Interactive 3D Quizzes and Assessments Using A-Frame

B. Sreevani

Department of CSE, JNTUA College Of Engineering (Autonomous), Ananthapuramu, Andhra Pradesh, India

Abstract—The evolution of online education necessitates more engaging and immersive assessment methods to enhance learner interaction and comprehension. This paper explores the implementation of interactive 3D quizzes and assessments using A-Frame, an open-source web framework designed for creating Web-VR experiences. The proposed system enables the development of web-based 3D quizzes accessible on standard desktop browsers, providing learners with spatially interactive environments that cater to various cognitive and visual learning styles. It includes multiple-choice questions with 3D elements, object identification tasks, and time-constrained activities, all designed with a simple A-Frame-based architecture. Real-time feedback, gamification components, and performance tracking mechanisms are integrated to support personalized learning. The design and development methodology is presented, along with a discussion of the pedagogical benefits observed. Results indicate that such immersive assessments improve learner engagement and foster deeper conceptual understanding. The study demonstrates the potential of A-Frame to transform traditional assessment models and contribute significantly to the effectiveness of online education.

Index Terms—A-Frame, interactive learning, Web-VR, online education, immersive quizzes.

I. INTRODUCTION

Virtual Reality (VR) has increasingly gained attention as a transformative tool in traditional education systems. By providing immersive and interactive experiences, VR enables learners to engage with content beyond the limitations of textbooks and two-dimensional screens. It facilitates experiential learning, allowing students to visualize complex concepts, conduct virtual experiments, and explore simulated environments. Traditional education, often characterized by passive learning methods, benefits from VR's ability to enhance student motivation, retention, and understanding. As educational institutions seek innovative methods to improve outcomes, VR emerges as a promising solution for bridging theoretical knowledge and practical application. Despite its potential, widespread adoption in traditional settings remains limited by factors such as cost, accessibility, and curriculum integration challenges.

A-Frame, an open-source web framework for building Virtual Reality (VR) experiences, offers a simplified approach to developing immersive environments using HTML and JavaScript. It enables the creation of interactive 3D content that can be accessed directly through web browsers without the need for specialized hardware or extensive programming knowledge. In the educational context, A-Frame provides a flexible platform for designing simulations, virtual laboratories, interactive tutorials, and assessment modules. Its compatibility with Web-VR and modern browsers ensures wide accessibility, making it suitable for institutions seeking cost-effective VR solutions. By leveraging A-Frame, educators can create spatially rich learning experiences that support visual, and experiential learning styles, thereby enhancing student engagement and comprehension. The framework's modular architecture and ease of integration further encourage the adoption of immersive learning tools in diverse educational disciplines.

The development of interactive 3D quizzes and assessments using A-Frame integrates fundamental web technologies such as HTML, JavaScript, and Web VR APIs to construct immersive educational environments. Educational content is organized through 3D models, spatially positioned quiz elements, and interactive virtual objects within the scene. Multiple-choice questions are implemented using clickable 3D buttons, while object identification tasks allow users to interact directly with designated elements. A-Frame's entity-component-system

architecture enables the definition of dynamic behaviours, animations, real-time feedback, scoring mechanisms, and time-based challenges. Deployment through standard web browsers ensures broad accessibility without the need for specialized VR hardware. This method enhances learner engagement and introduces gamified experiences, thereby promoting interactive, personalized, and effective learning outcomes.

After the development of interactive 3D quizzes, user responses and performance data are captured and stored using cloud-based database services such as Firebase. The system architecture employs modern web development frameworks, including Next.js for server-side rendering and efficient client-server communication, and Tailwind CSS for responsive and consistent user interface design. User interactions within the A-Frame environment are monitored through event listeners, which transmit the collected data to Firebase in real time. This approach ensures secure storage, scalability, and ease of access to assessment records. Upon completion of the quizzes, the system retrieves the stored responses, processes the results, and provides immediate feedback to the learner through dynamically generated user interfaces. The integration of these technologies enhances system performance, improves user experience, and enables seamless management of interactive 3D assessments in web-based educational platforms. The proposed 3D assessment system is also compatible with standalone VR headsets such as the Meta Quest 2, extending its functionality beyond desktop environments. Through Web XR support, A-Frame applications can be seamlessly rendered in immersive VR mode, allowing learners to engage with quiz content in a fully virtual space. This compatibility enhances accessibility and offers a more immersive user experience, especially for subjects requiring spatial interaction or practical visualization. Integration with devices like Meta Quest 2 aligns with the growing demand for mobile and untethered VR solutions in education. Compared to conventional assessment platforms, this approach promotes deeper cognitive engagement, reduces distractions, and fosters active participation. As educational institutions increasingly explore immersive technologies, such systems demonstrate significant potential in transforming digital assessments into experiential learning tools.

II. RELATED WORK

Several recent works have explored the use of A-Frame for developing web-based 3D learning environments. A-Frame's ease of use and support for immersive interactions make it well-suited for building quizzes that go beyond traditional 2D formats. Researchers have used A-Frame to implement educational modules featuring object interaction, spatial navigation, and real-time feedback. These efforts demonstrate the potential of Web-XR technologies in enhancing user engagement in assessments. While promising, many implementations focus primarily on content delivery rather than interactive assessments. The integration of rich quiz mechanics with immersive 3D experiences remains an area requiring further exploration, which this study aims to address.

Santos, S. G., & Cardoso, J. C. S. (2019) [1] evaluated the development effort of creating a 360º interactive virtual tour using the A-Frame framework. Aimed at multimedia designers with experience in HTML, CSS, and basic JavaScript, the study explored the ease of building web-based VR experiences. The authors found A-Frame accessible, but noted challenges such as the cumbersome process of positioning 3D objects, the absence of CSS for styling, and compatibility issues across browsers. Despite these drawbacks, A-Frame demonstrated potential as a viable tool for VR development. The paper suggests areas for improvement, including enhanced visual editors, better browser support, and more intuitive design tools to reduce the overall development effort.

Ramesh Chander Sharma &Yash Paul Sharma, (2021) [2] focused on enhancing student engagement through the design of virtual reality (VR) experiences in education. Their work aimed to support transformed pedagogies by fostering creativity, autonomy, and metacognitive skills among learners. The authors developed immersive learning environments using a blend of 360-degree real-world media and computer-generated synthetic content to create meaningful educational experiences. These VR scenarios, such as virtual tours of historically significant locations in India, were intended to support active learning through exploration, decision-making, and reflection. Positioned within the frameworks of cognitive fit theory and situated learning theory, their approach

emphasized deep student involvement and the potential of VR to provide life-enriching, discipline-specific educational engagements.

Udeozor, C., Chan, P., Abegão, F. R., & Glassey, J. (2023) [3] developed a Game-Based Assessment Framework (GBAF) for evaluating learning in immersive environments such as virtual reality (VR), augmented reality (AR), and digital game-based learning. The authors identified a gap in current assessment practices, which are often insufficient for measuring learning in these non-traditional environments. The proposed framework, grounded in Constructive Alignment and the Evidence-Centred Design (ECD) principles, provides a step-by-step approach to designing assessments for VR, AR, and digital games. They demonstrated the application of the GBAF through the design and implementation of a VR game assessment for evaluating health and safety competencies in a laboratory setting. The study concluded that the GBAF offers useful guidelines for educators and researchers to design effective assessments, capable of measuring both lower and higher-order cognitive skills in complex immersive environments.

Alcañiz, M., Parra, E., & Chicchi Giglioli, I. A. (2018) [4] explored the potential of virtual reality (VR) as an emerging methodology for leadership assessment and training. The authors highlighted how VR could create immersive and interactive environments that allow for the simulation of complex leadership scenarios, providing valuable insights into decision-making, emotional responses, and leadership skills. Through their research, they demonstrated how VR can be used to assess and train individuals in real-time, offering an innovative approach to leadership development. The study also emphasized the advantages of VR in creating controlled, repeatable, and realistic environments that traditional assessment methods cannot easily replicate. The authors concluded that VR has significant promise in leadership development, offering a new tool for both assessment and training purposes in various professional domains.

Makransky, G., and Mayer, R. E. (2016) [5] examine how immersive virtual reality (VR) enhances learning experiences. The study supports the immersion principle, demonstrating that virtual field trips improve engagement, knowledge retention, and conceptual understanding compared to traditional learning methods. The findings highlight VR's potential in multimedia learning by providing interactive and realistic educational experiences. By engaging students in a more immersive environment, VR enhances motivation and fosters deeper cognitive processing, making it a valuable tool in education. However, the research also discusses challenges such as the need for proper content design and the integration of VR into existing curricula.

Ali, L. (2018) [6] discussed the design of curriculum, assessment, and evaluation in higher education through the lens of constructive alignment. The paper explored how the principles of constructive alignment can be applied to create effective curricula that align learning outcomes, teaching methods, and assessment strategies. Ali emphasized the importance of ensuring that assessments are directly linked to the learning objectives and that the teaching activities are designed to facilitate students' achievement of these outcomes. The study highlighted the role of constructive alignment in improving the quality of education by fostering a more coherent and student-centered learning experience. The author also provided practical insights into how this framework can be applied in the design and evaluation of higher education programs, helping educators create more effective and meaningful learning environments.

Almond, R. G., Steinberg, L. S., & Mislevy, R. J. (2003) [7] presented a four-process architecture for assessment delivery, focusing on the connections between assessment design and its delivery. The paper proposed a structured approach for the creation and implementation of assessments that take into account four key processes: task creation, student response collection, scoring, and reporting. The authors emphasized the importance of aligning these processes to ensure that assessments are effective and meaningful. This architecture was designed to support both traditional and innovative assessment methods, including the use of technology in educational settings. By exploring these connections, the study provided valuable insights into how assessment systems can be designed to provide more accurate and actionable results, offering a framework that could be applied to both large-scale and more personalized learning environments.

III. METHODOLOGY

A. System Overview

This project involves the development of a web-based platform using the A-Frame framework to create interactive 3D quizzes and assessments. The system enables educators to design and upload any number of assessments, including multiple-choice and object-identification questions, directly within a virtual environment. Learners can then participate in these assessments through an immersive 3D interface, allowing for enhanced engagement and active participation. This immersive setup is intended to enhance learner engagement and improve the overall assessment experience through interactive 3D visualization. The platform is accessible through web browsers, ensuring cross-device compatibility without the need for external applications. Additionally, the system is scalable and can be adapted to various educational domains, supporting a wide range of learning outcomes.

B. Development Environment tools

The development of the 3D assessment platform was carried out using modern web technologies to ensure responsiveness, scalability, and an immersive experience. The frontend interface was built using Next.js, a popular React-based framework, which enabled server-side rendering and optimized performance. Tailwind CSS was integrated for utility-first, responsive UI design, allowing rapid styling and customization of components. The 3D virtual environment was implemented using A-Frame, an open-source Web-VR framework that simplifies the creation of interactive 3D and VR scenes directly in HTML. Additional tools and libraries such as JavaScript, HTML5, and CSS3 were used for interaction logic and layout structure. This tech stack collectively provided a seamless environment where educators could create, manage, and deploy quizzes and assessments within a virtual space, enhancing learner engagement and interaction.

C. Backend Implementation

The backend of the interactive 3D quiz platform is powered by Firebase, which offers a comprehensive suite of services for authentication, data storage, and hosting. Firebase Authentication handles user sign-ups, logins, and session management, supporting various authentication methods, including email/password, OAuth providers like Google and Facebook, and anonymous authentication. This eliminates the need for manual handling of sensitive data, such as passwords, while ensuring secure and efficient user management. Firebase generates ID tokens for session management, securely storing them in the client's browser to authenticate user requests and restrict access to sensitive operations. The platform's data is managed using Firebase's real-time database, which ensures seamless synchronization and storage of quiz responses and user progress. Additionally, Firebase offers robust security features, such as multi-factor authentication (MFA), token expiration, and customizable security rules, providing an added layer of protection to safeguard user data and ensure the platform's scalability.

D. Data Storage and Real-time Synchronization

Data for the quizzes, questions, and user responses in the platform is stored and managed using Cloud Firestore, Firebase's real-time NoSQL database. Firestore provides a scalable and secure way to store dynamic data, with real-time synchronization between the client and backend. The data structure is organized into collections and documents, such as "Users," "Quizzes," and "Responses," with references to user profiles, quiz details, and submitted answers. The Firestore structure is optimized for real-time updates, ensuring that any changes to quiz data, such as edits or new responses, are immediately reflected across all connected clients. For example, when a user submits a response, it is instantly updated in the database, and users receive real-time feedback, such as updated scores or correct answers. Security is enforced using Firestore's security rules, ensuring that access is restricted based on user authentication and roles. For instance, only the quiz creator can modify quiz metadata, and users can only access their own responses, ensuring data privacy and integrity.

E. Secure and Scalable Hosting

Firebase Hosting is utilized to deploy the frontend of the interactive 3D quiz platform, ensuring fast and efficient delivery of static assets (HTML, CSS, JavaScript) and dynamic content through Firebase's global Content Delivery Network (CDN). The CDN caches static assets and serves them from the nearest geographical location to the user, significantly reducing latency and improving page load times. Firebase Hosting also automatically provides SSL certificates for all domains, ensuring secure

communication between the client and server, which is crucial for protecting sensitive user data such as credentials and quiz responses. Additionally, Firebase Hosting supports seamless version control, allowing developers to deploy new application versions with a single command and easily revert to previous versions if necessary. This setup ensures the platform remains secure, responsive, and scalable.

F. Script Implementation
The script implementation of the interactive 3D quiz platform is developed using JavaScript in conjunction with the A-Frame framework to render immersive virtual environments. The Cursor component of A-Frame is utilized for user interaction, enabling gaze-based and click-based selection of 3D quiz elements within the scene. The implementation logic includes dynamic rendering of quiz content, real-time response handling, and communication with Firebase services for data retrieval and storage. JavaScript functions are integrated to control user navigation, manage state transitions between quiz phases, and process feedback based on the correctness of user responses. All scripts are deployed as part of the client-side application to ensure a seamless and interactive user experience, while maintaining performance and responsiveness in the browser environment.
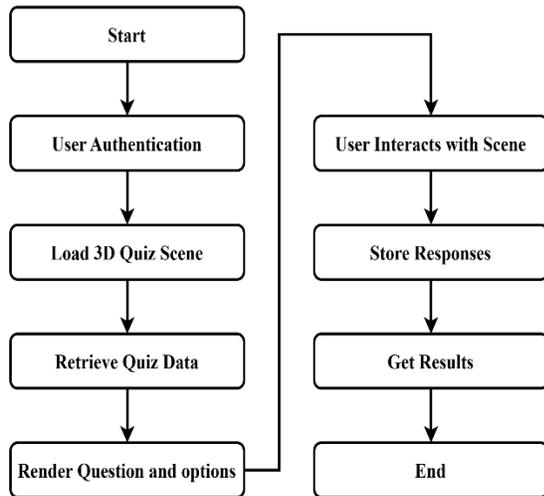

Fig.1 System Architecture

G) Immersion Enhancement and Application Deployment
To enhance user immersion and accessibility, the developed interactive 3D quiz platform is optimized for deployment on immersive head-mounted displays such as the Meta Quest 2. The platform's VR environment, built using A-Frame and deployed via Firebase Hosting, is accessible through Web XR-enabled browsers, allowing learners to experience and interact with the content in a fully immersive setting. By leveraging the capabilities of Meta Quest 2, users can navigate through virtual scenes, engage with 3D objects, and attempt assessments using intuitive gaze-based or controller-based interactions. This deployment model bridges conventional e-learning systems with immersive learning, enabling deeper cognitive engagement, increased motivation, and realistic simulation-based assessments. Additionally, cross-platform compatibility ensures that the application remains accessible on both desktop and mobile devices, supporting a wide range of deployment contexts from remote learning to classroom integration.

IV. RESULTS

This section presents the functional outcomes of the developed interactive 3D assessment platform. Through a sequence of user interface stages and system interactions, the project demonstrates how immersive technologies can be effectively utilized for educational evaluations in a virtual environment. The application integrates user-friendly design with responsive functionalities to support quiz creation, learner authentication, quiz participation, and result management. Each component was tested to ensure accuracy, engagement, and ease of use, highlighting the platform's potential for real-world implementation.
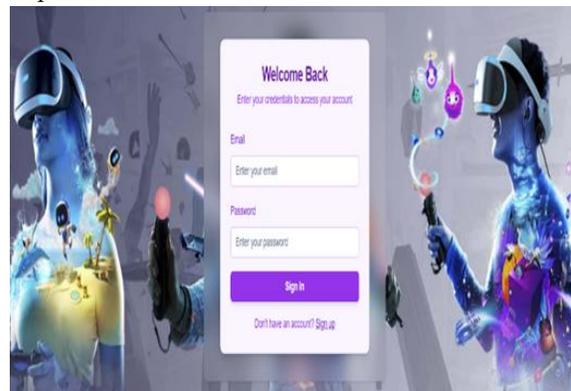

Fig.2 Sign Up Scene

Fig. 2. Shows the initial step in accessing the interactive 3D quiz environment is a user-friendly login interface, as depicted in the scene. This screen prompts users to enter their email and password to securely sign in to the platform. The visually engaging background, inspired by virtual reality elements, provides an immersive atmosphere that aligns with the theme of the 3D assessment system. This authentication process not only ensures access control but also offers a seamless entry point into the virtual learning and evaluation space, enhancing both usability and system security.
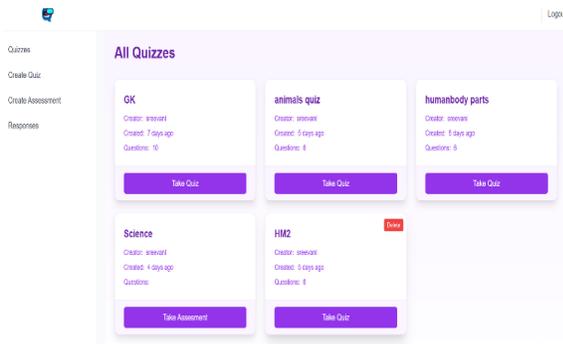

Fig.3 Home Scene

Fig. 3. After successful authentication, users are directed to the home interface where all available quizzes and assessments are displayed. As shown in figure 3, the dashboard presents a structured overview of the quizzes, including details such as quiz titles, the creator's name, creation date, and the number of questions. Each quiz card includes an action button labeled "Take Quiz" or "Take Assessment" depending on the type of content. The left sidebar facilitates navigation with options to view quizzes, create new quizzes or assessments, and check user responses. This organized layout ensures ease of access and smooth interaction, promoting an efficient learning experience.

Fig.4 MCQs Quiz Scene

Fig. 4. During execution, the system presents multiple-choice questions (MCQs) sequentially within an interactive 3D environment. Each question appears prominently at the center of the interface, with answer options arranged vertically beneath. Users can interact via gaze-based input or standard pointer clicks, depending on the device in use. Immediate visual feedback is provided to indicate correct or incorrect selections, enhancing engagement and understanding. The interface also displays dynamic metadata, such as the question number and cumulative score, which update in real time. This design ensures both clarity and interactivity, supporting immersive assessment within a browser-based virtual reality setting.

Fig.5 Object identification Quiz Scene

Fig. 5. In the object identification-based assessment module of the platform, users interact with 3D models rendered within the virtual environment instead of conventional text-based answer options. Each question is associated with a spatial scene in which multiple 3D objects are visually presented. Users are required to identify and select the correct object based on the question prompt. Interaction is enabled through gaze tracking or pointer-based inputs, depending on the user's device setup. This approach supports experiential learning by encouraging visual association and spatial reasoning, which are especially valuable in domains like biology, geography, or early education. Real-time visual feedback is provided upon selection, reinforcing the correct response and enhancing engagement.
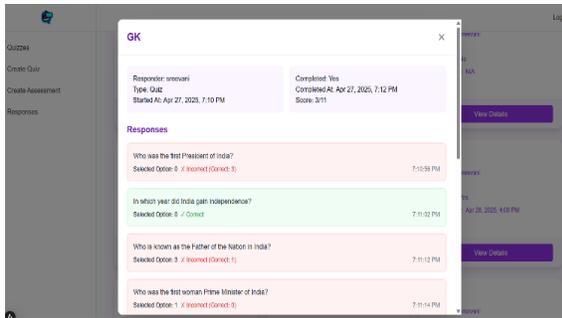
Fig.6 Response Scene

Fig. 6. The system displays a structured response summary interface after quiz completion, providing essential metadata such as user identity, quiz type, attempt duration, and final score. Each question response is listed sequentially, showing the selected answer and correctness status. Visual indicators, including color-coded cues, distinguish between correct and incorrect responses. Timestamps accompany each entry to support detailed review and time-based analysis. The interface facilitates self-assessment by presenting clear feedback and promoting reflection on performance. This format enhances the transparency and educational value of the assessment process within the virtual environment.

V. CONCLUSIONS

The interactive 3D assessment platform demonstrates the effective integration of immersive technologies into web-based educational environments. By combining virtual reality interfaces with dynamic quiz components such as multiple-choice and object identification tasks, the system delivers an engaging and responsive assessment experience. Utilizing Firebase for backend services enables real-time synchronization, secure authentication, and scalable deployment. Compatibility with VR devices, including Meta Quest 2, enhances user immersion and broadens accessibility. The platform aligns with contemporary educational practices and technological advancements, offering a foundation for future development in immersive online assessments and learning environments.

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