

INTERACTIVE SKILLS ENHANCER (ISE): A VIRTUAL REALITY-BASED LEARNING TOOL FOR CHILDREN WITH AUTISM SPECTRUM DISORDER AND INTELLECTUAL DISABILITY

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Abstract

Children with Autism Spectrum Disorder (ASD) and Intellectual Disability (ID) face challenges in social communication, emotional regulation, and life skills development. Traditional interventions often lack customization for their sensory and cognitive needs. This paper presents the design and preliminary evaluation of the Interactive Skills Enhancer (ISE), a customizable VR learning tool integrating AI-driven emotion recognition, realtime feedback, and a progress tracking dashboard. The VR environments simulate real-life scenarios such as classrooms, playgrounds, supermarkets, and city settings, tailored to individual sensory profiles. An exploratory study with children aged 7-14 showed promising engagement and skill acquisition, with VR-based emotional literacy training outperforming traditional methods in complex social tasks. Challenges related to hardware usability and facilitator dependence were noted. Future work includes expanded clinical trials, multi-platform support, and enhanced AI modalities. The results support VR as a dynamic, effective medium for social skills intervention in children with ASD and ID.

Keywords : Autism Spectrum Disorder, Intellectual Disability, Virtual Reality, Social Skills, Emotion Recognition, Assistive Technology, Personalized Learning.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) and Intellectual Disability (ID) are neurodevelopmental disorders characterized by impairments in social communication, emotional regulation, and adaptive behaviors. Approximately 30% of individuals with ASD have comorbid ID yet most existing interventions focus on high-functioning autism, leaving a significant gap in accessible, effective therapies for children with combined diagnoses. Traditional educational and therapeutic methods often fail to address the unique sensory sensitivities and cognitive profiles of these children, limiting engagement and skill generalization.

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Virtual Reality (VR) technology offers immersive, interactive environments that simulate real world social scenarios, providing safe, controlled settings for children to practice social, communication, and life skills. VR's adaptability allows customization of sensory inputs and task complexity, catering to individual needs. Moreover, integrating Artificial Intelligence (AI) for emotion recognition and in the moment feedback can personalize interventions and reinforce positive behaviors.

This paper introduces the Interactive Skills Enhancer (ISE), a VR-based learning tool designed specifically for children with ASD and ID. ISE features multiple virtual environments, AI-driven emotion recognition, and a dashboard for progress monitoring by therapists and caregivers. We describe the system design, implementation, and results from an exploratory clinical study. Our contributions include demonstrating VR's efficacy in accelerating social skill acquisition compared to traditional methods and outlining design considerations for this population.

II. LITERATURE SURVEY

Prior research has established VR as a promising intervention for children with ASD, particularly for improving social skills and emotional recognition. Reviewed 31 VR studies with children on the autism spectrum, concluding moderate evidence supports VR's effectiveness in social skills training. The emphasized immersive VR's potential but noted limitations such as small sample sizes and lack of autism specific control groups.

Several VR systems have been developed to teach life skills, including social interactions, emotion recognition, and communication. For example, used VR with machine learning to classify ASD vs. typically developing children with high accuracy. Designed VR environments for shape and color learning, demonstrating engagement and preliminary therapeutic benefit.

A recent randomized controlled study compared VR-based emotional literacy training to traditional therapist led interventions in children with ASD. While both methods yielded similar acquisition times for basic emotions, VR significantly accelerated learning of complex social emotional scenarios. This supports the hypothesis that immersive, context rich VR experiences facilitate faster and more stable social skill acquisition.

Despite promising results, challenges remain, including hardware usability, sensory overload, and limited longitudinal data. Our work builds on these findings by targeting children with comorbid ASD and ID, integrating AI emotion recognition, and providing a therapist dashboard for personalized intervention.

III. PROPOSED SYSTEM ARCHITECTURE AND FEATURES

The proposed system is a Virtual Reality (VR) - based in-teractive learning platform designed for children with Autism Spectrum Disorder (ASD) and Intellectual Disabilities (ID). It aims to create immersive, controlled environments that simulate real world scenarios, allowing users to develop cognitive, behavioral, and social skills at their own pace [12].

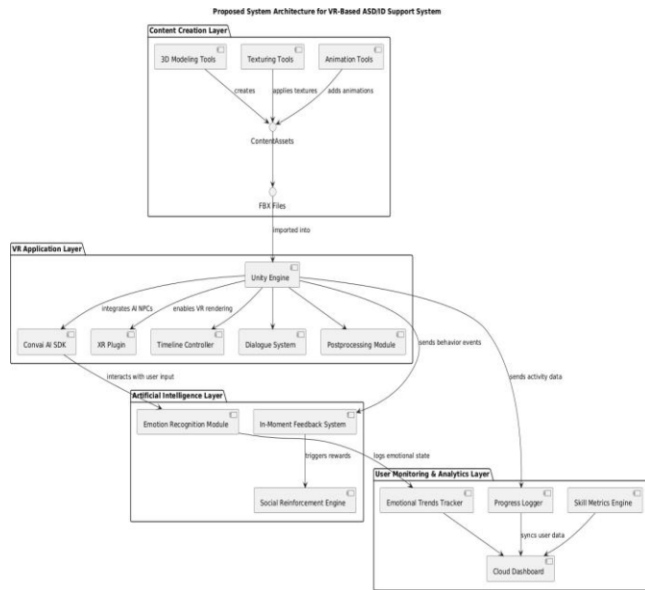


Fig. 1. Proposed System Architecture

A. System Architecture

The system architecture is modular, comprising four main layers which include content generation, immersive environment rendering, artificial intelligence integration, and user analytics, as illustrated in Fig.

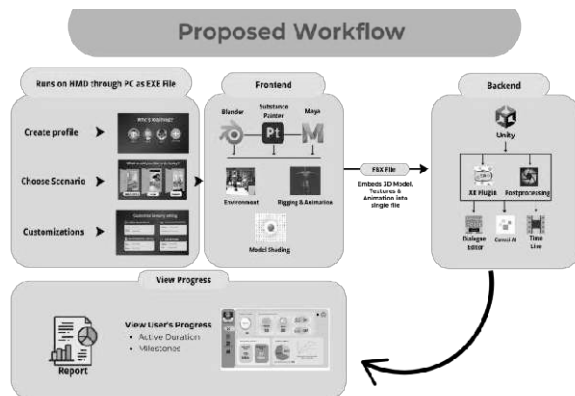


Fig. 2. System Workflow

1) Content Creation Layer :

3D assets are developed using industry standard software such as Autodesk Maya, Blender, and Substance Painter. Each virtual environment such as a school, supermarket, or playground is modeled with high levels of detail to ensure realism and immersion. Once completed, the assets are exported in FBX format to preserve associated textures, animations, and mesh fidelity for seamless integration into the VR development pipeline.

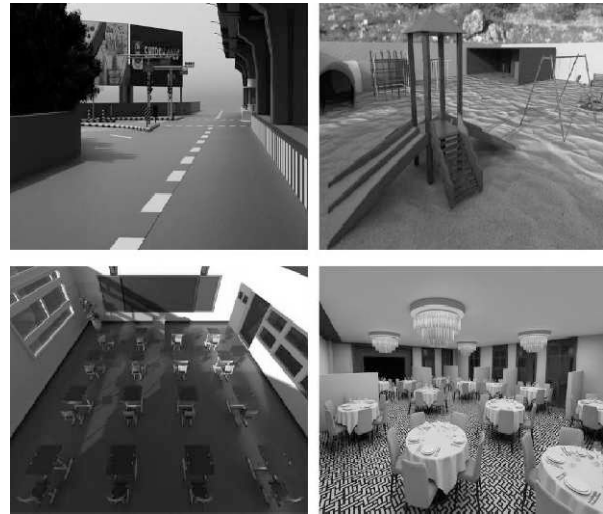


Fig. 3. Developed 3D Virtual Environments

2) VR Application Layer :

The Unity game engine serves as the development platform for rendering interactive VR environments, utilizing Unity XR plugins to ensure compatibility with major VR headsets. The system integrates several key subsystems to enhance user experience and interactivity. Postprocessing effects are employed to deliver a high level of visual and auditory realism through dynamic lighting, environmental sound design, and realistic shadow rendering. A timeline controller manages the structured flow of scenes and activities, enabling smooth transitions and narrative pacing. The dialogue system allows the incorporation of custom dialogues using a node-based editor, facilitating engaging interactions within the virtual environment. Additionally, AI integration enables natural language communication with non-player characters (NPCs) as shown in Fig. allowing users to converse with virtual agents in a fluid and responsive manner.



Fig. 4. User Interaction with AI Avatars

3) Artificial Intelligence Layer :

This enables the system to adapt dynamically to user behavior in real time. It incorporates emotion recognition capabilities that analyze visual cues and behavioral patterns to infer the user's emotional state. Based on these insights, the system provides in the moment feedback either corrective or encouraging tailored to support the user's engagement and performance. Furthermore, the AI layer employs social reinforcement strategies by delivering praise or virtual rewards to positively reinforce desirable behaviors, thereby fostering motivation and continued participation in learning activities.

4) User Monitoring and Analytics Layer:

It is designed to provide caregivers and educators with meaningful insights into each user's progress through a cloud-connected dashboard. This system captures and reports key performance indicators, including task completion rates, emotional trend logs, time spent on individual activities, and various skill development metrics. By analyzing this data, facilitators can better understand user behavior, adapt intervention strategies, and personalize support to meet each child's unique developmental needs.

B. Key Features

- 1) **Multisensory Learning Environments:** The VR scenarios combine visual, auditory, and kinesthetic stimuli. Tasks such as popping bubbles, navigating crowds, or matching emotional avatars foster skill acquisition through immersive engagement.
- 2) **Customizable Sensory Settings:** Users or facilitators can adjust environmental variables including sound intensity, visual clutter, and interaction complexity to match individual sensory profiles and cognitive load thresholds.
- 3) **Interactive Social Scenarios:** The system features multiple interactive social scenarios, including environments such as cityscapes, playground, classroom and restaurants that incorporate structured social challenges (e.g., paying bills, waiting in line, or greeting shopkeepers) to promote social integration, as visualized in Fig.
- 4) **Emotion Check-Ins:** At periodic intervals, the system prompts users to select or identify their emotional state via avatars or emotion cards. This feature encourages emotional awareness and supports self-regulation.
- 5) **Reward-Based Gamification:** A token economy system awards stars or badges for task completion. Positive reinforcement is delivered through visual animations and auditory cues.
- 6) **Adaptive Difficulty Levels:** The system automatically adjusts the complexity of tasks based on previous performance metrics, ensuring sustained engagement and challenge at an appropriate cognitive level.
- 7) **Calming Zones and Sensory Regulation:** Every environment incorporates optional calming spaces featuring guided breathing exercises, soft lighting, and soothing audio to help users manage sensory overload.

IV. RESULT AND DISCUSSION

A. Results

The proposed VR-based Interactive Skills Enhancer (ISE) system was designed to address the unique social, life, and interpersonal skill development needs of children with Autism Spectrum Disorder (ASD) and Intellectual Disabilities (ID). The system integrates customizable, multisensory VR environments (school, playground, restaurant, supermarket, city) with AI-driven emotion recognition, real time feedback, and a comprehensive progress tracking dashboard.

- 1) **Enhanced Engagement:** Children interact with realistic, gamified scenarios, resulting in higher engagement and motivation compared to traditional methods.
- 2) **Skill Acquisition:** The VR environments enable safe, repeatable practice of social cues, daily routines, communication, emotional regulation, and decision-making,

with adaptive difficulty to match individual needs

- 3) Personalization: Sensory settings and scenario complexity are adjustable, supporting children with diverse sensitivities and cognitive profiles
- 4) Immediate Feedback and Reinforcement: The AI modules provide in moment feedback and rewards, reinforcing positive behaviors and supporting emotional regulation
- 5) Progress Monitoring: The dashboard allows educators and caregivers to track skill development, emotional trends, and suggest individualized interventions

B. Comparative Analysis

A comparative analysis of key features between the proposed ISE system and existing VR solutions for ASD inter-vention is presented in Table

Table I Comparison of ISE with existing VR Solutions for ASD

Feature	ISE (Proposed)	Floreo VR	Autism VR	XR Health
Skill Coverage	Social, Life, and Interpersonal skills	Primarily social skills	Task-based training only	General rehabilitation focus
AI Integration	Real-time emotion recognition & feedback	None	Basic task completion tracking	Limited to movement analysis
Sensory Customization	Full visual/audio/adjustments	Limited brightness/volume control	Fixed environments	No sensory adaptation
Progress Tracking	Dashboard with milestones and AI report generation	Basic session logs	No tracking system	Therapist-only reports
Feedback Mechanism	In-moment AI-driven reinforcement	Pre-recorded prompts	Binary (correct/incorrect)	Delayed therapist feedback
Hardware	PC + HMD (Oculus/Quest)	Mobile/Tablet compatible	CAVE systems required	High-end medical VR rigs

As shown in Table this systematic comparison demonstrates ISE's distinct advantages in providing comprehensive skill development through real time AI-driven feedback and fully customizable sensory environments, while also highlighting the limitations of current market offerings in addressing the diverse needs of children with ASD The results clearly position ISE as a more holistic and adaptive solution compared to the narrowly focused approaches of existing platforms like Floreo VR, Autism VR, and XR Health.

C. Challenges and Limitations

- 1) Limited session duration due to physical discomfort affects therapeutic effectiveness

- 2) Need for specialized support personnel to facilitate effective use
- 3) Integration challenges with existing educational and therapeutic frameworks
- 4) Higher dropout rates among participants
- 5) Controller operation difficulties present barriers, especially for children with motor challenges

D. Future Improvements

- 1) Development of lightweight, more comfortable HMDs specifically designed for sensory sensitive individuals
- 2) AR/VR hybrid features enabling partial reality integration for better skill transfer
- 3) Multilingual support with culturally appropriate scenarios and interactions
- 4) Implementation of sensory calibration options before sessions to control cybersickness
- 5) Procedural generation of environments for endless unique scenarios without manual design

E. Discussion

The proposed VR-based ASD/ID support system demonstrates a comprehensive, modular approach to addressing the social, life, and interpersonal skill development needs of children with Autism Spectrum Disorder (ASD) and Intellectual Disabilities (ID). The system architecture integrates content creation, VR application, artificial intelligence, and user monitoring layers to provide several key advantages: (1) Personalized Learning through customizable VR environments that adjust sensory settings and task complexity for individual needs (2) Immersive Engagement via realistic, multisensory simulations that make learning social cues and daily routines more appealing (3) AI-Driven Feedback with emotion recognition and adaptive reinforcement to support emotional regulation and (4) Data-Driven Intervention through progress tracking dashboards for educators The system specifically addresses VR challenges like cybersickness and sensory overload through features such as calming zones and gradual exposure protocols Recent research supports the effectiveness of such immersive, tailored VR interventions for ASD populations The modular architecture enables future expansion including AR/VR hybrid features and multilingual support, positioning this solution as both an effective current intervention and adaptable platform for future development in special needs education

V. CONCLUSION

The proposed VR-based support system for children with ASD and ID offers an innovative, customizable, and immersive approach to social, life, and interpersonal skills training. By leveraging modular architecture combining content creation, VR application, AI-driven feedback, and robust user monitoring the system creates safe, engaging, and repeatable learning environments that can be tailored to each child's sensory and cognitive needs. Research consistently demonstrates that VR interventions can accelerate and reinforce the acquisition of social and emotional skills in children with ASD, often outperforming traditional methods in both engagement and skill generalization. The integration of AI further enhances adaptability by providing real time, personalized feedback and emotional support while dashboards empower caregivers and educators to track progress and adjust interventions. Despite challenges such as cybersickness, device acceptance, and the need for further standardization the system's design addresses these with sensory calibration, calming zones, and gradual exposure protocols. As VR and AI technologies continue to evolve, this approach holds strong promise for making skill building more accessible, effective, and enjoyable for children with ASD and ID, ultimately supporting their independence and quality of life in real world contexts.

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