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ENHANCING SCIENCE LEARNING OUTCOMES OF LOW VISION LEARNERS: IMPACT OF AN AUGMENTED REALITY-SUPPORTED INSTRUCTIONAL APPROACH IN MIDDLE SCHOOL

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Abstract: Augmented Reality (AR) has the potential to transform learning by making complex concepts and theories more engaging and easier for students to understand. This study examined the effectiveness of an AR-based instructional strategy on science learning outcomes among eighth-grade low vision students. A quasi-experimental pretest–posttest control group design was used, involving 60 students selected through simple random sampling from two government-sponsored, Bengali-medium, co-educational schools in the Kolkata municipality. The experimental group (n = 32) learned the 'World of Microbes' unit in science through AR-assisted pedagogy, which included interactive 3D models and immersive learning experiences. In contrast, the control group (n = 30) was taught the same unit using conventional methods. Data were collected using a self-developed standardized test with a reliability coefficient of 0.88. Two-way ANCOVA was applied to analyse the data. The results showed that students in the AR group achieved significantly higher learning outcomes than those in the control group. Further, girls showed better performance in comparison to their counterparts. Overall, the findings highlight the potential of AR-assisted pedagogy to enhance science education at the middle school level for low vision students.

Keywords: Augmented reality, Science, Learning outcomes, Low vision students, Middle school level.

1. Introduction

The participation of students with disabilities in schools is steadily increasing worldwide (Buchner et al., 2020). According to the United Nations' Universal Declaration of Human Rights, all learners have equal rights to education, regardless of race, colour, gender, language, religion, region, social and cultural background, or special needs (UDHR, 1948). The Rights of Persons with Disabilities (RPWD) Act, 2016, further states that individuals with visual impairment may experience significant limitations in the skills required for independent living and community participation, including challenges in communication, self-care, social interaction, safety, and self-direction (RPWD Act, 2016). Science, as a discipline, plays a crucial role in shaping everyday decisions and experiences. Therefore, it is important to adopt effective teaching strategies that enhance students' motivation and actively engage them in science learning (Nurita et al., 2017; Rosa et al., 2019). However, many school students struggle to understand a complex scientific concept, which often affects their interest and attitude toward the subject (Sahin & Yilmaz, 2020). To address these challenges, the use of interactive visual aids in the classroom is essential, as they help learners better grasp abstract and difficult concepts in science.

According to information available on the website of the Department of Women and Child Development and Social Welfare, Government of West Bengal, based on the 2011 Census, the total population of persons with visual impairment in Kolkata city is approximately 1.1 million. A large number of students with low vision studying in government-sponsored schools in the city remain severely marginalized due to the lack of an appropriate and supportive learning environment. At the Class VIII level, learners typically fall within the age range of 13–15 years, a stage at which they are capable of understanding abstract concepts and solving problems, as proposed by Piaget's theory of cognitive development. The integration of modern technologies in science education has been shown to enhance students' understanding of scientific concepts and improve their problem-solving skills (Uddin et al, 2023). In this context, augmented reality (AR) has emerged as a powerful tool in creating a more engaging and supportive learning environment (AlAli et al., 2025). AR is a three-dimensional technology that enables learners to better comprehend and experience the real world by overlaying it with virtual elements (Leung & Blauw, 2020). Numerous studies have highlighted the effectiveness of AR in teaching and learning science (Ibili & Sahin, 2015).

2. Review of Related Literature

According to Peikos and Sofianidis (2024), the use of augmented reality (AR) significantly enhanced the motivational and cognitive outcomes of primary school students. It also improved student engagement and understanding, while fostering a sense of creativity. A bibliometric study covering the period from 2010 to mid-2023 further revealed that science education and mobile AR have gained considerable importance in recent years (Singh et al., 2024). The integration of AR has also contributed meaningfully to making the teaching–learning process more effective. Several empirical studies highlight the positive impact of AR in secondary education. Bhardwaj (2023) reported that the use of mobile-based AR applications in teaching science to ninth-grade students led to significant improvements in their interest and academic performance. Similarly, Chander (2023) found that ninth-grade students taught with AR applications developed by NCERT showed notable gains in academic achievement. Talan et al. (2022) also observed that AR applications had a positive effect on secondary school students' academic performance in science, along with increased interest, motivation, and easier comprehension of concepts. In the same vein, Abdullah et al. (2022) reported a positive influence of AR on students' academic achievement in science. Furthermore, Çetin and Türkan (2021) demonstrated that incorporating AR into science instruction enhanced students' achievement and fostered more positive attitudes toward the subject, even in distance learning environments.

Augmented reality (AR) technology enriched the learning experience and proved to be an effective instructional approach, particularly in the context of remote learning during the COVID-19 pandemic. At the university level, the use of AR in physics laboratories was found to be beneficial in reducing students' cognitive load and enhancing their competency levels (Thees et al., 2020). Sahin and Yilmaz (2019) reported that integrating AR into science education improved students' academic achievement, fostered more positive attitudes toward the subject, and was well accepted by learners without increasing anxiety. In a comprehensive review of 68 studies, Akcayır and Akcayır (2017) observed that most AR-based research has been conducted with K–12 students. However, a synthesis of the existing literature reveals a significant gap: to date, no study has specifically examined the impact of AR-based instructional strategies on science learning outcomes among students with low vision.

3. Rationale of the Study

One of the most crucial aspects of implementing augmented reality (AR) applications in the classroom is their potential to enhance students' knowledge and skill development in course content. By creating an immersive and interactive learning environment, AR provides valuable opportunities to enrich both instructional practices and learning experiences (Fidan & Tuncel, 2019; Bujak et al., 2013; Dunleavy et al., 2009). In schools where access to well-equipped laboratory facilities is limited, the use of AR in science education becomes especially important, offering an effective alternative to conventional teaching methods. Thevin and Brock (2018) demonstrated that visually impaired learners benefited from interactive graphics when instruction was supported through audio augmentation. Similarly, Quintero et al. (2019) reported that AR is widely used in science education for inclusive purposes, showing significant advantages in increasing motivation, interaction, and interest among students with hearing, visual, motor, and cognitive impairments. Jones et al. (2020) concluded that digital simulators such as OpenVisSim can effectively replicate visual impairment challenges, thereby supporting better instructional design. Lo Valvo et al. (2021) found that AR applications helped visually impaired individuals improve their spatial awareness and interaction with their surroundings. Through training with ARIANNA+, which integrates convolutional neural networks (CNNs), users were able to identify objects and landmarks more effectively.

Furthermore, Abdelazim (2021) reported measurable improvements in pre- and post-assessments when AR-based notecards were used with children who have visual impairments. The study revealed that AR interventions had a significant positive impact on students' visual learning abilities, particularly in pictorial production and optical reading skills. Despite these advancements, earlier research has pointed out that inequalities in educational attainment still persist, especially in relation to gender (Breen & Jonsson, 2005).

This study aims to enhance the science learning competencies of children with low vision at the middle school level by integrating augmented reality (AR) applications as an instructional intervention, with particular attention to gender-related differences. For the purpose of experimentation, an important unit titled 'World of Microbes' from the Class VIII science textbook prescribed by the West Bengal Board of Secondary Education (WBBSE) was selected. This unit was chosen because many learners experience difficulties in understanding its concepts and applying them to real-life situations. Based on this rationale, the following objectives and hypotheses have been formulated.

3.1 Objectives

(i) To study the effect of treatment on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

(ii) To study the effect gender on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

(iii) To study the effect interaction between treatment and gender on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

3.2 Hypotheses

H_{01}**:** There is no significant effect of treatment on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

***H_{02}*:** There is no significant effect of gender on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

***H_{03}*:** There is no significant effect of interaction between treatment and gender on learning outcomes in science of students with low vision by assuming their pre-learning outcomes as a covariate.

3.3 Operational Definitions of the Terms Used

- **Learning outcomes:** It includes the academic performance of students in the learning outcome test developed by the researcher in science.
- **Science:** It includes the content matters of Physics, Chemistry, Biology, and Environmental Science in the same textbook for class VIII.
- **Low vision students***:* Students wearing glasses were considered.
- **Middle school level:** Students of class VIII in the age group of 13-15.
- **Gender:** It includes boys and girls.

4. Method of Research

4.1 Design used in the study: A quasi-experimental pretest-posttest control group design was used in the present study.

4.2 Population: students studying in class VIII in government–sponsored Bengali medium co-education schools of Kolkata Municipality in West Bengal were considered as population.

4.3 Sample: 62 students of class VIII from two schools of similar nature located in Kolkata Municipality were taken as samples for this study. The description of the sample is presented in Table 1.

Table 1: Description of the sample in terms of group, gender and family type

Sl. No.	Group	Gender		Total
		Boys	Girls	
1.	Experimental	15	17	32
2.	Control	13	17	30
	Total	28	34	62

4.4 Procedure of Experimentation

For developing AR based instructional materials, a Unite AR application was used. Permission was taken from the school authorities. Both groups were pretested through a learning outcomes test comprising 20 multiple-choice items on the 'World of Microbes' unit. For a correct response to each item, one mark was assigned, and for each wrong response, zero marks were assigned. The reliability coefficient was computed using the split-half method, which was obtained as 0.88. The test was validated by incorporating opinions collected from three subject experts. So the test was considered reliable and valid.

After the pretest, the two groups were taught the 'World of Microbes' unit. Students of the experimental group were taught using the AR applications. Students of the control group were taught using the conventional method. During the experimental work, the researcher behaved like a facilitator and guide. The researcher created an interactive learning environment throughout the experimentation period of four weeks. Visual representation of a few concepts of the living organism unit using AR applications, which were used during teaching-learning to the students of experimental groups, is given in Figure 1.

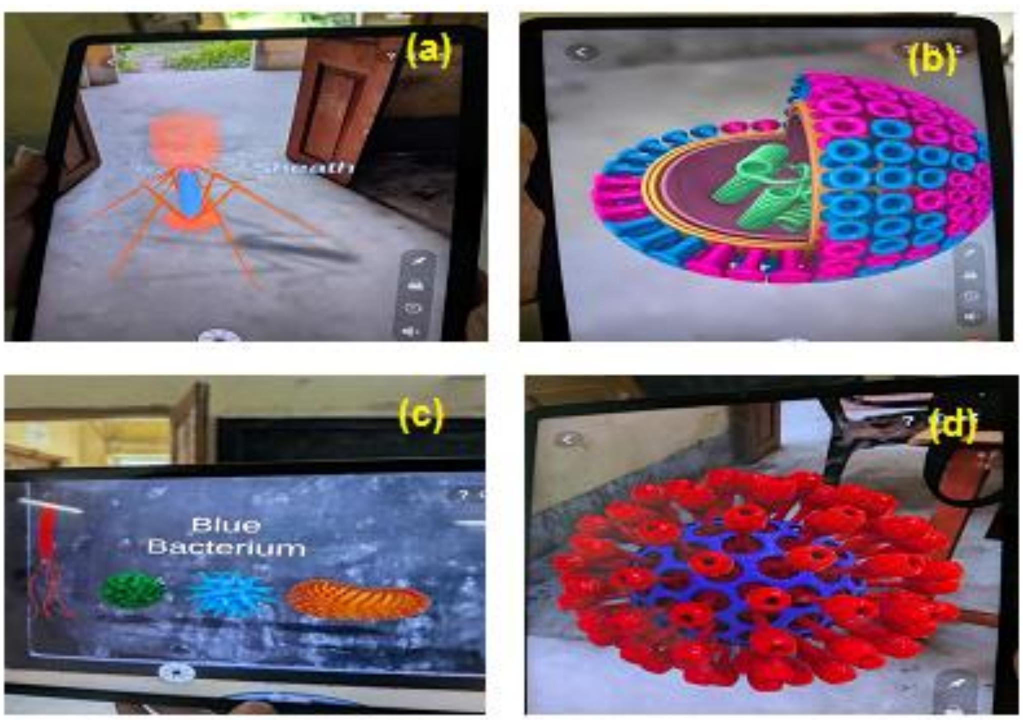

Figure 1: Experimental group students using AR applications in learning the concept of (a) Bacteriophage virus (b) Influenza virus (c) Bacteria and (d) Corona virus.

Figure 1(a) presents the structural components of a bacteriophage, a virus that infects bacteria. The AR application highlights key parts such as the sheath, enabling students to visualize the mechanical structure the virus uses to inject its genetic material into a host cell. Figure 1(b) illustrates the influenza virus through a cross-sectional 3D model that reveals its internal organization. Students can clearly observe the outer envelope, the arrangement of surface proteins, and the genetic material enclosed within. Figure 1(c) depicts different types of bacteria, labeled as “Blue Bacterium,” helping learners distinguish among various bacterial shapes, such as cocci and bacilli, and identify features like flagella that aid in movement. Finally, Figure 1(d) shows the coronavirus in detail, highlighting its distinctive spike proteins radiating from the surface. This visualization is especially useful for understanding how the virus attaches to and enters human cells.

Following the intervention, the same set of questions used in the pretest was used to administer a posttest to both groups.

4.5 Tool Used for Data Collection: A self-developed learning outcomes test comprised of 20 MCQ was administered for pretest and posttest.

4.6 Techniques Used for Data Analysis: A statistical technique, namely one way analysis of covariance was employed through “the Statistical Package for Social Science (IBM SPSS Statistics, Version 21)” and interpretation was done accordingly.

5. Results

Assumptions of normality and homogeneity of variances were tested; as a result, the data were found to be normal. Hence, parametric statistics were applied to test the hypotheses.

Testing of Hypotheses

Treatment had two levels, namely, AR strategy and conventional method. Gender also had two levels, namely, boys and girls. Data were analyzed using 2X2 factorial design ANCOVA, and the results are displayed in Table 2.

Table 2: Summary of 2X2 Factorial Design ANCOVA of learning outcomes of low vision students in science by assuming their pre-learning outcomes as a covariate

Source of Variance	$SS_{Y.X}$	df	$MSS_{Y.X}$	$F_{Y.X}$-Value	Remark	Effect size (η_p^2)
Treatment (P)	96.27	1	96.27	29.16	p< 0.01	0.338
Gender (Q)	24.98	1	24.98	7.57	p< 0.01	--
PXQ	4.45	1	4.45	1.35	ns	--
Error	188.19	57	3.30			
Total		61				

ns = Not significant

According to Table 2, the adjusted F-value for the intervention is 29.16, which is statistically significant at the 0.01 level with df = 1/57. This indicates a significant difference in the adjusted mean scores of learning outcomes between learners taught using the AR strategy and those taught through the conventional method, when pre-learning outcomes are taken as a covariate. Therefore, the null hypothesis stating that there is no significant difference in the adjusted mean scores of science learning outcomes between the two groups is rejected. Furthermore, Table 2 shows that the effect size of the treatment is 0.338, which is also significant at the 0.01 level. This suggests that the intervention accounts for 33.8% of the variance in learning outcomes. Hence, the AR-based intervention had a positive and meaningful impact on students' learning in science after controlling for pre-learning outcomes.

Table 2 also indicates that the adjusted F-value for gender is 7.57, which is statistically significant. This shows that, when pre-learning outcomes are considered as a covariate, there is a significant difference in the adjusted mean scores of learning outcomes in science between boys and girls. Consequently, the null hypothesis stating that gender has no significant effect on learners' science achievement is rejected. The differences in mean scores of learning outcomes based on gender are further presented in Table 3.

Table 3: Gender wise adjusted mean scores of learning and standard error

Gender	Mean	Std. Error
Girls	14.76	0.31
Boys	13.47	0.35

Table 3 indicates that the adjusted mean score of learning outcomes for girls is 14.76, which is higher than that of boys (13.47) when pre-learning outcomes are taken as a covariate. This suggests that girls performed relatively better than boys in science achievement.

Table 2 further shows that the adjusted F-value for the treatment–gender interaction is 1.35, which is not statistically significant. This indicates that, after controlling for pre-learning outcomes, there is no significant interaction effect between treatment and gender on the adjusted mean scores of learning outcomes in science. Consequently, the null hypothesis stating that there is no significant interaction effect on the science learning outcomes of low-vision learners is not rejected. Thus, it can be concluded that students' learning outcomes are independent of the interaction between instructional treatment and gender when pre-learning outcomes are considered as a covariate.

6. Discussion

The first objective of the study was to examine the effect of instructional treatment on the science learning outcomes of students with low vision who were taught using an AR-based strategy and the conventional method, with pre-learning outcomes taken as a covariate. This objective was addressed using a two-way ANCOVA. The findings revealed that students who were taught through AR applications achieved significantly better learning outcomes than those who learned the same content through conventional teaching methods, after controlling for pre-learning outcomes. These results are consistent with the findings of earlier studies (AlAli et al., 2025; Bhardwaj, 2023).

The second objective was to investigate the effect of gender on the science learning outcomes of students with low vision, again considering pre-learning outcomes as a covariate. Using two-way ANCOVA, the results showed that girls performed better than boys, which aligns with the outcomes of previous research (Breen & Jonsson, 2005).

The third objective was to study the interaction effect of treatment and gender on the science learning outcomes of students with low vision, with pre-learning outcomes as a covariate. This objective was also examined using two-way ANCOVA. The findings indicated that there was no significant interaction effect between treatment and gender on learning outcomes in science after controlling for pre-learning outcomes. This result is in agreement with the conclusions of earlier studies (Chaudhary & Tyagi, 2021).

7. Limitations

This study was limited to the following aspects: (i) the use of an AR-based instructional strategy, (ii) eighth-grade students, (iii) the science unit 'World of Microbes' (iv) a four-week period of experimentation, consisting of 40 minutes of instruction daily on working days in both schools, and (v) government-sponsored Bengali-medium co-educational schools affiliated with the West Bengal Board of Secondary Education.

8. Educational Implication

The findings of this study indicate that the AR strategy is a crucial factor influencing students' learning ability. However, students seldom use AR-based instructional approaches unless they are actively encouraged to do so. It is therefore the responsibility of teachers to ensure that learners adopt this strategy to enhance their understanding and develop their skills. Science teachers, in particular, may be encouraged to integrate AR-based methods while teaching various concepts. To support this, appropriate training in the effective use of AR applications can be provided to teachers through seminars, workshops, and conferences, as well as through

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initiatives led by educational institutions, government agencies, curriculum developers, and policymakers.

9. Conclusion

Teaching and learning science is a challenging task that demands strong critical thinking skills to understand concepts deeply and apply them to real-life situations. This study examined the effectiveness of an AR-based instructional strategy on the science learning outcomes of Class VIII students with low vision. The findings revealed that students taught using AR applications achieved better learning outcomes than their counterparts taught through conventional methods. Learners benefited more from the AR strategy because it supported them in understanding, applying, and retaining complex concepts and skills. Through AR applications, students moved beyond passive observation to active exploration, which enhanced both conceptual clarity and long-term retention. The immersive and interactive nature of AR made microscopic structures more visible, engaging, and easier to comprehend. Overall, the AR strategy brought about a substantial improvement in the effectiveness of students' learning.

References

Abdelazim, A. (2021). The effect of (AR) on develop visual learning skills for hearing-vision impairment students (Case study). *International Journal of Innovation in Computational Science and Engineering*, *2*(1), 31-39. file:///C:/Users/USER/Downloads/P4.pdf

Abdullah, N., Baskaran, V. L., Mustafa, Z., Ali, S. R., & Zaini, S. H. (2022). Augmented reality: The effect in students' achievement, satisfaction and interest in science education. *International Journal of Learning, Teaching and Educational Research*, *21*(5), 326-350. file:///C:/Users/USER/Downloads/5292-19790-1-PB.pdf

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational research review*, *20*, 1-11. https://www.sciencedirect.com/science/article/abs/pii/S1747938X16300616

AlAli, R., Wardat, Y., Aboud, Y. Z., & Alhayek, K. A. (2025). The effectiveness of using augmented reality technology in science education to enhance creative thinking skills among gifted eighth-grade students. *EURASIA Journal of Mathematics, Science and Technology Education*, *21*(6), em2644. https://doi.org/10.29333/ejmste/16416

Bilal, H. A., Tariq, A. R., Aleem, U., Shabbir, S. I., & Parveen, M. (2013). The effect of nuclear and joint family systems on academic achievements of students. Academic Research International, 4(5), 543.file:///C:/Users/USER/Downloads/NuclearFamily%20(1).pdf

Bhardwaj, S. (2023). Effect of Augmented Reality-Based Science Content on Learning Achievement among Secondary Level Students. *Indian Journal of Educational Technology*, *5*(I), 20-29. https://journals.ncert.gov.in/IJET/article/view/386

Breen, R., & Jonsson, J. O. (2005). Inequality of opportunity in comparative perspective: Recent research on educational attainment and social mobility. *Annual Review of Sociology*, *31*(1), 223–243. https://www.annualreviews.org/content/journals/10.1146/annurev.soc.31.041304.122232

Broer, M., Buchner, T., Shevlin, M., Donovan, M. A., Gercke, M., Goll, H., ˇ Siˇska, J., Janyˇskov´a, K., Smogorzewska, J., Szumski, G., Vlachou, A., Demo, H., Feyerer, E., & Corby, D. (2020). Same progress for all? Inclusive education, the United Nations Convention on the Rights of Persons with Disabilities and students with intellectual disability in European countries. *Journal of Policy and Practice in Intellectual Disabilities*, *18*(1), 17-22.
file:///C:/Users/USER/Downloads/16917309.pdf

Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education*, *68*, 536-544.
https://www.sciencedirect.com/science/article/abs/pii/S0360131513000560

Chaudhary, S., & Tyagi, S.K. (2021). Effectiveness of Computer-based Instructional Package 93 in Educational Psychology with Respect to Various Determinants *Journal of Indian Education*, XLVII (3), 93-106. https://journals.ncert.gov.in/IJET/article/view/331/96

Cetin, H., & Türkan, A. (2022). The Effect of Augmented Reality based applications on achievement and attitude towards science course in distance education process. *Education and Information Technologies*, *27*, 1397–1415.
https://link.springer.com/article/10.1007/s10639-021-10625-w

Chander, Y. (2023). Effect of Online Learning Augmented Reality Programme on Academic Achievement in Science. *Indian Journal of Educational Technology*, *5*(II), 8-23. https://journals.ncert.gov.in/IJET/article/view/553

Damar, S.Y., & Pesman, H. (2013).Relations of Gender and Socioeconomic Status to Physics through Metacognition and Self-Efficacy. *The Journal of Educational Research*, 106, 280–289.

Department of Women and Child Development and Social Welfare, Government of West Bengal. https://wcdsw.wb.gov.in/

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science*

Education and Technology, *18*(1), 7-22. https://link.springer.com/article/10.1007/s10956-008-9119-1

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635. https://www.sciencedirect.com/science/article/abs/pii/S0360131519301885

Ibili, E., & S¸ahin, S. (2015). Investigation of the effects on Computer Attitudes and Computer Self- Efficacy to use of Augmented Reality in Geometry Teaching. *Necatibey Faculty of Education Journal of Electronics, Science and Mathematics (EFMED)*, *9*(1), 332–350. https://dergipark.org.tr/tr/download/article-file/39923

Islam, T., & Uddin, M. J. (2024). Influence of gender, qualification and experience on teaching competency of teacher educators in Murshidabad District of West Bengal. *Third Concept: An International Journal of Ideas*, *38*(449), 51-53. file:///C:/Users/USER/Downloads/InfluenceofGenderQualificationandExperienceonTeaching.pdf

Jones, P. R., Somoskeöy, T., Chow-Wing-Bom, H., & Crabb, D. P. (2020). Seeing other perspectives: Evaluating the use of virtual and augmented reality to simulate visual impairments (OpenVisSim). *npj Digital Medicine*, *3*(32). https://doi.org/10.1038/s41746-020-0239-6

Lo Valvo, A., Croce, D., Garlisi, D., Giuliano, F., Giarré, L., & Tinnirello, I. (2021). A navigation and augmented reality system for visually impaired people. *Sensors*, *21*(9), 3061. https://doi.org/10.3390/s21093061

Leung, S. W., & Blauw, F. F. (2020). An augmented reality approach to delivering a connected digital forensics training experience. In K. J. Kim & H. Y. Kim (Eds.), *Information Science and Application* (pp. 353–361). Springer. https://pure.uj.ac.za/en/publications/an-augmented-reality-approach-to-delivering-a-connected-digital-f/

Nurita, T., Hastuti, W. P., & Sari, P. A. D. (2017). Problem solving ability of science students in optical wave course. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 341–345. file:///C:/Users/USER/Downloads/Problem-Solving_Ability_of_Science_Students_in_Opt.pdf

Peikos, G., & Sofianidis, A. (2024). What Is the Future of Augmented Reality in Science Teaching and Learning? An Exploratory Study on Primary and Pre-School Teacher Students' Views. *Education Science*, 14, 480. https://www.mdpi.com/2227-7102/14/5/480

Quintero, J., Baldiris, S., Rubira, R., Cerón, J., & Velez, G. (2019). Augmented reality in educational inclusion: A systematic review on the last decade. *Frontiers in Psychology*, 10, 1835. https://doi.org/10.3389/fpsyg.2019.01835

Rosa, O. F., Mundilarto, Wilujeng, I., & Sulistyani, M. A. (2019). Science in everyday life to build science literacy. *International Journal of Scientific & Technology Research*, *8*(12), 1148–1151.https://www.ijstr.org/final-print/dec2019/Science-In-Everyday-Life-To-Build-Science-Literacy-.pdf

Sahin, D., & Yilmaz, R. M. (2019). The Effect of Augmented Reality Technology on Middle School Students' Achievements and Attitudes Towards Science Education. *Computers & Education*, 144, 103710.doi: https://doi.org/10.1016/j.compedu.2019.103710.

Sahin, D., & Yilmaz R. M., (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers & Education*, *144*, 103710. https://doi.org/10.1016/j.compedu.2019.103710

Singh, S., Kaur, A., & Gulzar, Y. (2024). The impact of augmented reality on education: A bibliometric exploration. *Frontiers in Education*, *9*, 1458695. https://doi.org/10.3389/feduc.2024.1458695

Steiner, H., Silverman, M., Karnik, N. S., Huemer, J., Plattner, B., Clark, C. E., Blair, J. R., & Haapanen, R. (2011). Psychopathology, trauma and delinquency: Subtypes of aggression and their relevance for understanding young offenders. *Child and Adolescent Psychiatry and Mental Health*, *5*, Article 21. https://doi.org/10.1186/1753-2000-5-21

The Rights to Person with Disability Act, (2016). https://sarthakindia.org/disability_information_portal/

Talan, T., Yilmaz, Z. A., & Batdi, V. (2022). The Effects of Augmented Reality Applications on Secondary Students' Academic Achievement in Science Course. *Journal of Education in Science, Environment and Health*, *8*(4), 332-346. https://doi.org/10.21891/jeseh.1193695

Thevin, L., & Brock, A. M. (2018). Augmented reality for people with visual impairments: Designing and creating audio-tactile content from existing objects. In K. Miesenberger, G. Kouroupetroglou, & P. Penaz (Eds.), *Computers helping people with special needs: ICCHP 2018* (pp. 193–200). Springer. https://doi.org/10.1007/978-3-319-94277-3_30

Thees, M., Kapp, S., Strzys, M. P., Beil, F., Lukowicz, P., & Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior*, *108*, 106316. file:///C:/Users/USER/Downloads/1-s2.0-S0747563220300704-main.pdf

Uddin, M. J., Panda, B. N., & Agarwal, P. C. (2023). "I can now detect and rectify my error." New generation ninth-grade learner's problem solving skills during experiments in physics through metacognitive brainstorming strategy. *Physics Education*, *58*(3), 035023. https://doi.org/10.1088/1361-6552/acc296

Universal Declaration of Human Rights (1948). http://www.eycb.coe.int/compasito/chapter_6/pdf/1.pdf