

The Effectiveness of Augmented Reality with Adapted Books as Emotional Expression Media for Children with Autistic Spectrum Disorders (ASD)

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ABSTRACT

Autism Spectrum Disorder (ASD) is a neurological condition that affects a person's ability to recognize and understand emotions, thereby hindering social interactions. This research introduces AREmotion, an augmented reality (AR) mobile application integrated with an adapted book, designed to aid children with ASD in recognizing emotional expressions. Using images as markers in the AR application, AREmotion facilitates the learning process for these children. The study employed a pre-experimental design with a one- group pre-test and post-test to evaluate the application's effectiveness. Results indicated a significant improvement in the participant's ability to understand emotional expressions, with each respondent showing a significance value of less than 0.05. These findings demonstrate that combining AR technology with traditional printed books can effectively enhance emotional recognition in children with ASD, showcasing a promising advancement in this field.



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1. Introduction

Children with autism often face challenges in recognizing facial expressions. Autism is a neurological disorder that affects children's growth and development from birth, impacting their daily communication skills and social interactions [1]. According to the World Health Organization (WHO), approximately 1 in 160 children worldwide is diagnosed with autism [2]. The abilities and needs of individuals with autism vary widely; some can grow and live independently, while others require lifelong assistance. They typically exhibit three core characteristics: repetitive behaviors, difficulties with verbal and non-verbal communication, and challenges in social interactions [1]. These characteristics are further supported by the author's observations, which highlight the need for tailored learning approaches for children with autism who require assistance. Interactions between children with autism and their peers at school are often more solitary. However, by adapting the learning environment, such as incorporating the AREmotion application, learning for children with autism can become more structured, clearly programmed, and consistent. This adaptability enhances the learning experience and demonstrates the potential of such research.

During growth, ASD children have problems with social interaction from birth, i.e., (1) The development of interpersonal relationships is hindered. (2) More willingness to share hobbies and interests must be more voluntary. (3) Significant impairment of body language, gaze, and facial expressions when engaging in social interactions [3]. If children with ASD do not study emotional

facial expressions, it will negatively affect them. They grow up with a lack of empathy and difficulty responding appropriately to the emotional expressions of others. To avoid these problems, the treatment of children with ASD is needed to allow them to learn how to recognize the expressions of others at an early stage. Training children with ASD to learn social interaction requires treatment and guidance by a therapist, parents, and shadow teacher. Indonesian parents and experts, in particular, said more coordination is needed around children with ASD to provide better education and treatment. [4] In a literature study, the researcher found that parents' involvement in the education of ASD children can positively impact improving their skills, so parents can continue to be involved in the education of ASD children in the future [5].

Several methods are available for providing therapy to children with Autism Spectrum Disorder (ASD). One effective approach involves using drawings and sketches as art therapy. Sketch art is commonly used as a medium of psychotherapy for children [6]. ASD therapists often employ sketch art or illustration books to assist children in learning and recognizing facial and emotional expressions. Sketch art can stimulate non-verbal communication in both neurotypical children and those with ASD or other disabilities [7].

The use of technology in intervention methods for children with ASD has become increasingly prevalent. Between 2008 and 2020, 37 out of 95 relevant Scopus documents focused on autism and technology-based interventions, primarily conducted by researchers from the field of computer science. These technological interventions typically target specific skill areas [8]. Information and Communication Technology (ICT) has shown promise in developing social and emotional skills in children with ASD. Various technological tools have been found to enhance behavioral development and emotional responsiveness in children with specific disorders [9].

Technology development is now more flexible and practical because tablets and smartphones can quickly produce and visualize images. Augmented Reality (AR) is a technology that shows virtual objects in the virtual world in a real environment generated by a computer. AR technology has been widely used in many areas, such as education, medicine, and entertainment [10]. AR can provide a different experience and become an interactive medium for learning [11]. The application of AR in education can be integrated with other technologies, such as leap motion, virtual reality, and much-sophisticated software and hardware, developed as a cutting-edge and interactive computing platform. The form of interactive interaction in the Augmented Reality system can be implemented in three phases: gesture control, dynamic switch, and virtual display [12]. When this interactive AR technology can be appropriately applied, accompanied by collaboration from AR developers, experts, and teachers, it can give birth to a contemporary education that produces wider student learning opportunities [13]. AR can bring about a major transformation in education where this technology can provide a good and effective environment [14]. Many studies state that 56% of AR technology is used as a medium for learning social skills for children and adolescents with ASD aged 3-14 years [15].

Research that uses Augmented Reality (AR) with video modeling storybooks (ARVMS) to teach social skills to children with autism by understanding other people's expressions and emotions in a social environment is also exploring how AR can help children with ASD stay focused on objects during therapy and bridge the gap between the real and digital environments. [16]. Research related to AR as a medium for developing social and cognitive abilities for children with autism is a gamebook with Augmented Reality. [17]. Users were prepared to choose the appropriate expression according to the scenario story presented in the real environment. The researchers concluded that the ability to focus and memorize children with autism to recognize facial expressions has increased. As for research related to the adapted books for autistic children, namely adapted books for autistic children related to regulatory activities in the home involving parents and children, this study investigates whether there is an effect of adapted storybooks on children's overall reading effectiveness, with the results showing that children with autism show an increase in effectiveness in using adapted books with their parents as well as progress in regulating activities in the home. [18].

This research proposes an augmented reality application based on mobile augmented reality and adapted books as emotional recognition media for ASD children. The AREmotion application was developed using a user-centered design approach, obtaining usability results of 86.7%. The AREmotion application can be an educational medium for ASD children [19]. However, the previous study focused on the design aspect of educational media; this paper reports on the implementation results and effectiveness of the AREmotion application.

The effectiveness of the AREmotion media was evaluated through pre-test and post-tests and qualitative interviews. This study employed a pre-experimental design, specifically a one-group pre-test and post-test model, where the research subjects were observed after the treatment to determine any changes resulting from the intervention [20]. The significance of the difference between the pre-test and post-test scores of children with autism was assessed using a paired t-test, with a significance threshold of 0.05 for most paired t-tests [21].

The study aimed to analyze the effectiveness of the AREmotion media in enhancing the recognition of emotional expressions in children with autism spectrum disorder (ASD). The anticipated outcome is that augmented reality media can serve as an effective tool for recognizing emotional expressions. It is expected that children with autism will better understand the emotional expressions of those around them, thereby improving their social skills in everyday interactions.

2. Methods

2.1. Participants

This study involved two children with ASD, identified by the initials EN and AD. The inclusion criteria for participants were: (1) a clinical diagnosis of autism, (2) no physical disabilities, (3) comprehension of Indonesian or the local Javanese language, and (4) no cognitive function delays. All participants were recommended by therapists at a special school for autistic students in Malang City, with parental consent. Both participants exhibited limited social interaction skills, making it challenging to understand and respond to facial expressions corresponding to others' emotions. The evaluation took place at the participants' homes under the supervision of therapists and parents.

2.2. System Overview of AREmotion

The AREmotion application is designed to enhance emotional recognition in children with autism spectrum disorder (ASD) through an interactive and engaging platform that combines augmented reality (AR) with adapted printed books. The application consists of three main components: ARAnimation, Emotional Videos, and the ARBook as follows:

- The **ARAnimation** component includes animated videos of emotional expressions in AR format. These animations are designed to capture children's attention and provide a dynamic way of learning different emotional expressions. The animations use 3D objects that can be viewed through a smartphone or tablet, offering an immersive experience that enhances the understanding of emotions.
- The **Emotional Videos** menu features recordings of basic human emotional expressions. These videos serve as a reference for children to observe and learn how different emotions are expressed through facial cues and body language. Each video is designed to be clear and concise, providing an effective learning tool for recognizing emotions such as happiness, sadness, anger, fear, disgust, and surprise.
- The **ARBook** is an adapted printed book that contains stories about emotions with AR-based answer choices. It is designed to be used in conjunction with the AREmotion application. Each page includes illustrations and narratives that guide the child through different emotional scenarios. The book is printed at 21 cm x 16 cm, as shown in Figure 1, with each page divided into three sections: illustration, narrative layout, and marker layout, as shown in Figure 2. **The illustration Section** includes visual depictions of the story's events, helping children visualize and better understand the context of the emotions presented. **The Narrative Layout** section provides a simple, concise narrative of the story, written in sentences containing two to five words. The narratives are designed to be easy to follow and comprehend, ensuring children can engage with the content without feeling overwhelmed.

The Marker Layout: Each page contains markers that can be scanned using the AREmotion application. When a marker is scanned, the corresponding AR content is displayed, allowing children to interact with the story and answer questions about the depicted emotions. The AR interface indicates correct and incorrect answers, providing immediate feedback.

The development of the AREmotion application followed a user-centered design approach, ensuring that the needs and behaviors of children with ASD were carefully considered. The design process was carried out in two iteration cycles and included four core stages [19]:

- **Observation and Information Gathering:** Understanding the specific needs of children with ASD through observations and discussions with therapists and parents.
- **User Needs and Behavior Analysis:** Analyzing the collected data to identify key requirements and behaviors that the application should address.
- **Design and Development:** Based on the insights gained from the analysis stage, we created the AR-adapted book and developed the AREmotion application.
- **Evaluation and Feedback:** Testing the design with actual users and obtaining therapist feedback to refine and improve the application.

The development of the AREmotion application includes adapted printed books and a mobile application featuring augmented reality (AR) 3D objects. AREmotion displays six basic human emotional expressions: happy, sad, angry, afraid, disgusted, and surprised [22]. The adapted book contains 18 social stories and is a companion to the AR Animation menus. The ARBook menu is printed at 21 cm x 16 cm, as shown in Figure 1. The character models in the book are sketched, and the 2D animations are created using Cartoon Animator (formerly CrazyTalk Animator). The AR application is Android-based and developed using Unity Engine and Vuforia.

Each page of the adapted book has three sections: illustration, narrative layout, and marker layout. Each event story follows a sequence of events, described one by one, with sentences containing two to five words and an illustration for each sentence. The answers to questions in the social stories are provided through AR, as depicted in Figure 3. When the participant points the camera at the marker and answers the question, Figure 4 will display whether the answer is correct or incorrect.

The video menu featured recordings of basic human expressions, while the ARAnimation menu displayed animated flashcards of children's expressions using augmented reality. The ARBook contained a series of stories with questions and AR-based answers. Figure 6 illustrates an example from the ARAnimation menu, showing a 5-second video with audio to convey human emotions. For instance, the sound of laughter is used to help children recognize and understand a happy expression.

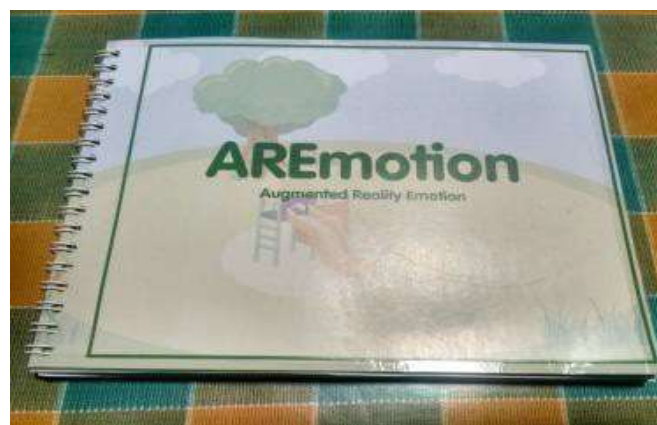


Fig. 1. AR Adapted Book

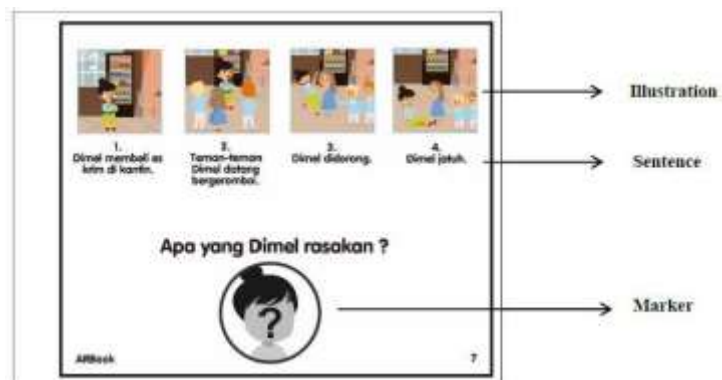


Fig. 2. Three-section format on ARBook layout



Fig. 3. Choice Answers Interface

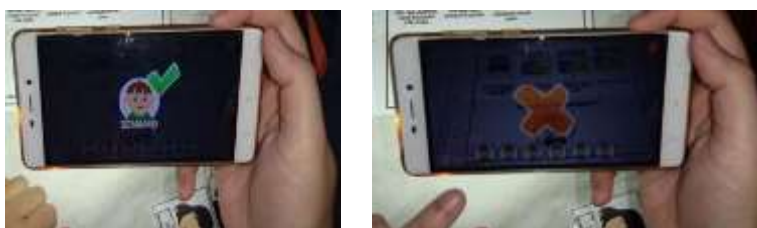


Fig. 4. The Interface of True or Wrong Answer



Fig. 5. Video Menu Interface



Fig. 6. Marker of ARAnimation menu



Fig. 7. ASD Children interact with AREmotion

2.3. AREmotion Evaluation Scenario

The pre-test assessed the children's understanding of emotions before using the AREmotion application. The pre-test duration was 15 minutes. During this time, children were provided with flashcards depicting various human emotions. These flashcards, commonly used by therapists, serve as a visual medium to introduce ASD children to different emotional expressions. In this stage, the children were asked to identify and name the emotions shown on the flashcards. The therapist used 18 flashcards, categorized into six emotions: happy, sad, angry, surprised, disgusted, and afraid.

After the pre-test, the children were introduced to the AREmotion application, which they used for 30 minutes to learn about emotions through augmented reality videos and animations. During this intervention, the therapist provided assistance and guidance. Following the application intervention, the children were presented with questions from the adapted book, answering through an augmented reality interface by pointing a smartphone camera at markers. The children were asked to identify the emotions depicted in the scenarios presented by the therapist. Each correct answer was awarded one point, while incorrect answers received zero points. The correct answers were calculated and statistically tested using the Paired T-test method.

3. Results and Analysis

3.1. Results to Respondent 1 (EN)

The therapist did not specify when the subject, EN, was diagnosed with autism, only mentioning that the diagnosis occurred during childhood. In addition to autism, EN also experiences speech delay and hyperactivity. The therapist has been working with EN on several therapies, including speech, motor, and behavior therapy and other skills such as reading and writing.

Before using the AREmotion application, EN was taught to recognize emotions such as happiness, sadness, and anger. This foundational training is reflected in the pre-test results, where EN could identify these emotions by pointing to corresponding pictures. The therapist utilized

images to teach these emotions and would demonstrate each expression. For instance, the therapist would smile to show what happiness looks like.

When the EN subject was introduced to the AREmotion application, the subject was afraid, refused, and cried. The subject indicated by moving away from the desk where the study was carried out and said aloud, "Don't want to, don't like it.". The therapist tried to help the researcher introduce the AREmotion application to the EN subject on the second day. Initially, the EN subject refused, but the researchers continued to scan markers, and the subject became interested in animated videos in Augmented Reality (AR).

The post-test results given to the subject at the end of the study show that the EN can recognize six categories of emotional expression. EN subject can also distinguish and recognize twelve emotional faces on the ARBook menu. This experiment showed that the subjects experienced an increase in their ability to recognize emotions, which initially could recognize three categories of emotions into six types of emotions.

Table 1. Pre-Test and Post-Test Score EN Subject

Test Results for 1st Respondent		
Categories	Pre-Test	Post Tes
Number of Emotions	7	16
Number of Emotions Categories	3	6
Emotions Categories	- Happy	- Happy
	- Sad	- Sad
	- Angry	- Angry
		- Surprised
		- Afraid
		- Disgust

3.2. Results to the 2nd Respondent (AD)

The education level of respondent 2 (AD) when this research was conducted was elementary school. The therapist did not mention when AD was diagnosed with ASD. Since the researchers met with AD subjects during their observations, AD has been highly interested in gadgets. AD subjects were looking for a smartphone when the therapist gave the subject a task. If the therapist does not fulfill the wishes, AD subjects become angry and shout incoherently while moving their body. The AD subject's verbal ability is insufficient (speech delay). AD subjects are active children, but AD tends to be silent and immediately rejects the task when AD is reluctant to do the job.

When conducting a pre-test with pictures, the result obtained by AD subjects was able to recognize two categories of emotions, i.e., happy and angry. AD is a child who is easily concentrated and interested in new things. AD subject tried the video menu and used it well when the researcher attempted to apply it. AD subject tries to press the buttons in the application. When AD tried the application that contained an augmented reality object, AD looked enthusiastic several times. AD tried to move away and bring the camera closer to the markers in the book. According to the therapist, it may be the first AD subject to use an application with augmented reality objects.

On the second day of introducing the AREmotion application, the AD subject immediately went to the researcher and asked for the researcher's smartphone, trying to open and look for the AREmotion application. According to the therapist, the application that AREmotion had used the previous day to study caught his attention. The obstacle that AD subjects often face is AD's character, who tend to get bored quickly and reluctantly and do not want to be pressured to do the given task.

When interacting with AREmotion, AD subjects recognized these emotions well and were able to imitate the gestures of each of them. After giving the need to use AREmotion, the AD subject recognized six categories of emotions. Disgust and fear are emotions that are difficult to recognize for AD because AD is often wrong in answering questions on the ARBook menu. When three questions were in the disgusting category, the subject answered two with angry answers. While in the fear category, the issue answered sad answers.

The post-test results given to the subjects at the end of the study showed that AD subjects could recognize the six categories of emotional expression provided. The subject can also distinguish and

acknowledge fourteen randomly emotional expressions on the ARBook menu. This experiment showed that AD subjects experienced an increased ability to recognize emotions, which initially could recognize two categories of emotions (happy and angry) to 6 types.

Table 2. Pre-Test and Post-Test Score AD Subject

Test Results for 2 nd Respondent		
Categories	Pre-Test	Post Tes
Number of Emotions	6	14
Number of Emotions Categories	2	6
Emotions Categories	- Happy	- Happy
	- Angry	- Sad
		- Angry
		- Surprised
		- Afraid
		- Disgust

3.3. Analysis of Test Results

From the pre-test and post-test results conducted over five sessions, each respondent exhibited varying outcomes in response to the emotional questions posed by the therapist during each panel. For instance, the subject EN significantly improved in each post-test session. However, the following day, when the pre-test was administered again, EN showed a decrease in the number of questions answered correctly. These fluctuations in respondents' answers are characteristic of individuals with Low Functioning Autism Spectrum Disorder (LF-ASD), who often experience difficulties with explicit learning related to previous experiences, concepts, and factual information [23]. The comparison of the pre-test and post-test results for the two subjects is presented in Table 3.

Table 3. Recap of Day-by-day Results

Day	Test Results			
	EN Pre-Test	EN Post-Test	AD Pre-Test	AD Post-Test
1	7	11	6	10
2	9	14	7	14
3	11	16	6	17
4	7	17	8	15
5	8	16	8	14

To begin the analysis of the scores, a statistical test is performed. The normality of the data was assessed using the Kolmogorov-Smirnov test, which indicated that the distributions for both subjects were normal. Specifically, the p-values for subjects EN and AD were greater than 0.05, confirming the normality assumption. Further statistical testing is necessary to determine if there are significant differences between pre-test and post-test scores. Given that the data follows a normal distribution and consists of two groups of dependent paired data, a paired t-test is appropriate for this analysis. The scores for each subject are analyzed individually. The result of the test from SPSS is shown in Table 4. Table 4 indicates that the p-value for subject EN is 0.005, less than 0.05, and the p-value for subject AD is 0.004, also less than 0.05. This suggests that both subjects' pre-test and post-test scores differ significantly, with post-test scores showing improvement over pre-test scores.

Table 4. Kolmogorov-Smirnov test

Test Results for 2 nd Respondent		
Subject	P-value	Statement
EN	0.050	Significantly different
AD	0.004	Significantly different

In the pre-test results, the subject EN, who was treated with the AREmotion application, could only identify three types of emotions: happy, sad, and angry. After the intervention with the AREmotion application, this increased to six categories of emotions (happy, sad, angry, surprised, afraid, and disgusted). Figure 8 illustrates that the post-test results for the EN subject showed an improvement in emotion recognition in each testing session. On average, the EN subject was able to answer 14 questions correctly in each post-test session. In the final test session, the EN subject demonstrated further enhancement in emotion recognition following the AREmotion application intervention.

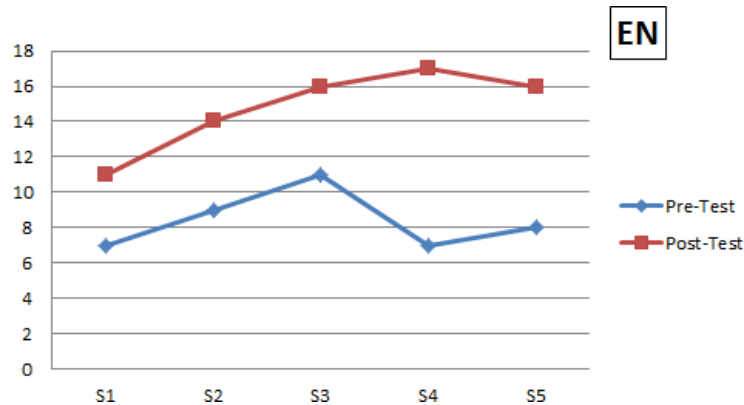


Fig. 8. Visualization graph of respondent 1 (EN)

This value also happened to the AD subject. At the pre-test stage, they identified two types of emotions (happy and angry). Since treatment with the AREmotion application, AD increasingly can recognize all emotions. The pre-test and post-test results of the AD subject are presented in Figure 9.

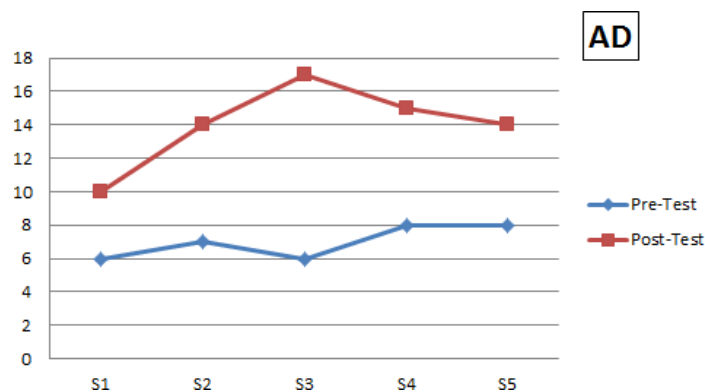


Fig. 9. Visualization graph of respondent 2 (AD)

From Figure 9, it can be seen that AD subjects experienced an improvement in emotion recognition at each session. The chart shows that the AD subject in the 3rd session of the test got the highest score, which answered 17 post-test questions in the adapted book proposed by the therapist. In the final result of the last test session using the AREmotion application, AD subjects experienced an increase in emotion recognition compared to the pre-test results in the first session. The analysis results above show that the two subjects experienced an average increase in recognizing emotional expressions using the AREmotion application. The comparative graph of the average growth of the two subjects is depicted in Figure 10.

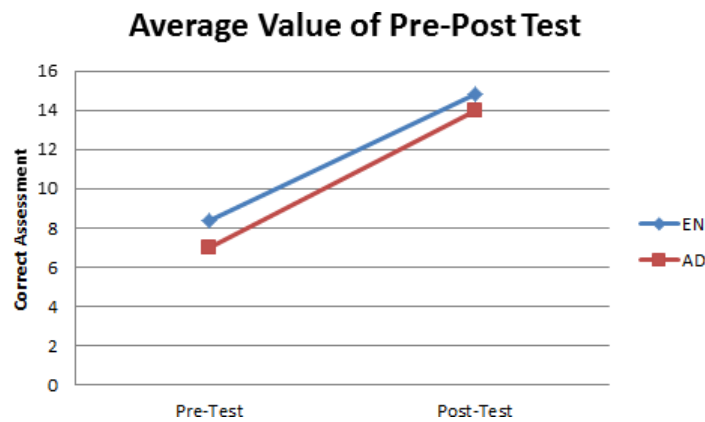


Fig. 10. Visualization of average score pre-post test

4. Conclusion & Future Work

This paper examines the effectiveness of the Augmented Reality Adapted Book (AREmotion) application in enhancing emotional recognition and improving social skills among children with Autism Spectrum Disorder (ASD). The study utilized a pre-experimental design with a one-group pre-test and post-test approach to evaluate the media's impact on two ASD children. The findings revealed a significant increase in emotional understanding for both children following the AREmotion application. Statistical tests supported the effectiveness of AREmotion, demonstrating significant differences between pre-test and post-test scores, with a significance value of 0.05. Additionally, both children showed improved recognition of various emotions. These results suggest that using augmented reality applications, combined with adapted books and printed cards, can effectively address the challenges ASD children face in recognizing emotional expressions.

While the study was limited to a small sample size of two participants, the significant improvements in their ability to recognize and understand emotional expressions highlight the potential impact of the AREmotion application. Despite the limited number of children involved, the findings suggest that augmented reality, combined with adapted books, can be an effective tool for emotional learning in children with ASD. This initial success paves the way for future research with larger participant groups, reinforcing the importance of personalized and innovative approaches in special education.

Future research should focus on expanding the participant pool to include a larger and more diverse group of children with ASD, ensuring the findings are generalizable across different demographics and levels of ASD severity. Longitudinal studies are necessary to assess the sustained impact of AREmotion on emotional recognition and social skills development over time, determining the lasting benefits and any potential need for ongoing intervention. Additionally, exploring the integration of AREmotion with other therapeutic approaches, such as speech therapy or occupational therapy, could provide insights into the combined effects on the holistic development of children with ASD.

Personalization of the AREmotion application is another critical area for future work. Developing and testing more personalized versions tailored to individual learning styles, preferences, and specific emotional recognition challenges could enhance its effectiveness. It would also be beneficial to investigate the role of parents and teachers in the application's implementation and develop training programs to equip them with the necessary skills to support children in using AREmotion.

Moreover, expanding the range of emotional expressions included in AREmotion to cover more complex and subtle emotions, such as jealousy, pride, or empathy, could further enhance the emotional literacy of children with ASD. Conducting cross-cultural studies would provide valuable insights into the application's effectiveness in different cultural contexts, considering how cultural differences in emotional expression and recognition might impact its efficacy.

Technological enhancements, such as integrating machine learning algorithms to adapt the difficulty level and provide real-time feedback, could improve the learning experience. Adding more interactive and gamified features would likely increase engagement and motivation for children, making the learning process more enjoyable and effective. Finally, investigating the direct impact of improved emotional recognition on real-world social interactions and relationships is crucial, measuring how well skills learned through AREmotion translate to everyday situations. These future work directions aim to build on the current findings and enhance the application's utility and effectiveness in supporting children with ASD.

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Declarations

Author contribution. Herman Tolle, Tika Miningrum, and Fitra A. Bachtiar contributed to the conception and design of the study. Herman Tolle developed the AREmotion application. Tika Miningrum conducted the experiments and collected the data. Fitra A. Bachtiar performed the statistical analysis. All authors contributed to the writing and revision of the manuscript and approved the final version.

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Additional information. No additional information is available for this paper.

Data and Software Availability Statements

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. **Software Availability:** The AREmotion application, including the ARBook developed for this study, is available from the corresponding author upon reasonable request.

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