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Enhancing sexual education for children with special needs through augmented reality: development and evaluation of the Magical SeDu application

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ABSTRACT

This research focuses on the educational obstacles encountered by children with special needs (CWSN), specifically in sexual education, through developing and evaluating the Magical SeDu application. Using a three-phase instructional design model, the study followed the planning, design, and development phases to create user-centered features that meet diverse learning needs. User acceptance testing (UAT) further confirmed the usability and effectiveness of the app, with a satisfaction rating of 86.04%. These findings underscore the transformative potential of augmented reality (AR) technology in inclusive education, fostering interactive and visually stimulating learning experiences. The study also emphasizes the importance of involving stakeholders in the development process to ensure the app meets the specific needs of its users. Future research should focus on enhancing the app's features and exploring its integration into broader educational environments to maintain accessibility and continuous improvement. This study contributes to the advancement of inclusive education strategies and highlights the critical role of sex education in increasing self-awareness and protection for children with special needs.

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1. INTRODUCTION

Sexual education plays a vital role in individual development, particularly for children with special needs (CWSN). These children, including those with autism and dyslexia, often encounter distinct challenges when it comes to understanding and navigating issues related to sexuality. Effective sexual education can equip them with essential knowledge to safeguard themselves against sexual violence and foster healthy relationships [1]–[5]. Despite its significance, many special education institutions, such as Pelita Bunda Education Center in Samarinda, East Kalimantan, find it difficult to deliver sexual education content effectively. The risk is 3-4 times more likely to experience sexual abuse than their peers, yet they often lack access to proper sexual education. Studies show that only 4% of CWSN receive formal sex education, leaving them vulnerable to exploitation. Research proves these approaches work structured sex education increases abuse recognition by 72%, and augmented reality (AR)-based learning improves knowledge retention by 40%. With 85% of parents supporting specialized sex ed for CWSN, such programs are vital for safety, awareness, and empowerment [6].

A primary obstacle is the insufficient availability of suitable educational resources tailored for conveying this material to students with special needs. The lack of adequate visual aids frequently hampers the learning experience, especially for children with autism who rely heavily on visual and interactive methods [7], [8]. Studies indicate that customized sexual education can mitigate the risk of abuse while enhancing children's awareness of their bodies and personal boundaries [9], [10]. Moreover, involving relevant experts in developing educational materials is essential to address the diverse needs of CWSN effectively [11]–[14]. It, particularly those with autism and intellectual disabilities, face distinct challenges in accessing and understanding sexual education. Unlike typically developing children, CWSNs often struggle with abstract concepts, limited communication skills, and sensory sensitivities, which can make traditional teaching methods less effective. A significant barrier is the lack of accessible and adaptive learning materials tailored to their cognitive and behavioral needs. Many educational resources are not designed to accommodate visual learning preferences, structured repetition, or simplified language elements that are crucial for CWSN. There is often insufficient teacher training in delivering sensitive content to special needs learners, leading to discomfort or avoidance of the subject altogether. Another significant barrier is social stigma and parental discomfort, which can result in delayed or restricted access to sexual education due to fear, shame, or cultural taboos. CWSNs are also at higher risk of sexual abuse and exploitation due to limited awareness of personal boundaries and difficulties in reporting inappropriate behavior. These factors collectively highlight the urgent need for inclusive, interactive, and developmentally appropriate educational tools, such as Augmented Reality applications, that can bridge communication gaps and foster understanding safely and engagingly.

Sex education for individuals with special needs often lacks inclusivity and tailored approaches [15]. Challenges include cultural sensitivities, communication barriers, and the need for specialized materials [16]. AR could address these by offering personalized, interactive learning experiences. The use of AR in education has evolved significantly, particularly in supporting children with special needs. AR technologies have demonstrated immense potential in enhancing interactive learning, making abstract concepts more tangible through visual and sensory stimulation. Recent research of AR's role in overcoming educational barriers for children with disabilities, especially those with ASD and intellectual disabilities, by providing personalized, visual, and interactive learning experiences. Studies have shown that AR can improve knowledge retention, engagement, and comprehension, crucially addressing the specific learning needs of children with special needs [15], [17], [18]. In the realm of sexual education, AR has been applied to teach body awareness, self-protection, and developmental stages, areas where children with special needs often lack adequate support due to the absence of inclusive and adaptive educational materials. The current literature indicates that AR not only facilitates understanding of complex topics but also promotes self-awareness and empowers children by offering them a safe space to explore sensitive issues [3], [7]. While these advancements are promising, challenges remain, including the need for further research on long-term efficacy, user acceptance, and broader application within educational institutions [8], [12], [14]. The integration of AR into sexual education is still in its developmental stages, suggesting a need for continued innovation and refinement to meet the evolving needs of children with special needs.

In this paper, AR technology presents an innovative solution. AR has the potential to create engaging and interactive learning experiences that encourage students to actively participate in their education [17]–[19]. A key technique within AR is image-based tracking, which allows digital content to be projected onto specific images or physical objects. This method functions by detecting and recognizing images as triggers for displaying AR content [20]–[22]. The process consists of several critical steps: initially, the device must recognize the image through a training phase that involves analyzing key features of that image. Once identified, the system tracks the image's position during interactions, ensuring that the AR content remains aligned with the image even as the camera angle shifts [23], [24]. This capability of AR not only enhances engagement but also promotes deeper understanding through experiential learning. By providing immediate visual feedback and interactive elements, students can explore complex concepts in a more intuitive manner. AR can cater to various learning styles, making it a versatile tool for educators aiming to meet the diverse needs of their students [25]–[27].

The strength of image-based tracking lies in its versatility; it can utilize various types of images as triggers from posters to textbooks, making it adaptable for different educational scenarios. In applications focused on sexual education for children with special needs, this technology can animate learning materials through interactive visualizations that are captivating and easy to understand [28]. For example, when students point their device's camera at a specific image in a textbook or poster, AR content can provide further explanations about concepts related to sexuality in a more engaging and comprehensible manner [29]–[32]. By employing image-based tracking techniques, this study aims to create interactive AR-based educational media for sexual education at Pelita Bunda Education Center. It is expected that this technological implementation will not only enhance students' comprehension of sexuality but also contribute positively to their overall quality of life. Existing methods for sexual education for CWSN include visual

aids, role-playing, customized curricula, and caregiver training, which offer tailored content but often lack interactivity and scalability. Technology-enhanced interventions, such as computer-based programs and AR/VR tools, improve engagement but are rarely designed for sexual education. This study advances the field by developing the Magical SeDu AR application, which explicitly addresses body awareness, self-protection, and developmental stages through marker-based AR, ensuring accessibility and user-centered design, unlike prior AR interventions focused on general social skills.

Through this research, we aspire to make a meaningful contribution toward developing inclusive educational strategies that address the needs of children with special needs. This study seeks to raise public awareness regarding the importance of appropriate sexual education for these children. With adequate support from families, educators, and society at large, children with special needs can realize their full potential in everyday life.

2. MATERIALS AND METHOD

Magical SeDu application is developed using model and development from [33]. Other studies also apply this model [34]–[36]. This model has three stages: planning, design, and development, followed by attributes that are always there, like standards, ongoing evaluation, and project management. Figure 1 shows the model for this research.

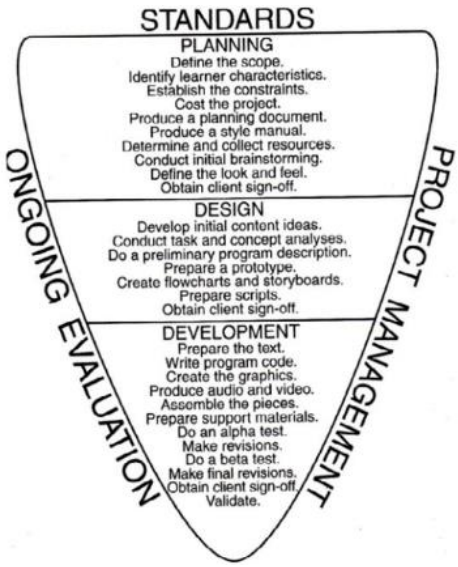


Figure 1. Instructional system design (ISD) model [33]

This research employed a quantitative approach with a descriptive statistical analysis to evaluate and describe data collected from students of Pelita Bunda Education Center. The study focused on understanding the impact of the Magical SeDu application in delivering sexual education. This study involved 30 students from Pelita Bunda Education Center, which is an inclusive school. The participants were selected using a purposive sampling technique, in which the chosen students had to fulfil some predetermined inclusion criteria. The selected participants were 14th to 16th-grade students with autism spectrum diagnoses. The selection of students with autism spectrum was based on the need to understand how AR technology can support their understanding of sensitive sexual concepts. In addition, the selected students have matured cognitive abilities and learning styles, so they can follow the material provided and understand the information taught. Prior knowledge and experience with sexual education are essential factors in ensuring that students have an adequate foundation to receive the material delivered through the app. Facilitators and parents use this app to teach sex education to students so that students do not use this app without a companion.

Research highlights several evidence-based strategies for teaching CWSN about body awareness, developmental stages, and self-protection, addressing their unique cognitive, sensory, and communication challenges. Visual and structured learning such as social stories, picture schedules, and anatomically correct dolls helps concretize abstract concepts [37], [38]. Role-playing and behavioral modeling are effective for

practicing self-protection skills (*e.g.*, recognizing inappropriate touch) in a safe environment [39]. Technology-aided interventions including AR and interactive apps, enhance engagement through multisensory experiences [40], [41]. Stakeholder involvement training parents and educators to reinforce lessons is critical for consistency and cultural sensitivity [42], [43]. Challenges persist, such as sensory overload risks in AR/VR, resource constraints, and societal taboos. Tailoring content to individual needs and combining multiple strategies appears most effective. This approach ensured comprehensive data collection for participant, emphasizing reliability and depth in capturing the educational outcomes and usability of the application. The features of the Magical SeDu app were identified through an analysis of the needs of children with autism, including an understanding of their learning styles and the challenges they face. This process involved gathering feedback from parents, teachers, and inclusive education experts to ensure the relevance of the app. The user interface (UI) design was simplified with significant elements, calm colors, and consistent navigation to improve accessibility. The app uses AR technology to display interactive visual elements that help children understand sexual education concepts firsthand. The materials are organized in step-by-step modules to facilitate progressive learning according to the child's ability. Other features include immediate feedback, as well as progress monitoring by parents and teachers. The user testing process ensures that these features are practical and meet the needs of learners.

3. RESULTS AND DISCUSSION

This study employed the instructional design model by Alessi and Trollip, which emphasizes three primary stages: planning, design, and development [33]. These stages were systematically applied to create the augmented reality Magical SeDu (AR Magical SeDu) application, an interactive learning tool aimed at enhancing user engagement and comprehension through AR technology

3.1. Development Magical SeDu application

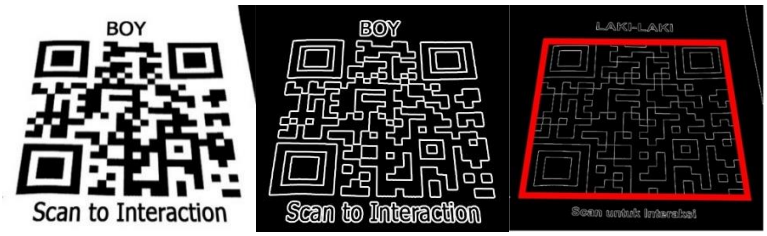
The three-stage instructional design model used in this study includes three main stages, namely planning, design, and development, each of which has specific steps. In the planning stage, the primary focus is on setting clear learning objectives that are appropriate to the needs of the students, *i.e.*, children on the autism spectrum. The objectives include an increased understanding of body awareness, developmental stages, and self-protection strategies. Next, the researcher conducts an analysis to identify the learners' characteristics and determine appropriate learning strategies, such as the use of AR technology that enables an interactive learning experience. At this stage, researchers also design assessment instruments, as well as plan user acceptance testing (UAT) to evaluate user satisfaction.

In the design stage, the steps focus on creating application elements that are in line with the set objectives. This includes structuring the sexual education materials to suit the cognitive development of children with autism, as well as creating a simple and easy-to-navigate user interface (UI) design. The UI design considers elements such as color, button size, and the use of icons that facilitate accessibility. In addition, the development of multimedia content, such as images, animations, and sounds that are easy to understand, is also an essential part of the design stage. Afterwards, an interactive prototype of the app was developed and tested by the facilitator to ensure that the app met the needs of the users.

In the development stage, the design is implemented into a functional application. This stage involves coding the application using appropriate software and frameworks to develop AR elements and integrate multimedia. Once the application has been created, testing is conducted to evaluate its functionality and identify potential technical or usability issues. Data from these tests was collected to determine the user experience and used to improve the application. Based on user feedback, the app was refined to ensure that the content, user interface, multimedia elements, and navigation were optimized so that the app could be effective in teaching sexual education to children with autism. At this stage, educators were involved in the development of the Magical SeDu app by providing input on the design and learning materials, such as body parts that others should not touch, what to do if others feel the body, and parts of the human reproductive body. They helped identify concepts that were difficult for students to understand and suggested effective methods for delivering sexual education materials. Educators also played a role in testing the app in the classroom to ensure suitability with the curriculum and students' abilities.

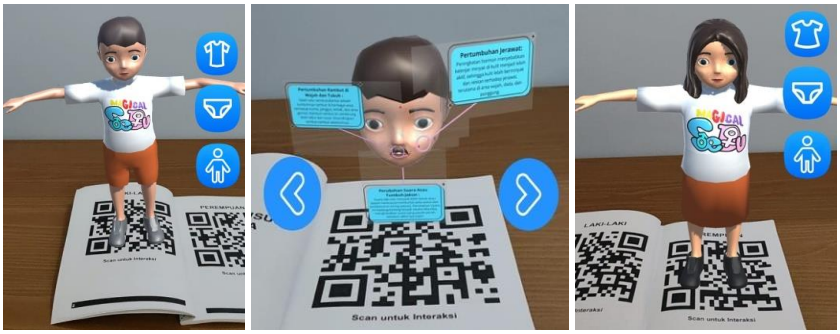
The Magical SeDu application identifies markers to display 3D objects. Figure 2(a) shows two identical markers with the text "boy' and the instruction "Scan to Interaction". These markers are custom patterns designed to be recognized by an AR system. The markers function as indicators for devices to determine where to place the 3D objects to be displayed. Next, the image processing process by detecting the boundaries (contours) of the marker as shown in Figure 2(b) After the contour is found, the system will look for corner points on the marker as shown in Figure 2(c). These corner points are very important to determine the shape and position of the marker accurately.

In the next step, the system will look for two distinctive parallel lines on the marker. These lines are often used as references to determine the orientation of the marker in 3D space. By knowing the position and orientation of these parallel lines, the system can calculate the position and orientation of the marker more precisely. The detected marker image will be normalized. The image will be resized and rotated to match the template that has been stored in the system. The normalized marker image is then compared to the existing marker template. If there is a sufficiently high match, the system will assume that the marker has been recognized. After the marker is recognized, a 3D object will appear on the device as shown in Figure 3(a), and the Figure 3(b) shows one of the male changes found on the face. These include facial and body hair growth, voice changes and growth of Adam's apple, and facial acne. The image also displays information about each male change that students can find out about. Figure 3(c) is a 3D object for girls that displays a complete object image using clothes and skirts. On the display, there are buttons to remove clothes, underpants, and all clothing. In this object, students must be accompanied by educators or parents so that they can get accurate information from educators or parents.



(a) (b) (c)

Figure 2. 3D object marker identification process: (a) marker 3D object, (b) contour extraction and corner detection, and (c) distinctive parallel



(a) (b) (c)

Figure 3. 3D augmented reality (AR) object display: (a) 3D object a boy, (b) body changes on a boy face, and (c) 3D object of girl

3.3. Effectiveness and usability of AR Magical SeDu

User acceptance testing (UAT) is a critical method for evaluating the effectiveness and usability of augmented reality (AR) applications across various domains [44]–[46]. This evaluation process helps determine how well users can interact with AR systems and how effectively these systems meet user needs. Questionnaire-based survey was conducted with a sample of users to evaluate the effectiveness and usability of AR Magical SeDu. The questionnaire assessed four main aspects: content, user interface, multimedia elements, and navigation. A Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to measure user satisfaction. The results of evaluating the effectiveness and usability of the AR Magical SeDu application, obtained through a questionnaire distributed to 12 facilitators. The evaluation assessed four key aspects: content, user interface (GUI), multimedia elements, and navigation, using 16 questions rated on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Then, the responder value's percentage average may be calculated in formula (1).

$$x = \frac{4+39+408+375}{16 \times 12 \times 5} \times 100\% = 86.04\% \quad (1)$$

Table 1 shows that the content aspect received high scores, with most respondents agreeing that the content is clear, easy to understand, relevant to sex education, and engaging. However, 8.3% of respondents indicated that the content was not particularly interesting. For the user interface, most elements, including the main menu, QR Code menu, information menu, and about menu, were rated positively. A minor issue was noted with the "About Menu Scene," where 8.3% of respondents expressed dissatisfaction. In the multimedia elements category, attributes such as font type, font size, graphics, buttons, and color were highly rated. Only one respondent (8.3%) felt that the font size needed improvement. The navigation aspect was also positively received, with most respondents agreeing that the navigation was clear, easy to use, and that the QR Code scanning functioned well. Nevertheless, 8.3% of respondents rated some elements as neutral, indicating room for improvement in usability.

The application achieved a total score of 375 out of a possible 408, resulting in a UAT percentage of 86.04%. This high satisfaction rate demonstrates the application's effectiveness and usability, although certain areas, such as content engagement and minor UI improvements, could be further enhanced. The evaluation results provide valuable feedback for refining the application and ensuring a better user experience in future iterations.

Table 1. Result of evaluating effectiveness and usability

Item (weight)	Strongly Disagree 1	Somewhat Disagree 2	Neutral 3	Somewhat Agree 4	Strongly Agree 5
Content					
The content is clear			2 (16.7%)	4 (33.3%)	6 (50%)
The content is easy to understand			1 (8.3%)	6 (50%)	5 (41.7%)
The content is related to Sex Education				5 (50%)	5 (50%)
The content in Magical SeDu is interesting	1 (8.3%)		2 (16.7%)	2 (16.7%)	7 (58.3%)
GUI					
Main Menu Scene			2 (16.7%)	6 (50%)	4 (33.3%)
Scan QRCode Menu Scene				9 (75%)	5 (25%)
Information Menu Scene			1 (8.3%)	8 (66.7%)	3 (25%)
About Menu Scene		1 (8.3%)		7 (58.3%)	4 (33.3%)
Multimedia Element					
Appropriate font type				7 (58.3%)	5 (41.7%)
Appropriate font size		1 (8.3%)		7 (58.3%)	4 (33.3%)
Appropriate graphics			2 (16.7%)	4 (33.3%)	6 (50%)
Appropriate button			1 (8.3%)	6 (50%)	5 (41.7%)
Appropriate color				6 (50%)	6 (50%)
Navigation					
Navigation is easy			1 (8.3%)	9 (75%)	2 (16.7%)
Navigation is clear and concise				8 (66.7%)	4 (33.3%)
Scan the QR code clear			1 (8.3%)	8 (66.7%)	3 (25%)
Total		2 (1.04%)	13 (6.77%)	102 (53.13%)	75 (39.06%)
Weighting		4	39	408	375
UAT Percentage					**86.04%**

4. CONCLUSION

The findings of this study indicate that the AR Magical SeDu app effectively improves sexual education outcomes for children with special needs. The results of UAT, with an overall satisfaction rating of 86.04%, indicated high usability of the app and positive reception by facilitators. Content clarity, user interface design, and multimedia elements were rated as excellent, although minor improvements were suggested for font size and content engagement. The transformative potential of AR technology in enhancing the educational experiences of children with special needs. The AR Magical SeDu application successfully bridges the gap in traditional educational resources, particularly in the domain of sensitive sexual education. Future research should explore additional features and adaptations to address broader educational contexts and ensure continued engagement and effectiveness. This study emphasizes the critical need for inclusive educational strategies that integrate advanced technologies to meet the diverse needs of learners.

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