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Enabling Inclusive Learning through AR for Children with Different Abilities

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***Abstract*—The potential of Augmented Reality (AR) technology to revolutionize inclusive education for children with diverse abilities. Inclusion in education is a fundamental right, and AR offers a promising solution to address the unique learning needs of children with disabilities. The technology's ability to offer multi-modal content, such as auditory, visual, and haptic feedback, ensures that children with different abilities can access and comprehend educational materials more effectively. Moreover, AR's interactive and immersive nature promotes engagement and motivation, fostering a more inclusive learning environment. Creating a 3D pop-up book using Unity software follows a linear, sequential model that combines assets from Adobe Illustrator, Vuforia, and Unity to craft an engaging and educational tool. It begins with conceptualization and storyboarding to define content and structure, by taking into account developer conveniences such as accessibility . To effectively communicate with children with autism, it's crucial to develop prototypes or materials tailored to their specific characteristics and needs. This ensures that the information or message can be more readily understood and accepted by these children.**

***Index Terms*— Augmented reality, Differently Abled Children, Inclusive Education, Interactive Learning, Cognitive Development.**

I. INTRODUCTION

Augmented reality (AR) is a technology [1] that merges virtual objects with the real world [2] using specific markers [3]. It combines computer-generated information with the physical world, making virtual elements interact with reality [4]. In education, AR significantly impacts learning [5] by providing contextual knowledge and optimizing learning time [6]. Its interactive nature enhances engagement and caters to diverse learning styles, making learning enjoyable and accessible [7, 8]. AR also adapts content to individual students, improving learning outcomes [9].
Previous research has explored AR's role in improving reading skills for children with autism. Cihak, McMahon, Wright, and Bell [10] used marker-based AR to enhance scientific vocabulary, positively impacting understanding. Rooks-Ellis, Howorth, and Flanagan [11] improved phonic awareness and reading fluency with marker-based AR, enhancing letter and word retention. Kassim et al. [12] used AR with markers to teach reading globally, enabling learners to engage with a digital world and supporting their development.
The research aims to address two main questions:

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• What are the steps involved in creating AR prototypes for individualized early reading in children with autism?
• Is it practical to implement these AR prototypes?

The article is structured as follows: Section II presents Motivation and Literature Review, Section III outlines the proposed methodology, Section IV analyzes the results, and Section V provides a condensed version of the entire article.

II. MOTIVATION & LITERATURE REVIEW

Previous studies primarily applied AR to aid in improving communication skills in children with autism due to their known challenges in this area . However, in recent years, there has been a notable shift towards focusing on enhancing The scholarly abilities of these learners. The previous seven years have seen AR gained traction as a tool to support the development of academic competencies in this population. Notable examples include Kellems et al.'s use of AR to enhance mathematics skills, resulting in are you significant skill improvement [13], and McMahon, Cihak, Wright, and Bell's application of AR to increase kids' vocabulary in science, with all of them demonstrating better definition and labeling skills [10]. AR has also been employed to teach reading skills, as seen in Kolomoiets and A. Kassim's use of Howorth, RootksEllis, Flanagan employed AR as instructional support in the form of videos to supplement reading teaching [11]. Furthermore, merged motion control and AR to facilitate alphabet and number learning, resulting in increased knowledge and student motivation [2]. Kellems et al.'s research showcased significant improvements in mathematics skills retention through ARbased interventions. McMahon, Cihak, Wright, and Bell's study revealed enhancements in science vocabulary knowledge among students using AR, indicating better comprehension and application of scientific terms [14]. Additionally, Kolomoiets and A. Kassim's work emphasized the use of AR to facilitate reading skill development through a reading method globally, while Rooks-Ellis, Howorth, Flanagan integrated AR videos to enhance reading comprehension, expanding accessibility and engagement with educational content [15].Antao˜ et al.'s innovative combination of AR with motion control techniques not only improved alphabet and numbers learning but also significantly boosted motivation among students, providing an immersive and exciting learning experience.Overall, these research papers collectively illustrate the potential of AR technology to empower differently-abled students, particularly those with autism, by not only addressing their academic challenges but also enhancing motivation, engagement, and knowledge retention, thereby fostering a more inclusive and supportive learning environment.

III. METHODOLOGY

In this research, the software development model employed is the Linear Sequential Model, as defined by Pressman [16]. This choice is based on the model's structured and systematic approach, where each step is clearly defined, ensuring a well-understood development process. You can visualize the development flow in Figure 1, which provides a visual representation of the model's sequential steps.

A. Communication

In the initial communication stage, teachers and the development team collaborate at the "Extraordinary School" to gather data on the educational challenges. A thorough literature review is then conducted to gather research from various sources, including books, journals, and references. This information helps define the features and functionalities of the software. The findings from this phase highlight the instructional principles commonly used for children with autism. Education for autistic children follows a structured approach, starting with basic materials and progressing as they master each level. Activities are structured with consistent procedures both at home and in the classroom. Educational programs are designed to progress incrementally based on each child's abilities, allowing for easier evaluation and improvement. Consistency is crucial in behavior therapy and education for autistic children. Positive responses to stimuli should be reinforced promptly to encourage positive behavior. Education for autistic children shares similarities with that of neurotypical children, emphasizing continuous learning. This continuity extends beyond the school environment to include activities at home and in the broader surroundings, promoting a seamless learning experience.

B. Modelling

By observing it has employed an object-oriented modeling approach using a Unified Modeling Language (UML) notation known as a use case diagram to represent the software's functionality. The use case diagram serves as a visual description of the activities that the software needs to perform and illustrates how the user interacts with the software, thus outlining the available functions. As depicted in Figure 1, one of the features is "Select

Group," allowing the user to choose from three reading skill levels: high [1], moderate [2], and low [7]. The user can also use the software to scan markers within a provided book. When a marker is scanned, the software generates outputs in the form of 3D objects, text, and audio. The audio associated with a 3D object can be replayed as per the user request, they can click on the 3D object. This use case diagram effectively conveys the essential functions and interactions within the software.
This application is designed for individuals with autism, and its user interface is crafted following the Autism Guide, a usability guideline tailored to users on the autism spectrum. To effectively model the data flow within the application, the developer team has created a data flow diagram (DFD).

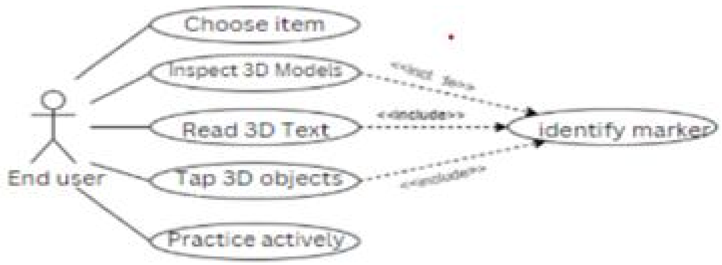

Fig. 1. Learning App for Autism - Usage Chart

Autism presents with diverse symptoms like challenges in social communication, and repetitive behaviors. Every child with autism is distinct, with varying needs and abilities.

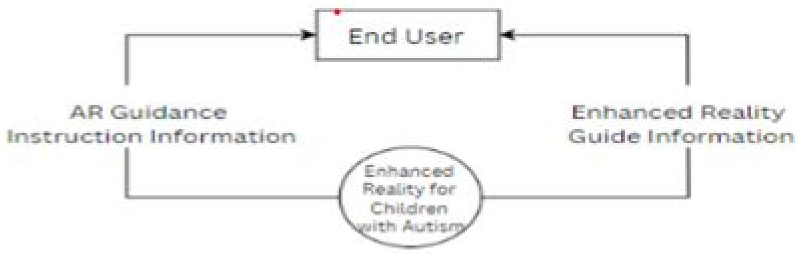

Fig. 2. System Overview

The initial part of this DFD is the context diagram, depicted in Figure 2, which outlines the system's scope. Within this context diagram, the central focus is on an AR process specifically developed for individuals with autism with the user being the primary entity within this system. This context diagram serves as an overarching view of how the application interacts with its users and operates within a broader context.

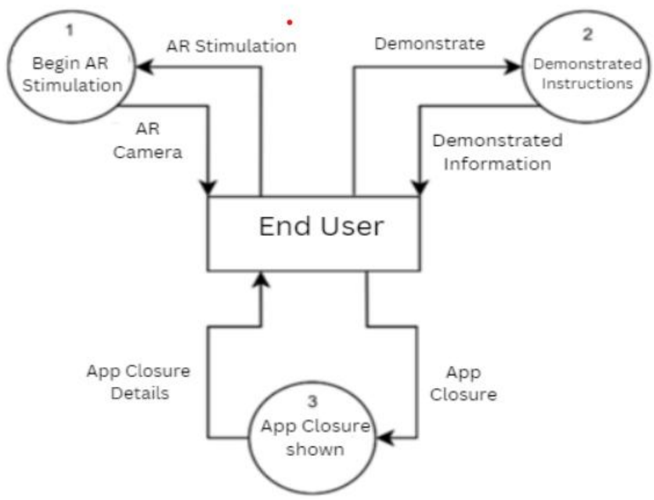

Fig. 3. Level 1 Information Movement Chart

The context diagram is then split up into smaller sections. Figure 3. The AR camera will be displayed by the system after the user clicks the menu to initiate AR. In addition to the guidelines menu, the user can view the application guidelines by clicking on the guidelines, which will be shown by the system as an image. Lastly, the user can use the exit button to close the application. The system will ask the user to confirm that they want to close the application.This process allows users to interact with augmented reality content tied to the markers they identify. Developers typically design markers using specific visual patterns or codes that can be recognized by AR software like Vuforia. These markers serve as triggers for AR content and are then integrated into Vuforia’s dedicated AR Marker database. Once integrated, the markers become recognizable to the AR system. When a user employs the AR camera, scans an area and detects one of these markers, the system initiates a scanning and recognition process within the AR marker data.

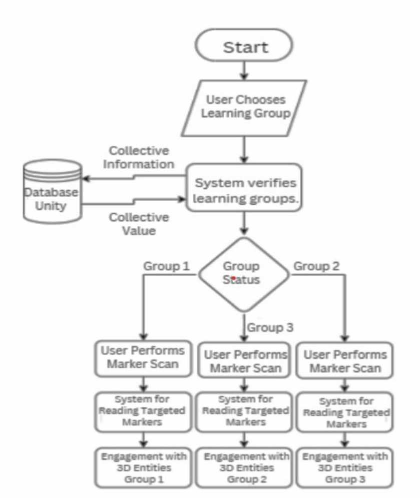

Fig. 4. Level 2 Information Movement Chart

This involves comparing captured marker visual features with those stored in the database. If a match is found, indicating the detected marker corresponds to one within the database, the system activates the associated 3D object or content, enabling users to engage with AR content tied to identified markers. In the advanced level, the developer creates a marker, enters it into Vuforia, and stores it in the AR Marker database. The system checks the AR marker database when a user employs the AR camera to identify a marker, presenting related 3D items and further information if the marker is in the database. Developers design markers with specific visual patterns recognized by AR software like Vuforia, integrated into Vuforia's AR Marker database. Once integrated, these markers become recognizable to the AR system. When a user scans an area and detects a marker, the system initiates a recognition process within the AR marker database, comparing the captured marker's features with those stored. If a match is found, the system activates the associated 3D object or content, allowing users to engage with AR content directly linked to identified markers.

The application employs personalized learning by allowing users to select a group from a Unity database and adjusts presented information based on the group's abilities. This goes beyond simple content adaptation, enabling students to engage with material aligned with their interests. User preferences are recorded and stored in the Unity database, marking a notable advancement in personalized learning.

Vuforia is chosen for AR-based app development due to its seamless integration with Android and iOS. Blender 3D is used for 3D models on AR markers. Black box testing and marker detection trials are conducted to ensure alignment and optimize performance. The system's performance is evaluated at various distances and tilt angles.

C. Deployment

After coding and testing, media specialists assess the application to ensure it meets standards and identify areas for improvement. Following this evaluation, the program undergoes further development based on feedback, preparing it for testing with autistic users. Two autistic students use the AR reading application in a customized learning approach, as depicted in Figure. 5, to evaluate its effectiveness in improving reading skills.

Fig. 5. 3D Pop-up image

TABLE I: THE DETAILED EXPLANATION OF THE PROJECT FOR UNDERSTANDING TO STUDENTS AND THE TEACHERS

Syntax	Learning Activities	Learning Activities in AR Media
Delivering Objectives and preparing Giving Feedback	1. Prepare students physically and mentally to encourage active participation, including using a video for engagement. 2. Share lesson goals and provide an overview of the reading material.	Videos in Augmented Reality (AR) aid learners in understanding concepts, such as chanting to recognize alphabets.
Students arranging	***Guide:*** Allow students to choose reading materials they haven't mastered or offer suggestions based on reading skills assessment. ***Students:*** Express enthusiasm to learn and determine initial reading material.	In AR media, students form groups based on reading assessments and choose material from the FunReado book based on interests. The book contains 15 words for students to learn.
Getting or obtaining information.	***Guide:*** Assist students in finding initial reading material information through media and encourage seeking assistance when needed. ***Students:*** Find material details through the media and seek assistance if facing challenges.	In this process, the teacher guides students to scan markers on books using the SAS method, with options to switch stages on AR media. Students are encouraged to explore and ask questions.

IV. RESULTS AND DISCUSSION

The study focused on two autistic students, Student A and Student B, highlighting challenges such as difficulty with similar-looking letters and pronunciation errors despite letter recognition ability. By the study's conclusion, both students showed improved reading outcomes, supporting the effectiveness of personalized learning for special needs students. While letter recognition did not significantly improve, which is considered a foundational skill, personalized learning was still beneficial overall. The study received positive feedback on its structure, documentation, and content quality but suggested improvements in providing broader word exploration and introducing reading through simple sentences for better comprehension.

IV. CONCLUSION

This research developed an AR application prototype for children with autism, focusing on enhancing reading skills through engaging features like spelling words and recognizing letters. The development process followed a systematic approach, considering the Autism Guide to ensure user friendliness. Both media and autism experts assessed the AR prototype, giving it a positive score for utility. Feedback highlighted the need for adding practice questions and simplifying instructions. Plans involve incorporating meaningful sentence reading material, integrating reading skills with other subjects, and diversifying learning activities to maintain student interest.

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