35	35	35	35	35	35

Table 5. Result of Reliability Statistics

Cronbach's Alpha	Part 1	Value	,594
		N of Items	3[a]
	Part 2	Value	,621
		N of Items	3[b]
	Total N of Items		6
Correlation Between Forms			,615
Spearman-Brown Coefficient	Equal Length		,762
	Unequal Length		,762
Guttman Split-Half Coefficient			,753

The result of pretest dan posttest show at Table 6. The number of pretest and posttest questions is 6 questions, each correct answer will get a score of 16.77. The total score is obtained from the average of the students' scores. The average posttest score is higher than the average pretest score. To evaluate the effectiveness of AR learning media, the average pretest score was 65.29, and the average posttest score was 92.88. The research results show that there was an increase in learning outcomes by 42.26% after learning using AR learning media. The Kolmogorov-Smirnov data normality test results from the pretest and posttest showed that the data was normally distributed. Based on table 7, the significant value of the test results is greater than the alpha value of 0.01 for both pretest and posttest.

Table 6. The result of Pretest and Posttest

	Pretest score	*Posttest* score
Average	65,29	92,88

Table 7. Normality Test Result

One-Sample Kolmogorov-Smirnov Test

		Pre_Test	Post_Test
N		33	33
Normal Parameters[a,b]	Mean	65,6685	81,3215
	Std. Deviation	19,06805	26,60031
Most Extreme Differences	Absolute	,187	,274
	Positive	,158	,241
	Negative	-,187	-,274
Kolmogorov-Smirnov Z		1,073	1,573
Asymp. Sig. (2-tailed)		,200	,014

Vol. 10, No. 3 : September 2024
E-ISSN: 2442-7667
pp. 1001-1011
Email: jklppm@undikma.ac.id

Table 8. t-Test Result

	Paired Differences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre_Test-Post_Test	-15,65303	29,14957	5,07429	-25,98902	-5,31704	-3,085	32	,004

The parametric statistical test t-test or comparison test between the pretest and posttest shows a significance level of 0.004 or lower than the alpha value (0.01). It could be concluded that there is a significant difference in learning outcomes between pretest and posttest (see Table 8). This means that the use of AR as a learning medium to introduce musical instruments to deaf students has a positive impact on learning outcomes. This is in line with the results of previous research (Ployjiw & Michel, 2023) which stated that learning outcomes of the hearing-impaired students or deaf students after using AR were significantly higher than before the intervention. Based on the findings of this research, it can be said that AR-based learning media for the introduction of musical instruments for elementary school deaf students has a positive and effective impact on learning for children with special needs. The conceptual implication of the results of this research is that this research strengthens the results of previous research. This finding also has practical implications, namely AR can be an alternative learning media for deaf students, thus opening opportunities for future research to develop AR learning media for children with other special needs.

Conclusion

Based on the alpha test results, the AR application functions well. The validity of the material and media is tested by experts, which shows the AR application is suitable for use. According to beta testing, the student acceptance rate of AR applications is 81.09%, which means a high acceptance rate. Although, 25% of students stated that 3D sound was audible. Based on the comparison test between the pretest dan posttest, there is a significant difference in learning outcomes between the pretest and posttest, which means AR as a learning media could improve learning outcome of deaf students. This implies that AR can be an alternative learning media for deaf students.

Recommendation

For further research, it is necessary to develop an AR application with audio features that pay attention to sound standards that can be heard by deaf students and develop certain methods or techniques so that sounds can be heard or felt by deaf students. With these findings, teachers of children with special needs at this time should improve their skills in utilizing technology-based learning media, especially AR, so that they can use this technology in learning.

References

Adel, R. (2024). Augmented Reality (AR) Generated Value-in-Use Experiences: Literature Review and Analysis. *Arab Journal of Administration*, *44*(3), 227–241. https://doi.org/10.21608/aja.2021.108470.1182

Al-Jabari, M. O., Tamimi, T. K., & Ramadan, A.-A. N. (2019). Multimedia Software Engineering Methodology A Systematic Discipline for Developing Integrated Multimedia and Software Products. *Software Engineering*, *2019*(1), 1–10.

https://doi.org/10.5923/j.se.20190801.01

Aleem, S., Capretz, L. F., & Ahmed, F. (2016). Game development software engineering process life cycle: a systematic review. *Journal of Software Engineering Research and Development*, *4*(1), 1–30. https://doi.org/10.1186/s40411-016-0032-7

Alice-Ann Darrow. (2016). The Role of Music in Deaf Culture: Deaf Students' Perception of Emotion in Music. *Journal of Music Therapy*, *2*(1), 2–15.

Alkhattabi, M. (2017). Augmented Reality as E-learning Tool in Primary Schools' Education: Barriers to Teachers' Adoption. *IJET*, *12*(2), 91–100.

Anggrawan, A., Hairani, H., & Satria, C. (2023). Improving SVM Classification Performance on Unbalanced Student Graduation Time Data Using SMOTE. *International Journal of Information and Education Technology*, *13*(2), 289–295.

Anggrawan, A., Ibrahim, N., Suyitno, M., & Satria, C. (2018). Influence of Blended Learning on Learning Result of Algorithm and Programming. *Third International Conference on Informatics and Computing*, 1–6. https://doi.org/10.1109/IAC.2018.8780420

Anggrawan, A., Saputri, D. S. C., & Satria, C. (2023). Developing Augmented Reality Learning and Measuring Its Effect on Independent Learning Compared to Traditional Learning. *TEM Journal*, *12*(2), 975–987. https://doi.org/10.18421/TEM122-44

Bahl, H. (2020). The Deaf and Hard-Hearing and Their Perception of Music. *Research Square*, *December*, 1–17.

Basumatary, D., & Maity, R. (2023). Effects of Augmented Reality in Primary Education: A Literature Review. *Human Behavior and Emerging Technologies*. https://doi.org/10.1155/2023/4695759

Brétéché, S. (2021). The Deaf Musical Experience: Bodily and Visual Specificities: Corpaurality and Vusicality. *Lecture Notes in Computer Science*, *12631 LNCS*, 422–448. https://doi.org/10.1007/978-3-030-70210-6_28

Chen, Y., Wang, Q., Chen, H., Song, X., Tang, H., & Tian, M. (2019). An overview of augmented reality technology. *Journal of Physics: Conference Series*, *1237*(2), 1–5. https://doi.org/10.1088/1742-6596/1237/2/022082

Churchill, W. N. (2015). Deaf and hard-of-hearing musicians: Crafting a narrative strategy. *Research Studies in Music Education*, *37*(1), 21–36. https://doi.org/10.1177/1321103X15589777

da Silva, N. M., Alves, J. F., de Castro, A. B. C., & de Santana Varela, J. H. (2020). Music education for the deaf: Characteristics, barriers and successful practices. *Educacao e Pesquisa*, *46*, 0–2. https://doi.org/10.1590/S1678-4634202046221995

Hash, P. M. (2013). Teaching Instrumental Music to Deaf and Hard of Hearing Students. *Research and Issues in Music Education*, *1*(1), 1–7.

Hwang, G. J., Wu, P. H., Chen, C. C., & Tu, N. T. (2016). Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. *Interactive Learning Environments*, *24*(8), 1895–1906. https://doi.org/10.1080/10494820.2015.1057747

Hwang, G. J., Wu, P. H., & Ke, H. R. (2011). An interactive concept map approach to supporting mobile learning activities for natural science courses. *Computers and Education*, *57*(4), 2272–2280. https://doi.org/10.1016/j.compedu.2011.06.011

Javornik, A. (2016). Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behaviour. *Journal of Retailing and Consumer Services*, *30*, 252–261. https://doi.org/10.1016/j.jretconser.2016.02.004

Kairu, C. (2021). Augmented Reality and Its Influence on Cognitive Thinking in Learning. *American Journal of Educational Research*, *9*(8), 504–512.

https://doi.org/10.12691/education-9-8-6

Kaplesh, P., & Pang, S. K. Y. (2020). Software Testing. In *Software Engineering for Agile Application Development* (pp. 189–211). IGI Global. https://doi.org/10.4018/978-1-7998-2531-9.ch008

Ke, S., Xiang, F., Zhang, Z., & Zuo, Y. (2019). A enhanced interaction framework based on VR, AR and MR in digital Twin. *Procedia CIRP*, *83*, 753–758. https://doi.org/10.1016/j.procir.2017.04.009

Nickl, M., Huber, S. A., Sommerhoff, D., Codreanu, E., Ufer, S., & Seidel, T. (2022). Video‐based simulations in teacher education: the role of learner characteristics as capacities for positive learning experiences and high performance. *International Journal of Educational Technology in Higher Education*, *19*(45), 1–24. https://doi.org/10.1186/s41239-022-00351-9

Ployjiw, U., & Michel, P. C. (2023). Development of Augmented Reality Learning Materials for the Hearing Impaired Students in Primary I. *International Journal of Information and Education Technology*, *13*(11), 1696–1703. https://doi.org/10.18178/ijiet.2023.13.11.1978

Ramota, R., & Bialik, G. (2023). Toward a consensual definition of educational research anddevelopment: a Delphi study. *Higher Education Research & Development*, *42*(2), 427–441. https://doi.org/https://doi.org/10.1080/07294360.2022.2052814

Ridha, A. M., & Shehieb, W. (2021). Assistive Technology for Hearing-Impaired and Deaf Students Utilizing Augmented Reality. *Canadian Conference on Electrical and Computer Engineering (CCECE)*. https://doi.org/10.1109/CCECE53047.2021.9569193

Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A Review of Research on Augmented Reality in Education: Advantages and Applications. *International Education Studies*, *8*(13).

Schmitz, A., Holloway, C., & Cho, Y. (2020). Hearing through vibrations: Perception of musical emotions by profoundly deaf people. *ArXiv*, 1–17.

Torppa, R., & Huotilainen, M. (2019). Why and how music can be used to rehabilitate and develop speech and language skills in hearing-impaired children. *Hearing Research*, *380*(September), 108–122. https://doi.org/10.1016/j.heares.2019.06.003

Torres, J. (2019). *Perception of Music in the Deaf and Hard of Hearing Perception of Music in the Deaf and Hard of Hearing*.

Wang, J., Erkoyuncua, J., & Roy, R. (2018). A Conceptual Design for Smell Based Augmented Reality: Case Study in Maintenance Diagnosis. *6th CIRP Global Web Conference*, 109–114. https://doi.org/10.1016/j.procir.2017.04.009