ORIGINAL ARTICLE

Assessing the potential impact of an oral health education package integrated with augmented reality on improving oral health knowledge in children: a pre-post study design.

Suci Rahmasari[1*]
Mustika Arini[1]
Rahmi Khairani[2]

[1]Department of Community Dental and Oral Health Sciences, Faculty of Dentistry, Andalas University, Indonesia
[2]Department of Dental Materials, Faculty of Dentistry Andalas University, Indonesia

* Correspondence:
suci@dent.unand.ac.id

ABSTRACT

Introduction: Augmented reality (AR) technology provides a novel approach to oral health education. This study examines the impact of AR-based educational tools on improving children's oral health knowledge, specifically assessing whether AR can significantly enhance knowledge compared to baseline. The primary objective is to determine if AR technology can increase oral health knowledge in children. **Methods:** This pre-experimental study used a pre-test and post-test design involving a single group of 49 children aged 7 years. The augmented reality (AR)-based tool was developed using the ADDIE model and implemented over a two-week period. The effectiveness of the tool was evaluated through a standardized oral health knowledge questionnaire, and the data were analyzed using paired t-tests. **Results:** The results indicated a significant increase in children's knowledge following the intervention, showing mean scores rising from 5.27 (SD = 1.36) to 8.65 (SD = 0.90) (p < 0.05). The proportion of children with good knowledge increased from 8.2% to 88% after intervention. **Conclusion:** The study demonstrates that AR-based tools can significantly improve children's oral health knowledge. This suggests that AR could serve as an effective educational medium for promoting better oral health practices among young learners.

KEYWORDS

Augmented Reality, Oral Health Knowledge, Children's Dental Hygiene, Educational Technology, Pre-Post Study

INTRODUCTION

The significance of effective oral health education for children cannot be overstated, given its long-term implications for overall health and well-being. Traditional methods of health education, while beneficial, often fail to engage young learners effectively, leading to suboptimal retention and application of knowledge. Augmented Reality (AR) technology, with its interactive and immersive capabilities, presents a promising alternative. Recent studies highlight the potential of AR in enhancing educational experiences across various domains,

including health education.[1] This innovative approach can bridge the gap between theoretical knowledge and practical application, making learning both enjoyable and impactful.[1,2]

Furthermore, the incorporation of augmented reality (AR) into educational settings has been shown to significantly enhance student engagement and learning outcomes. For instance, the RealityScan application, which allows users to create detailed 3D models of objects by scanning them with a mobile device, along with markerless dynamic rendering, which enables AR experiences without the need for physical markers, has demonstrated substantial improvements in student performance and content understanding. These technologies make learning more interactive and visually engaging, helping students better visualize and grasp complex concepts by bringing them into a tangible, three-dimensional space.[3,] The primary challenge in traditional oral health education lies in its inability to sustain children's interest and engagement. Conventional methods, such as lectures and pamphlets, often fail to capture the attention of young learners, resulting in poor knowledge retention and inadequate behavioral change. This issue necessitates the exploration of more engaging and interactive educational tools that can effectively convey important health information and foster positive behavioral outcomes.[5,6]

The integration of AR technology into educational frameworks offers a viable solution to this problem. By transforming abstract concepts into tangible experiences, AR can make learning more accessible and enjoyable for children. The interactive nature of AR allows for real-time feedback and personalized learning experiences, which can significantly enhance understanding and retention of information.[7,8] Studies have shown that AR-based educational tools can lead to improved learning outcomes and greater student satisfaction.[9] Therefore, implementing AR in oral health education could potentially overcome the limitations of traditional methods and provide a more effective and engaging learning experience for children.[10] Several studies have investigated the application of AR in educational contexts, providing valuable insights into its potential benefits and challenges. For example, Mochamad et al. developed an AR-based application for teaching science to elementary school students, which resulted in increased engagement and improved learning outcomes.[11] Similarly, Soumik explored the use of markerless dynamic rendering in AR, demonstrating its effectiveness in creating interactive and immersive educational experiences.[12] These findings suggest that AR can be a powerful tool for enhancing educational practices, particularly in subjects that require visualization and hands-on learning.

In the field of health education, AR has demonstrated significant potential in promoting better understanding and retention of information. For instance, a study examining the application of AR in pharmaceutical education found that the technology significantly improved students' ability to visualize and comprehend complex concepts.[13] Another study conducted by Jamila and Cakır highlighted the positive impact of AR on student performance in health education, noting that the interactive and engaging nature of AR helped students retain information more effectively.[14] These studies underscore the potential of AR to revolutionize health education by making learning more interactive, engaging, and effective.[15] Building on these insights, the present study aims to develop and evaluate an AR-based educational tool specifically designed for oral health education in children. By leveraging the interactive capabilities of AR, this tool is designed to enhance children's understanding of dental hygiene practices and promote positive behavioral changes. The study will employ a rigorous experimental design to assess the effectiveness of the AR-based tool in comparison to conventional educational methods, providing valuable evidence regarding the potential of AR to transform oral health education for young learners.[11]

Despite the promising findings from previous studies, there is still a need for further comprehensive research on the effectiveness of AR in specific educational contexts, such as oral health education for children. While existing studies have demonstrated the potential of AR to enhance learning outcomes, they often focus on general educational applications or specific subjects like science and pharmacy. The unique challenges and requirements of oral health education necessitate targeted research to fully understand the impact of AR in this field.[12] Moreover, many studies on AR in education have primarily examined short-term outcomes, such as immediate knowledge retention and engagement.[13] There is a lack of research on the long-term effects of AR-based education on behavior and knowledge retention, particularly in the context of oral health. Understanding the sustained impact of AR on children's dental hygiene practices is crucial for assessing its true effectiveness as an educational tool.[14]

The current study aims to address these existing gaps by conducting a comprehensive evaluation of an AR-based oral health education tool for children. By focusing on both immediate and long-term outcomes, this study will provide a more complete understanding of the potential benefits and limitations of AR in this specific educational context. The findings will contribute to the existing body of knowledge on AR in education and offer valuable insights for educators and policymakers seeking to improve oral health education for young learners.[15]The current study focuses on children aged 7 years. This age group was selected based on the developmental framework established by the National Association for the Education of Young Children (NAEYC). This framework emphasizes that children at this stage are highly receptive to interactive learning methods, particularly those involving visual aids and hands-on activities (NAEYC, 2024). AR's capacity to deliver real-time, interactive feedback makes it especially effective for young children who are in the early stages of developing self-care routines.[9] Additionally, research suggests that children aged 7 are developmentally capable of understanding and applying basic dental hygiene concepts when these concepts are presented in an engaging manner.[10]

Despite the existing studies on AR in education, research on its application in oral health education remains limited, especially concerning its long-term impact on knowledge retention.[11] This study aims to address this gap by evaluating the effectiveness of an AR-based educational tool specifically designed specifically for oral health. By employing the ADDIE model for the development of this tool, the study investigates whether AR can significantly enhance children's oral health knowledge. The novelty of this research lies in its focus on using AR technology specifically for oral health education in children, an area that has been relatively unexplored. The study aims to evaluate not only the immediate effects of AR on knowledge acquisition but also to assess its potential as a sustainable educational tool for fostering long-term behavior change in dental hygiene practices.[12] This research employs a pre-experimental design, using a pre-test and post-test approach to assess the impact of AR-based oral health education. By comparing the knowledge levels of children before and after the intervention, this study provides valuable insights into the effectiveness of AR in promoting better oral hygiene practices among children.

METHODS

The materials used in this study consist of an Augmented Reality (AR) application specifically designed for oral health education. This application features interactive modules that instruct children on proper brushing techniques, the effects of sugary foods on dental health, and the importance of regular dental check-ups.[1,5] Additionally, the study incorporates educational content obtained from reputable dental health resources, tablets for deploying the AR application,

and standard dental hygiene tools such as toothbrushes and toothpaste for demonstrations.

The research team developed a dental health education module that included critical information about the habits leading to dental issues and the best practices for maintaining oral hygiene. This module, integrated with the AR application, provided children with interactive lessons on how improper brushing, excessive sugar intake, and neglecting dental visits could result in toothaches and other dental problems. The module also emphasized preventive measures, such as proper brushing techniques, the importance of flossing, and regular dental check-ups. As a result of engaging with this module, children showed significant improvement in their dental health knowledge, as evidenced by the pre-test and post-test results. The mean knowledge scores increased substantially, reflecting the module's effectiveness in educating the young participants about essential dental hygiene practices.[15,16,17]
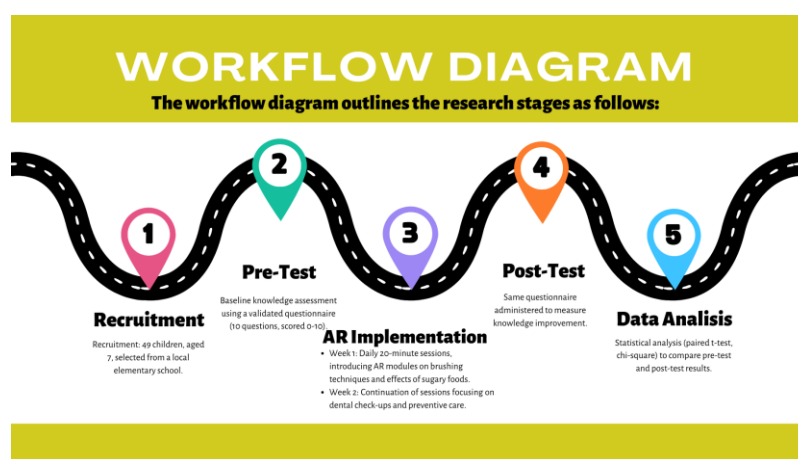

Figure 1. The workflow diagram outlines the research stages

The AR tool used in this study was developed following the ADDIE model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. During the Analysis phase, the educational needs related to children's oral health were identified through surveys and interviews with pediatric dental experts. This analysis served as the basis for designing age-appropriate educational content for 7-year-old children.

In the Design phase, the AR application was developed to incorporate interactive modules that taught proper brushing techniques, the effects of sugary foods on dental health, and the importance of regular dental check-ups. The design aimed to engage children through visually appealing content and intuitive interactions.

The Development phase involved the actual creation of the digital content and the coding of the AR application. A team of graphic designers, software developers, and pediatric dental experts collaborated to build the application. It was subsequently pilot-tested with a small group of children to ensure that the user interface was child-friendly and that the content was easily comprehensible.

For the Implementation phase, the AR application was installed on tablets and introduced to children in a classroom setting. The children participated in a brief training session on how to use the application. Children used the AR tool for 20 minutes daily under supervision. AR modules provided interactive lessons on oral hygiene. Progress was monitored through observations, and engagement levels were recorded. Finally, in the Evaluation phase, the effectiveness of the AR tool was assessed through a post-test that measured the children's knowledge of oral health. Additionally, feedback from both the children and their parents was collected to evaluate the application's engagement and usability.

This study utilized a pretest-posttest design to assess the effectiveness of an augmented reality (AR)-based educational tool. The sample for this study consisted of 49 children, aged 7 years, who were selected from a local elementary school using a purposive sampling method to ensure that the participants accurately represented the target age group. The children were organized into a single group that participated in both the pre-test and post-test phases of the study. Prior to the intervention, parental consent was obtained, and children were informed about the study's objectives and procedures. The AR application was installed on tablets, and the children received instructions on how to use the devices and interact with the educational content.

The experimental setup utilized a pre-test and post-test design to evaluate the effectiveness of the AR application. Initially, the children's knowledge of oral health was assessed using a standardized questionnaire. Following the pre-test, the children engaged with the AR application for a duration of two weeks, during which they completed various interactive modules. The intervention was conducted in a classroom setting under the supervision of researchers. After the intervention, a post-test identical to the pre-test was administered to measure changes in knowledge levels.[6,9] The experiment was designed to minimize any external influences and ensure a controlled environment for accurate data collection.

The primary parameter measured in this study was the children's knowledge level regarding oral health. This was assessed using a validated questionnaire that was reviewed and approved by a panel of experts in pediatric dentistry and educational technology from the Faculty of Dentistry at Universitas Andalas. The questionnaire included questions on proper brushing techniques, the impact of sugary foods on dental health, and the importance of regular dental visits, providing a comprehensive evaluation of the children's understanding of these key concepts. Secondary parameters included the engagement and usability of the AR application, which were measured through observational checklists and feedback forms completed by the children and their parents.[14]

The knowledge questionnaire contained 10 items, each designed to evaluate key aspects of oral hygiene. The questions were scored on a scale from 0 to 10, with higher scores indicating better knowledge. The categories for knowledge assessment were divided into three levels: poor (0-4), fair (5-7), and good (8-10).[6] Validity and reliability tests were performed to ensure the accuracy of the questionnaire, yielding a Cronbach's alpha of 0.85, which indicates high internal consistency.[11] Data from the pre-test and post-test were analyzed using paired t-tests to determine the significance of changes in knowledge scores. Descriptive statistics, including the mean, standard deviation (SD), and standard error (SE), were calculated to summarize the data. A p-value of less than 0.05 was considered statistically significant. The shifts in knowledge categories (poor, fair, good) were analyzed using chi-square tests.[6]

RESULTS

The research team created an augmented reality module for dentistry and oral health education as a result of this study. Additionally, an application was created to scan the images from educational module and generate an augmented reality experience. The following are some outcomes of augmented reality:

Figure 2. E-Dental Module. This module includes information about oral hygiene practices and habits that can lead to toothaches.

The application of Augmented Reality (AR) as an educational tool for promoting oral health is demonstrated through various interactive modules. Figure 2 showcases the AR module designed to teach children proper brushing techniques, the effects of sugary foods on teeth, and the importance of regular dental check-ups. The visual and interactive nature of these modules aims to enhance engagement and retention among young learners.
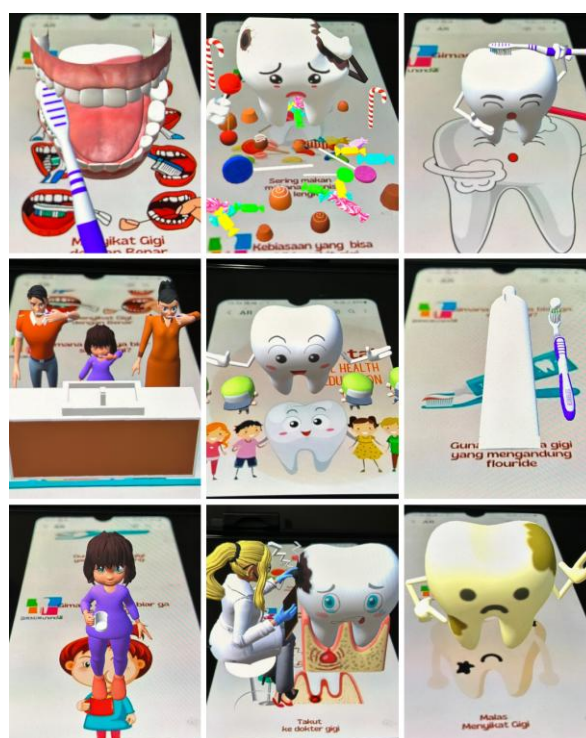

Figure 3. Augmented Reality as an Educational Media and Dental Health Promotion

The figure 3 illustrates the interactive modules of the AR-based educational tool designed to teach children about oral hygiene. These modules address

several key topics, including the proper brushing techniques, the consequences of consuming sugary foods, and the importance of using fluoride toothpaste. The animations also emphasize supervised brushing, regular dental check-ups, and the dangers of neglecting oral hygiene, such as plaque buildup and tooth decay. The visual representations are intended to engage young learners by making dental health education both interactive and accessible, thereby helping them retain important oral hygiene habits.

Table 1. Analysis of Knowledge Score of Dental and Oral Health Before and After Education Using Augmented Reality (n=49)

Variable	Mean	SD	SE	P value
Knowledge Level				
Pre-test	5.27	1.36	0.19	0.00
Post-test	8.65	0.9	0.13	0.00

Table 1 illustrates the shift in knowledge levels among 49 children before and after the AR-based oral health education intervention. Prior to the intervention, 61.2% of participants were categorized as having "poor" knowledge, a figure that significantly decreased to 12% following the intervention. In contrast, the percentage of participants categorized as having "good" knowledge increased dramatically from 8.2% in the pre-test to 88% in the post-test. The "fair" knowledge category experienced a slight decline, dropping from 30.6% to 12% after the AR education. This significant improvement underscores the effectiveness of the AR tool in enhancing children's oral health knowledge.
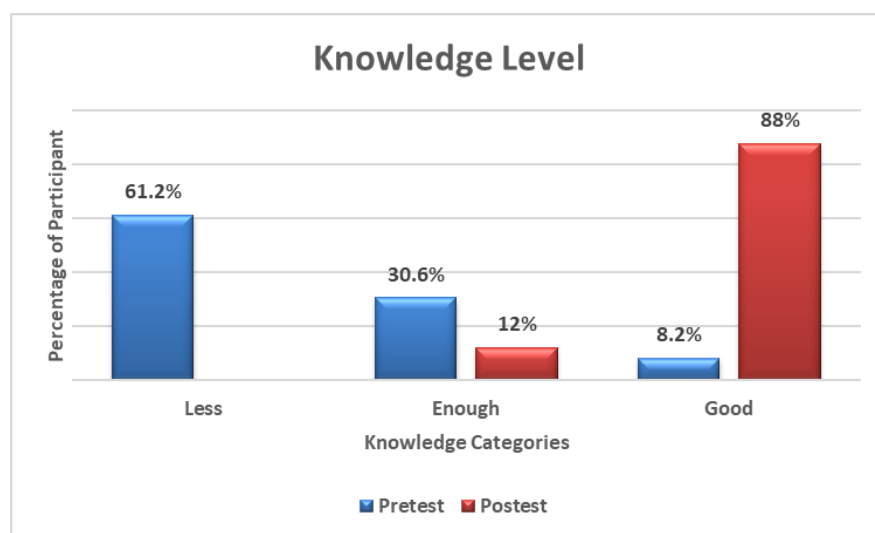

Figure 4. Frequency Distribution of Knowledge about Dental and Oral Health Maintenance Before (Pretest) and After (Postest) Education Using Augmented Reality Media

The statistical analysis presented in Figures 3 and 4 indicates a significant improvement in children's knowledge of oral health following the intervention. The mean knowledge score increased from 5.27 (SD = 1.36) in the pretest to 8.65 (SD = 0.90) in the posttest, with a p-value of 0.00, demonstrating a statistically significant improvement. Furthermore, the distribution of knowledge levels shifted markedly, with the percentage of children exhibiting good knowledge rising from 8.2% to 88%.

Table 2. Distribution of Knowledge Scores Before and After AR Intervention

	Pre-test		Post-Test	
	Total	Percentage	Total	Percentage
Less	30	61.2	0	0
Enough	15	30.6	6	12.2
Good	4	8.2	43	87.8
Total	**49**	**100.0**	**49**	**100.0**

The knowledge levels were categorized into three groups: poor (0-4), fair (5-7), and good (8-10). As shown in Table 2, the percentage of children with "good" knowledge increased dramatically from 8.2% in the pre-test to 88% in the post-test. Conversely, the percentage of children in the "poor" category dropped from 61.2% to 12%. This significant shift in knowledge levels, as illustrated in Table 2, indicates that most children improved from the "poor" and "fair" categories to the "good" category after the AR intervention.

DISCUSSION

The findings of this study demonstrate that the augmented reality (AR)-based educational tool significantly improved children's oral health knowledge, as evidenced by the increase in the mean knowledge score from 5.27 to 8.65 (see Table 1). This substantial improvement aligns with previous research that highlights the effectiveness of AR in enhancing educational outcomes across various fields, including health education.[1,2]

In comparing the results with similar studies, it is evident that augmented reality (AR) has a notable impact on knowledge retention. For instance, a study conducted by Mochamad et al. (2023) on the application of AR in science education also reported substantial increases in student engagement and knowledge retention, similar to the findings of this study. However, the current study extends these findings to the field of oral health education, suggesting that AR can be effectively adapted to various educational contexts with similar benefits.[2]

The effectiveness of AR in this study aligns with previous research demonstrating its utility of AR in educational settings. For instance, Mochamad et al. reported that AR applications significantly enhance student engagement and learning outcomes in science education, which parallels our findings in dental health education.[1] Similarly, Soumik and Mohammad et al. highlighted the advantages of markerless dynamic rendering and other AR technologies in creating engaging and effective educational experiences.[4,9] These studies collectively support the premise that AR can substantially improve children's comprehension and retention of health-related information.

The results of this study are also supported by Jamila and Cakır, who observed significant improvements in student performance in health education through AR systems.[20] Moreover, Yoga demonstrated that interactive mobile AR for health learning facilitates better understanding and retention of information among children.[11] These findings further reinforce the effectiveness of AR in promoting improved health knowledge and behaviors, making it a valuable complement to traditional educational methods.

The findings of this study have significant implications for the future of health education, particularly in oral health for young learners, as shown in Table 1. The notable improvement in knowledge scores following the intervention indicates that AR can be a powerful tool for enhancing children's understanding

of dental hygiene practices. This improvement can lead to better health outcomes by promoting positive behavioral changes from an early age.[4,20,22]

Table 2 showed that the interactive and engaging nature of AR was assessed through both observational and feedback methods during the study. Children interacted with the AR application, which included features such as real-time feedback, interactive quizzes, and animated demonstrations of dental hygiene practices. These elements were designed to capture the children's attention and encourage active participation. Researchers observed the children's engagement levels throughout the intervention, noting their frequency of interaction, attentiveness, and enthusiasm. Additionally, feedback forms completed by both the children and their parents provided qualitative data regarding their experiences and satisfaction with the AR tool.[4,9,19]

The effectiveness of these interactive features was assessed by comparing pre-test and post-test knowledge scores, along with analyzing the feedback data. The significant improvement in knowledge scores, combined with positive feedback from participants, suggests that the engaging nature of AR was a key factor in the successful educational outcomes observed. By making learning more enjoyable and memorable, AR helps overcome the limitations of traditional methods, which often fail to sustain children's interest and engagement.[20,22]

The successful application of augmented reality (AR) in this study suggests that similar approaches could be employed in other areas of health education, potentially transforming how health information is conveyed to young audiences. Future research should explore the long-term impact of AR-based education on behavior and health outcomes, as well as its applicability across various educational contexts. This exploration is crucial for understanding the sustained effectiveness of AR in health education and to devise strategies for its broader implementation.[1,2,6,,9]

Despite the promising results, several challenges must be addressed to fully realize the potential of AR in dental health education. Accessibility to AR-supported devices, such as smartphones and tablets, remains a significant barrier, particularly for children from low-income families or those living in resource-limited settings.[6,7,8] Additionally, the high cost of developing and maintaining quality AR applications poses another challenge. Additionally, ensuring stable and high-speed internet access is also critical for the successful implementation of AR in education, particularly in remote areas.[21,22]

Furthermore, the long-term effectiveness of AR in changing dental health behaviors remains underexplored. Most studies, including this one, have focused on short-term outcomes, leaving a gap in understanding the sustainability of the positive behavioral changes induced by AR. Regular follow-up evaluations could offer valuable insights into the longevity of the improvements in dental health knowledge and practices observed in this study.[9,10] For instance, ongoing evaluations at certain intervals could help determine whether the dental health knowledge and practices acquired through AR are maintained over time.[4,9]

Moreover, the interactive and visually engaging nature of AR can significantly enhance children's interest and motivation to learn. AR applications can provide personalized learning experiences tailored to individual needs, such as giving immediate feedback based on the children's brushing techniques. This personalized approach helps children better understand and retain concepts related to dental health through direct interaction and visualization. Another significant advantage of Ar is its ability to offer practical exercises in a safe and controlled environment. The AR application used in this study guided children through proper brushing techniques, providing real-time feedback that enable them to correct their methods. This finding is consistent with Emini's research, who reported that AR improves practical dental care skills by facilitating hands-on learning experiences.[11]

While augmented reality (AR) offers numerous benefits, it also presents challenges that need to be addressed. An excessive reliance on AR technology might reduce essential face-to-face interactions with dental health professionals, which are vital for accurate dental assessments and treatments.[11,12] Therefore, AR should be regarded as a complementary tool that enhances traditional educational methods rather than a replacement for them. Additionally, the infrastructure and financial requirements for developing and maintaining high-quality AR applications can also be prohibitive, particularly in resource-limited settings. Ensuring stable and high-speed internet access, particularly in remote areas, is critical for the successful implementation of AR in dental health education.[14]

Table 2 indicates that the findings from this study highlight the potential of AR technology as an effective tool for promoting dental health education. However, to maximize its benefits, it is essential to address the challenges of accessibility and long-term effectiveness. Future research should focus on longitudinal studies to evaluate the sustainability of AR-induced behavioral changes and explore ways to make AR technology more accessible and cost-effective. The integration of AR into dental health education programs has the potential to significantly reduce the prevalence of dental caries among children and improve the overall quality of dental health within the community. The results and implications of this study should be discussed in the broadest possible context, considering both the benefits and the limitations of AR technology.[17,18,21]

The application of Augmented Reality (AR) technology in oral health education has proven to be highly effective in enhancing children's understanding of dental hygiene. According to the findings from this study, there is a significant increase in knowledge levels after children received education through the AR module. This improvement is evident in Table 1 and Figure 4, which illustrate the changes in knowledge distribution before and after the intervention. These findings are consistent with previous research. For instance, a study by Mochamad et al. (2023) also demonstrated that AR significantly improved learning outcomes and engagement in younger learners, particularly in health-related education. Similarly, Jamila et al. (2022) found that AR was an effective tool in improving health-related knowledge retention in children. Both studies, like the current research, indicate that AR's interactive and visual features provide children with a more engaging and comprehensible learning experience, resulting in improved knowledge retention.

However, this study goes beyond previous research by specifically focusing on oral health education, whereas most prior studies have concentrated on broader health topics. The findings of this study demonstrate that AR can be successfully adapted to specific educational domains, such as dental hygiene, yielding similarly positive outcomes. A significant distinction of the current study is its targeted approach in improving children's understanding of brushing techniques, the effects of sugary foods, and the importance of dental visits-areas that have not been extensively explored in prior studies.

In contrast to studies conducted by Mohammad et al. (2022) and Soumik (2023), which did not emphasize measuring long-term behavioral changes following AR interventions, this study highlights the potential for AR to be further investigated in longitudinal studies. Future research should focus on assessing whether the knowledge improvements observed in this study lead to sustained changes in oral hygiene practices over time.

Overall, while the current study aligns with previous research regarding the effectiveness of AR in improving children's health knowledge, it offers new insights into the application of AR specifically within the context of oral health education. This opens up opportunities for further research to explore how AR can support long-term learning and promote behavioral improvements in children's dental care.

Before the intervention, most children had limited knowledge regarding dental hygiene. As shown in Figure 4, 61.2% of respondents were categorized as having "Poor" knowledge, while only 8.2% demonstrated "Good" knowledge. The mean knowledge score at the pretest stage was 5.27 with a standard deviation (SD) of 1.36, as outlined in Table 1. These figures indicate that children's understanding of oral hygiene was relatively low before the AR intervention.

This aligns with findings from Jamila et al. (2022), where students in a health education program also exhibited low baseline knowledge prior to exposure to interactive educational tools like AR. Both studies reveal that traditional methods of health education are often insufficient for younger learners, resulting in poor initial knowledge levels. However, Mohammad et al. (2022) reported slightly higher pretest knowledge in their AR-based health education study, likely due to the participants' previous exposure to health-related information. This finding highlights the variability in baseline knowledge across different studies.

The low pretest scores observed in this study, compared to those seen in other research such as Soumik (2023), could be attributed to the specific focus on oral hygiene, a subject that might not have been as thoroughly addressed in general health curricula. This difference underscores the need for more targeted interventions in areas like dental health, where knowledge gaps may be more pronounced.

Despite the differences in initial knowledge levels, the significant improvement after the AR intervention in this study mirrors the results of prior research, indicating that AR's interactive and engaging nature effectively addresses these gaps, regardless of the subject matter. Future studies could further explore how variations in baseline knowledge influence the effectiveness of AR interventions, particularly in specialized fields like oral health.

However, following the introduction of the AR module was introduced, there was a substantial improvement in the children's knowledge. Figure 4 reveals that post-intervention, 88% of respondents demonstrated "Good" knowledge, while the percentage of those categorized as "Poor" knowledge drastically decreased to only 12%. This improvement is also reflected in the mean knowledge score, which increased to 8.65 with a standard deviation of 0.9, as presented in Table 1. The p-value of 0.00 confirms that this increase is statistically significant.

The augmented reality (AR) module used in this study played a crucial role in achieving these positive outcomes. Figures 3 and 4 provide visualizations of the module, which covers essential aspects of dental hygiene, including proper brushing techniques, the importance of using fluoride toothpaste, and the harmful effects of consuming sugary foods. The AR-based educational approach was not only informative but also interactive, allowing children to learn in a more engaging and effective manner. This is evidenced by the significant improvement in their knowledge after participating in the program.

The results of this study are consistent with several previous studies that also highlighted the effectiveness of augmented reality (AR) technology in education. For example, research conducted by Mochamad et al. found that the implementation of AR applications can enhance student engagement and improve learning outcomes, particularly in the context of science education. This research demonstrates that the visualization and interactivity provided by AR can significantly improve students' comprehension, which aligns with the findings of this study in the context of oral health education.[1,2]

Additionally, the study conducted by Jamila and Cakır supports these findings by showing that augmented reality (AR) can enhance student performance in health education. They discovered that the use of AR in learning environment improves information retention and comprehension, contributing to overall knowledge gains. This is also reflected in the post-test results of this study, in

which the majority of children showed significant improvements in their understanding of dental hygiene.[20]

The findings from this study suggest that AR technology can be a highly effective tool in health education, particularly for children. The significant improvement in knowledge, as seen in Table 1 and Figure 4, indicates that children can not only understand the information delivered through AR but also retain and apply this information in their daily lives.[20,21,22]

However, it is important to note that while the short-term results of this AR intervention are very positive, further research is needed to evaluate the long-term impact of AR-based education on children's health behaviors. This emphasizes the importance of ongoing evaluation to understand how AR can influence sustained behavioral changes over time.[11]

Despite the promising results, this study has several limitations that should be acknowledged. First, the study only evaluated short-term outcomes without considering the long-term impact of AR education on children's dental health behaviors. Additionally, the study was limited to a relatively small sample size, which may not adequately represent the broader population.[14,16]

For future research, it is recommended that longitudinal studies with periodic follow-ups be conducted to assess the long-term effectiveness of AR-based education. Furthermore, larger and more diverse samples are essential to validate the findings and identify additional influencing factors.

This study demonstrates that AR technology is an effective tool for enhancing children's knowledge of dental hygiene, as supported by the results presented in Table 1 and Figure 4. However, to maximize its potential, further research should focus on the long-term impacts of AR technology and its application across various educational contexts.

Despite the promising results, this study has several limitations. The sample size of 49 children is relatively small, which may affect the generalizability of the findings. Moreover, the study focused on short-term outcomes; future research should investigate the long-term effects of AR on oral health behaviors over time. Conducting research in real-world settings, rather than controlled environments, and minimizing self-report bias will also be important in enhancing the robustness of future studies. Larger, long-term studies in more diverse and practical environments are necessary to fully evaluate AR's impact on health education.

CONCLUSION

This study demonstrates that the AR-based educational tool significantly improved children's knowledge of oral health knowledge. The interactive nature of AR made complex dental hygiene concepts more accessible and engaging for young learners. While the short-term results are promising, further research is needed to assess the long-term effects of AR on sustained knowledge retention and behavioral changes. The findings suggest that AR has the potential to be integrated into oral health education programs, offering an innovative approach to enhance children's understanding of oral hygiene practices.

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Data Availability Statement: Data supporting reported results can be requested.
Conflicts of Interest: The authors declare no conflict of interest.

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