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AR-Based Study Helper: An Interactive 3D Learning System for Education

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Abstract
In the modern era of digital education, students often encounter challenges in comprehending complex theoretical concepts through conventional text-based learning approaches. To overcome these limitations, this paper proposes an Augmented Reality (AR)-Based Study Helper that enhances the learning experience by integrating interactive 3D visualization, voice- based narration, and automated quiz assessment. The Proposed System is designed as a web-based platform consisting of three main modules: Student, Expert, and Admin. The student module allows learners to log in, select topics using search or dropdown options, view interactive 3D models with synchronized voice and text explanations, and assess their understanding through quizzes. The expert module enables subject experts to add topics, upload 3D models with explanations, and create quiz questions. The admin module is responsible for approving experts, monitoring student performance, tracking expert contributions, and managing system statistics. All modules are supported by an integrated database for efficient data management. This interactive approach greatly improves student interest, understanding of concepts, and long-term learning compared to traditional methods.
Keywords: *Augmented reality learning; Interactive 3D visualization; Online quiz assessment; Voice-assisted learning; Web-based education system.*

1. Introduction

In the modern era of digital education, students often face challenges in understanding complex theoretical concepts when learning is limited to conventional text-based materials and classroom lectures. Such approaches provide minimal interactivity and visualization, which are essential for effective learning, particularly in science and engineering disciplines. To address these challenges, recent research has focused on integrating emerging technologies that support interactive and learner-centered educational environments (Azuma, 1997; Dunleavy & Dede, 2014). Augmented reality (AR) has emerged as a promising approach for enhancing learning by enabling interactive visualization of digital content, such as 3D models and audio explanations, thereby improving conceptual understanding (Billinghurst et al., 2015). In this work, augmented reality refers to a web-based, screen-oriented visualization approach that allows learners to interact with 3D educational content without requiring camera-based tracking. Furthermore, web-based education platforms improve accessibility by allowing learners to access content through web browsers. Integrating AR-supported visualization with web-based systems reduces dependency on specialized hardware and enables scalable and cost-effective learning solutions (Radianti et al., 2020). When combined with voice-assisted learning and automated assessment, such systems can further enhance learner engagement.

1.1. Related Work

Several studies have explored the use of augmented reality (AR) to enhance learning in educational environments. Azuma (1997) provided a foundational definition of AR and highlighted its potential for combining real and virtual elements to support interactive learning. Dunleavy and Dede (2014) reported that AR-supported learning environments promote experiential learning and improve student engagement. Similarly, Billinghurst

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et al. (2015) demonstrated the effectiveness of AR in creating interactive and collaborative educational experiences. Research on 3D visualization has shown positive effects on learning performance. Ivanj and Delgado-Klaus (2018) observed improved conceptual understanding among students using AR-supported instructional content, while Radianti et al. (2020) concluded that AR-supported learning environments enhance learner motivation and knowledge retention. In addition, Wu et al. (2013) reported positive learning outcomes when AR-based approaches were applied in science and engineering education. Recent studies have also highlighted the advantages of web-based AR learning platforms. Virkudaka et al. (2014) emphasized the scalability and accessibility of AR integration in educational systems, while Cheng and Tsai (2013) and Makransky and Petersen (2019) demonstrated that multimedia and immersive technologies positively influence learners' academic performance and engagement. However, many existing solutions lack an integrated framework that combines interactive visualization, assessment, and system management.

1.2. Research Contributions

To address the limitations of conventional learning approaches, this paper presents a web-based augmented reality study helper designed to enhance students' understanding of complex theoretical concepts. The proposed approach promotes interactive and immersive learning by integrating augmented visualization with visual and auditory learning techniques, thereby improving conceptual clarity and learner engagement. The primary contribution of this work is the integration of interactive 3D visualization, voice-assisted explanations, and automated online assessments within a unified learning environment. Unlike traditional text-based or video-based methods, the proposed approach supports active exploration and immediate self-evaluation, enabling learners to better comprehend abstract and spatial concepts.

In addition, the study emphasizes accessibility and flexibility in digital education through a web-based framework supported by cloud-enabled data management. This approach allows learners to access educational content across different devices and learning environments, contributing to an effective and scalable learning model that enhances engagement and long-term knowledge retention.

2. Method

2.1. System Architecture

The proposed AR-Based Study Helper is designed using a client-server web-based architecture that supports multiple user roles and interactive learning features. The architecture is modular, ensuring scalability, security, and efficient data management. The system is divided into three main layers: the User Interface Layer, the Application Logic Layer, and the Database Layer.

2.1.1. User Interface Layer

This layer provides an interactive and responsive interface for all users. Students can access the dashboard to select topics, visualize 3D models, and participate in quizzes. Experts can add topics, upload 3D models, and create quiz questions. Administrators can monitor system activity, approve expert requests, and track student progress.

2.1.2. Application Logic Layer

The logic layer handles all processing tasks, including authentication, content management, quiz generation, and performance evaluation. It ensures that each user role has access to appropriate functionalities. The 3D visualization engine is integrated in this layer, providing real-time interaction with 3D models along with synchronized voice and text explanations.

2.1.3. Database Layer

The database layer uses Firebase Firestore to store user information, topics, 3D model references, quiz questions, and student performance data. Firebase authentication services support secure login and role-based access, while real-time database updates ensure data consistency across multiple users.

2.1.4. System Workflow

- Student Module: Logs in → selects topic → views 3D model → listens to explanations → takes quiz → receives immediate feedback.
- Expert Module: Logs in → adds topics and quiz questions → manages previously added content.
- Admin Module: Logs in → approves expert

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requests → monitors student and expert activity → views statistical summaries.

The modular architecture enables the system to handle multiple concurrent users efficiently and allows future enhancements without affecting existing system functionalities.

2.2. Proposed System

The proposed system is a web-based AR-supported study helper designed to provide an interactive 3D learning experience for students. The platform allows learners to search and select educational topics using a drop-down menu or search functionality. Upon selecting a topic, the system presents an interactive 3D model accompanied by voice narration and optional text explanations to support improved conceptual understanding. The system is organized into three primary user modules: student, expert, and administrator. The student module supports learning activities such as topic visualization, audio-guided explanations, and participation in quizzes. The expert module enables subject experts to add new learning topics, upload 3D model content, and create quiz questions related to each topic. The administrator module manages user access, approves expert registrations, monitors system usage, and reviews student performance. To assess learning outcomes, the system automatically generates quizzes after the completion of each topic. Students receive immediate feedback in the form of scores and percentage results. As a web-based platform, the system is accessible on both desktop and mobile devices without requiring specialized hardware, ensuring ease of access and usability. Fig. 1 Interaction overview of the proposed AR-Based study helper illustrating the relationship between student, expert, and administrator modules.

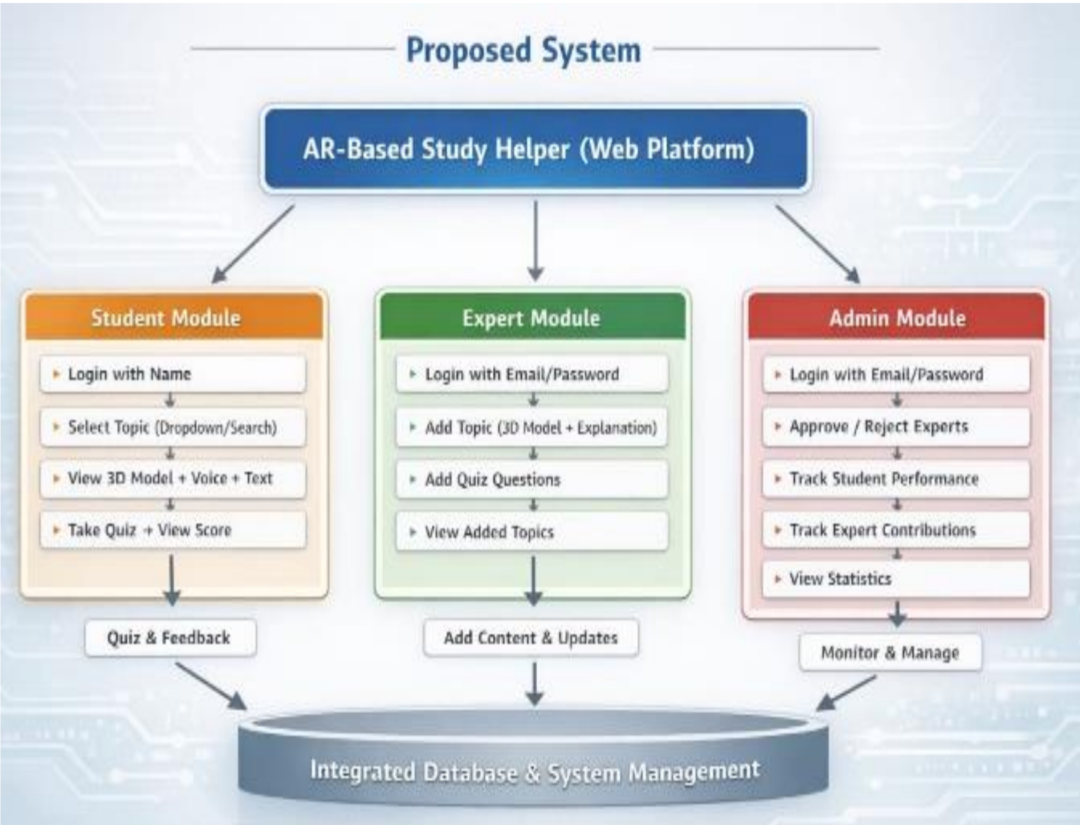

Figure 1 **Proposed System**

3. Results and Discussion

3.1. Results

This section presents the functional results and user interface outputs of the proposed AR-Based Study Helper system.

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Figure 2 Home Page of AR-Based Study Helper

The home page provides access to student, expert, and administrator login options, serving as the entry point to the overall AR-Based Study Helper system.

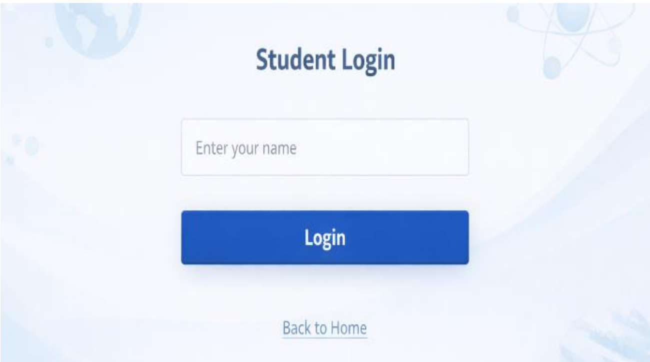

Figure 3 Student Login Page

The student login interface enables learners to securely access the system and begin their learning activities.

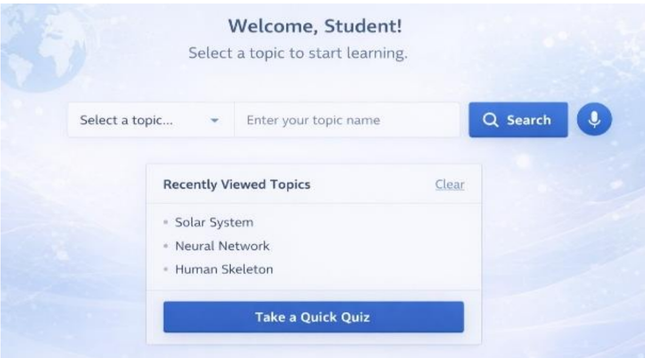

Figure 4 Student Dashboard

The student dashboard allows learners to select topics, access interactive 3D learning content, and participate in quizzes.

Figure 5 3D Model Learning Page

This interface demonstrates interactive 3D visualization with voice-assisted explanations to support improved conceptual understanding.

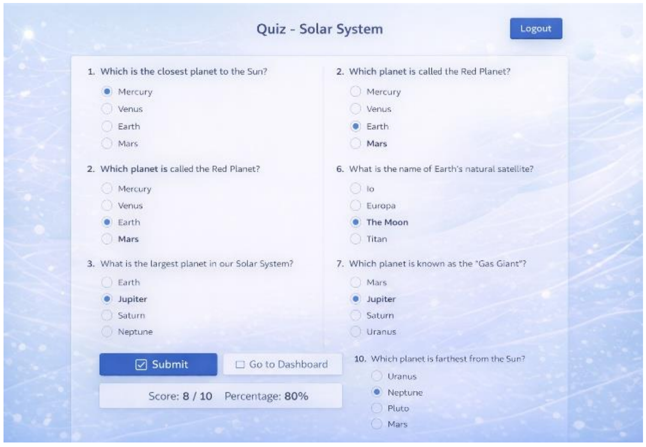

Figure 6 Quiz Page

The quiz interface assesses students' understanding after each topic and provides immediate feedback in the form of scores.

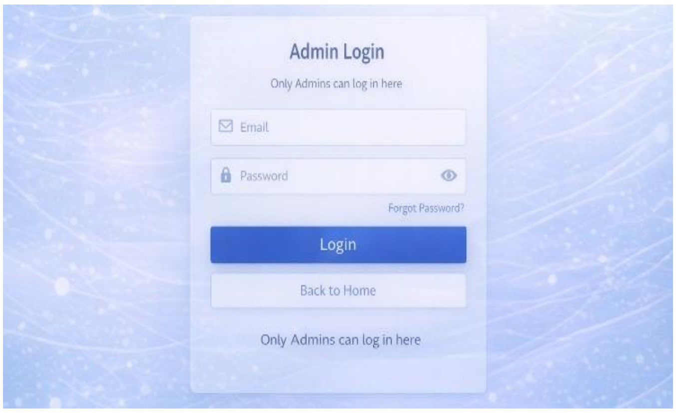

Figure 7 Admin Login Page

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The administrator login interface is used to manage system access and perform administrative operations

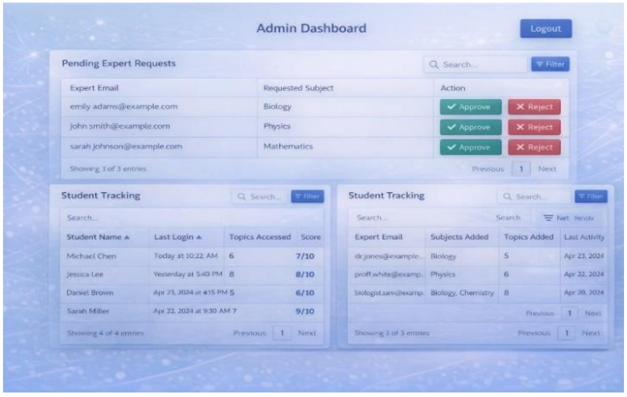

Figure 8 **Admin Dashboard**

The administrator dashboard supports monitoring of student performance, expert activities, and overall system usage.

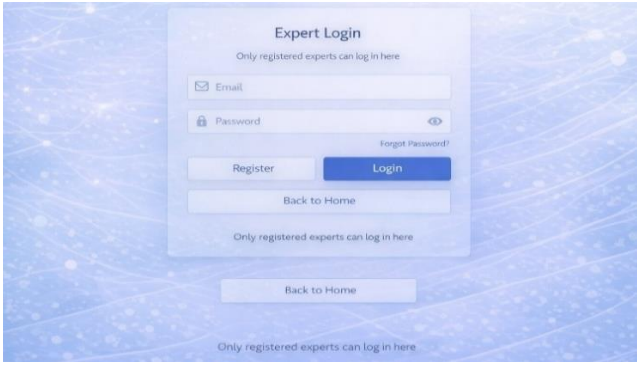

Figure 9 **Expert Login Page**

The expert login page allows subject experts to securely access content management functionalities.

Figure 10 **Expert Dashboard**

The expert dashboard enables experts to add learning topics, upload 3D models, and create quiz questions.

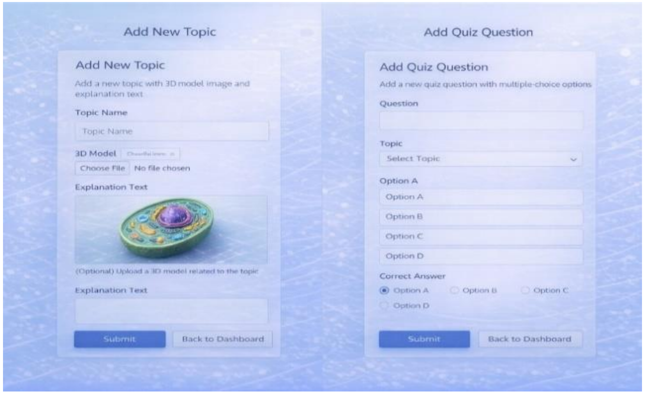

Figure 11 **Add Topics and Quiz Questions Page**

This interface represents the content management page where experts add new topics and associated quiz questions.

3.2. Discussion

The results demonstrate that the interactive 3D visualization, combined with voice-assisted explanations, significantly enhances learner engagement and conceptual understanding. Compared to traditional text-based learning methods, the proposed approach encourages active participation, supports immediate self-evaluation, and promotes better long-term knowledge retention.

Conclusion

This paper presented a web-based AR-supported study helper and interactive 3D learning system designed to enhance digital education through immersive 3D visualization, voice explanations, and automated quizzes. The system integrates student, expert, and administrator modules, providing a unified platform for learning, content management, and performance monitoring. Students can explore topics using interactive 3D models and evaluate their understanding through quizzes, improving engagement and conceptual comprehension. Experts and administrators can efficiently manage content and users, ensuring scalability and usability. Overall, the proposed system effectively addresses the limitations of conventional e-learning methods by offering an interactive and engaging learning experience. The integration of 3D visualization,

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audio explanations, and automated assessment enhances learner motivation and knowledge retention, providing a strong foundation for modern digital education. Future enhancements may include personalized learning using AI, Camera-based augmented reality integration and collaborative multi-user learning features to further improve system effectiveness.

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