EduVerse 3D: 3D Model Learning System for Education

Reshma B[1], Arpitha C A[2], Ayush Somayaji A[3], Harshini D Patgar[4]
[1]Professor, Srinivas Institute of Technology
[2,3,4]Student, Srinivas Institute of Technology
doi.org/10.64643/IJIRTV12I12-206745-459

Abstract*—Education is a cornerstone of societal development, playing a crucial role in building knowledge, skills, and critical thinking abilities across various academic disciplines. However, conventional learning methods often rely on textbooks, lectures, and two-dimensional visual aids, which can limit students' ability to effectively understand complex and abstract concepts. This project presents EduVerse 3D, an interactive and immersive 3D model–based learning system designed to enhance conceptual clarity and student engagement. The platform enables learners to explore high-quality three-dimensional educational models under a controlled and user-friendly environment. Key learning features such as real-time interaction, model rotation, zooming, and detailed structural visualization are integrated to support deeper understanding. These interactive elements allow students to better analyze spatial relationships and dynamic processes that are difficult to convey through traditional methods. The proposed system is flexible, scalable, and suitable for multiple educational domains. By offering an engaging and visual learning approach, EduVerse 3D supports improved knowledge retention, reduces learning complexity, and provides practical benefits for both educators and students. This system contributes to modernizing digital education and promoting more effective, technology-driven learning experiences.

Index Terms*—EduVerse 3D, 3D models learning system, interactive visualization, immersive education, digital learning platform, virtual learning environment, educational technology.

I. INTRODUCTION

Education is a fundamental part of learning, known for developing knowledge, skills, and critical thinking across various academic disciplines. Due to the increasing complexity of educational content, students often face difficulty understanding concepts when taught using traditional methods such as textbooks, lectures, and two- dimensional visuals. Conventional learning approaches may be time-consuming and may not always provide clear conceptual understanding. Three-dimensional learning systems offer an effective alternative by presenting content through interactive visual models. By examining spatial structures, depth, and real-world representations using 3D models, learners can better understand complex topics. When combined with interactive technologies, an educational platform can be developed to enhance learning efficiency and engagement. This approach supports faster conceptual understanding for students while assisting educators in delivering content more effectively. Furthermore, interactive learning reduces dependency on static resources and enables consistent learning experiences across different subjects and learning levels.

II. LITERATURE REVIEW

Recent advancements in digital education technologies have created a growing need for interactive and effective learning systems, leading researchers to focus on 3D visualization, virtual environments, and immersive learning techniques. In paper [1], Smith demonstrated that 3D learning environments significantly improve student engagement and conceptual understanding when compared to traditional teaching methods, emphasizing the importance of visual interaction for effective learning outcomes. In paper [2], Kumar and Rao studied the use of interactive 3D models in science education, showing that spatial visualization helps students better understand complex structures, though challenges remained in terms of system accessibility and hardware requirements. In paper [5], Lee proposed a virtual learning platform using 3D models for engineering education, successfully enhancing practical understanding under controlled environments, but performance varied with device capabilities and rendering quality. In paper [6], Johnson compared traditional e-learning systems with

3D-based learning approaches, highlighting the importance of interactive elements in improving knowledge retention and learner motivation. In paper [4], Brown applied WebGL-based visualization techniques for real-time educational content delivery, achieving smooth interaction, although complex models increased computational load. Similarly, in paper [20], Patel and Sharma used immersive 3D environments for virtual classrooms, confirming the benefits of interactive learning while noting limitations related to scalability and network performance. In paper [3], Williams explored virtual reality techniques for education, emphasizing the role of spatial interaction in enhancing learning experiences. In paper [8], Mehta investigated model-based visualization approaches for technical education, showing that combining multiple interaction features improves learning effectiveness. In paper [9], Singh applied interactive visualization for non-destructive conceptual learning, demonstrating automated and user-driven exploration methods. In paper [21], Park developed a lightweight 3D learning framework suitable for web-based platforms, allowing efficient implementation, though performance declined with complex scenes or limited hardware resources. In addition, integrating 3D visualization, real-time interaction, and immersive technologies significantly enhances modern education.

III. PROPOSED APPROACH

This paper This paper presents an approach to develop an interactive 3D model–based learning system using modern visualization and web-based technologies. The first step of the process is to identify suitable educational topics that benefit from spatial and visual representation, such as scientific structures, engineering components, or conceptual models. High-quality 3D models related to the selected topics are either designed or sourced and prepared for integration into the learning system. To ensure smooth visualization and consistent performance, all models are optimized under controlled parameters, including polygon count, texture resolution, and lighting setup. A neutral and minimal virtual environment is used so that learners can focus entirely on the educational content without visual distractions. Each model is tested multiple times to ensure stability, usability, and accurate representation of real-world structures.

The system architecture is then implemented using interactive rendering techniques that allow users to rotate, zoom, and explore models in real time. Standardization of model formats is applied to maintain consistency across the platform. Rendering optimizations are performed to reduce latency and ensure smooth interaction across different devices. Appropriate lighting, shading, and camera controls are applied to enhance depth perception and highlight important structural details. In addition, user interaction mechanisms are integrated to support active learning and intuitive navigation. The proposed approach emphasizes visual clarity, interactivity, and performance, thereby improving conceptual understanding and providing an effective digital learning experience.

IV. METHODOLOGY

The project methodology begins with the identification and collection of educational content, which forms the foundation for developing an interactive 3D learning system. Learning topics suitable for three-dimensional visualization are selected from academic curricula, and corresponding 3D models are created or sourced from reliable repositories. Models are collected from multiple sources to ensure variation in structure, scale, and complexity. To maintain consistency across the system, all models are categorized and labeled according to subject and learning objectives. Proper classification of models is essential for effective content organization and smooth integration into the learning platform.

Next, all collected 3D models are prepared for visualization by optimizing model size, reducing polygon count, refining textures, and standardizing file formats. These preprocessing steps improve rendering performance and ensure smooth interaction during real-time visualization. A controlled virtual environment is used to maintain consistent lighting and camera settings, allowing learners to focus only on the educational content. Model alignment and scaling are performed to ensure accurate representation and reduce visual distortion. By standardizing the models in this manner, the system achieves better stability and improved learning clarity.

The core of the methodology consists of interactive rendering and user engagement mechanisms. Real-time interaction features such as rotation, zooming, and focused inspection are implemented to allow learners to explore models effectively. System testing and evaluation are conducted to measure performance, usability, and responsiveness across different devices. Feedback from user interaction is analyzed to improve system efficiency and learning effectiveness. The developed system provides a non- invasive and accessible learning solution that does not require physical models or laboratory setups. This methodology ensures a scalable, efficient, and user-friendly educational platform suitable for both classroom instruction and self- directed learning.

A. Image Acquisition

The 3D models used in the EduVerse 3D learning system play a critical role in determining the effectiveness and accuracy of the learning experience. A sufficient number of high-quality 3D models must be collected to ensure comprehensive coverage of educational topics and concepts. All models are obtained or created under controlled design conditions to maintain consistency in scale, geometry, and visual clarity, thereby minimizing distortions that may affect conceptual understanding. Open-source repositories, educational model libraries, and custom-designed models created using standard 3D modeling tools are suitable sources, as they are reliable and easily accessible. If required, multiple versions of the same model are prepared with varying levels of detail and orientations to support different learning perspectives. This approach helps create a diverse and well-structured model dataset that enhances visualization accuracy and improves the overall effectiveness of the 3D learning system.

The first step in developing the EduVerse 3D learning system involves acquiring high-quality 3D models that accurately represent educational concepts under consistent design parameters. Models are collected or created using standard 3D modeling tools and educational repositories, ensuring uniform scale, orientation, and visual clarity.

Next, model preprocessing is performed to optimize performance by reducing polygon count, refining textures, and removing unnecessary details while preserving essential structural features. The models are then converted into standardized formats such as GLB or GLTF to ensure compatibility and smooth rendering across platforms.

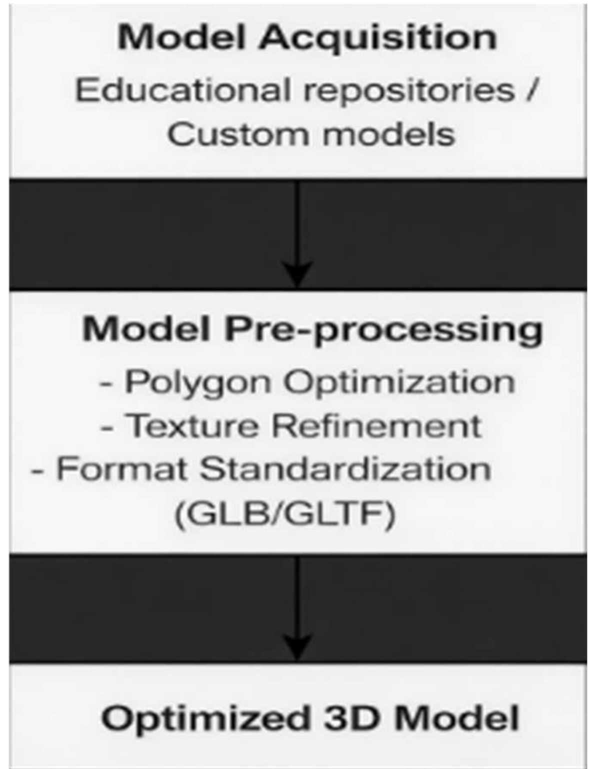

Fig. 1. Image processing

Lighting and shading techniques are applied to enhance depth perception and highlight important components of the models. Finally, model normalization ensures consistency in size, alignment, and interaction behavior, preparing the optimized 3D models for real- time rendering and effective use within the EduVerse 3D learning environment.

B. Interactive Visualization and Model Optimization

After preprocessing, the optimized 3D models are integrated into the EduVerse 3D learning system with interactive visualization features that support effective learning. Model optimization techniques such as polygon reduction and texture refinement ensure smooth rendering and stable performance across different devices. Interactive controls including rotation, zooming, and viewpoint adjustment are implemented to allow users to explore models from multiple perspectives. Proper lighting and camera settings are applied to enhance depth perception and clearly highlight important structural components. These interactive visualization features help students better understand spatial relationships and complex concepts, thereby improving engagement and learning effectiveness.

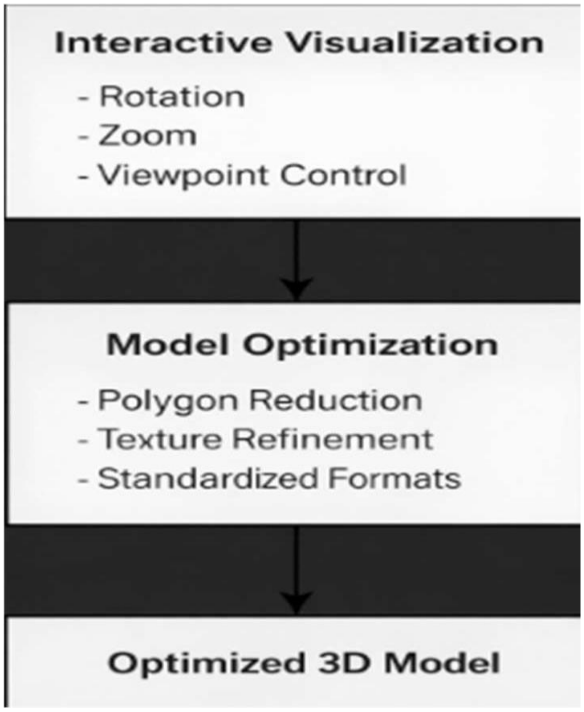

Fig. 2. Interactive Visualization and model Optimization

C. Workflow of EduVerse 3D Learning System

The workflow of the EduVerse 3D learning system begins with loading preprocessed and optimized 3D models into the visualization engine. The input models are first passed through a rendering pipeline that prepares geometry, textures, and lighting parameters to ensure accurate visual representation. A camera and interaction layer then manages real-time user inputs such as rotation, zooming, and viewpoint adjustment, enabling smooth and responsive model exploration. The rendering module continuously updates the scene based on user interaction, ensuring consistent frame rates and visual clarity. In contrast to static learning methods, EduVerse 3D follows an interactive visualization approach designed for efficient conceptual learning, where real-time rendering and user control play a central role. Together, optimized 3D rendering provides accurate spatial visualization, while interactive controls offer an engaging learning experience, making the overall workflow suitable for real-time educational environments and resource-efficient learning systems.

D. System Evaluation and Real-Time Interaction

To evaluate the effectiveness of the EduVerse 3D learning system, performance and usability testing are conducted across different devices and usage scenarios. The system is assessed based on rendering performance, interaction responsiveness, and visual clarity to ensure a smooth learning experience. User interaction feedback is analyzed to measure ease of navigation and understanding of educational content. Real-time rendering ensures that changes in viewpoint and interaction occur without noticeable delay, supporting continuous engagement. The evaluation confirms that the system provides a reliable, scalable, and interactive learning environment suitable for both classroom instruction and self- directed learning without requiring specialized hardware.

E. Performance Optimization

Performance optimization is carried out to enhance both the efficiency and responsiveness of the EduVerse 3D learning system. During system development, key parameters such as polygon count, texture resolution, rendering quality, and frame rate are carefully adjusted to ensure smooth visualization and stable interaction. Model optimization techniques, including mesh simplification and texture compression, are applied to reduce computational load while preserving visual clarity.

Efficient lighting, camera handling, and resource management further improve real-time rendering performance. Continuous testing and monitoring of system responsiveness guide further refinements during development. These optimization strategies help minimize latency, improve user interaction, and make the system suitable for practical deployment in real-time educational learning environments.

F. Cross-Verification

Cross-verification is performed to ensure the reliability and consistency of the EduVerse 3D learning system. The system is tested across different 3D models, interaction scenarios, and device configurations to verify stable performance. Visual clarity, interaction responsiveness, and rendering behavior are compared across multiple test cases.

This process helps identify potential performance issues and ensures consistent system behavior. Through repeated testing and evaluation, the robustness of the system is validated, making it suitable for real-world educational environments.

IV. IMPLEMENTATION

A. Educational Content and Asset Collection

Educational content collection is a crucial step in developing the EduVerse 3D learning platform. High-quality 3D models related to subjects such as Anatomy, Chemistry, Physics, and Astronomy are collected from reliable open-source repositories and custom-designed sources. Along with 3D assets, supporting learning materials such as topic descriptions and labels are curated based on academic syllabi. All assets are carefully organized and categorized to ensure accurate visualization and smooth integration into the interactive learning system.

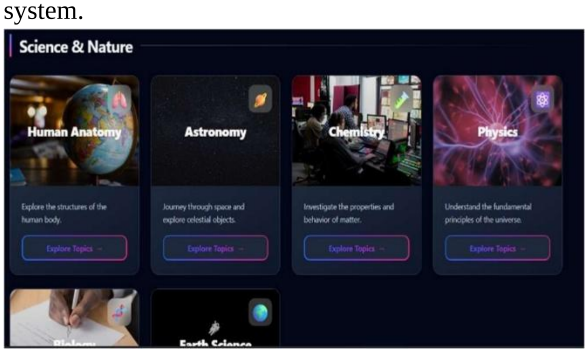

Fig. 3. EduVerse 3D– Subjects Dashboard

B. 3D Model Processing and Optimization

The process begins with improving the quality of collected 3D models by optimizing geometry and refining visual details, which enhances clarity during interaction. Techniques such as polygon reduction, texture compression, and material adjustment are applied to highlight important structural components like shape, depth, and spatial layout. Model alignment and scaling methods are then used to ensure consistent orientation and size across all assets. By processing the models in this manner, the system can deliver clear and accurate visual representations that form the basis for effective interactive learning.

After optimization, the processed 3D models are analyzed to identify key structural and visual elements that support conceptual understanding. These elements capture subtle spatial relationships, proportional differences, and design details that are difficult to interpret using static two- dimensional content. Model normalization is performed to maintain consistency across different subjects and device configurations. This structured 3D processing pipeline ensures that the learning experience remains reliable, immersive, and less affected by variations in hardware performance or rendering conditions.

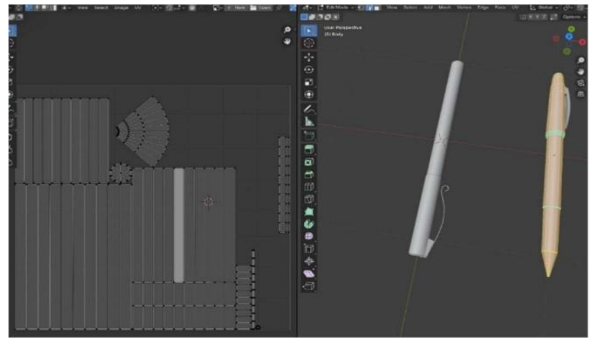

Fig. 4. Assest Optimization

C. System Integration and Interactive Learning

System integration is the stage where the EduVerse 3D platform is configured to deliver interactive and immersive learning experiences. The optimized and processed 3D models are loaded into the system using WebGL and Three.js for real- time visualization and interaction. During integration, the system adjusts rendering parameters, lighting, camera controls, and interaction logic to ensure smooth exploration of models. Techniques such as asynchronous loading, resource management, and performance tuning are used to improve system responsiveness and avoid rendering delays.

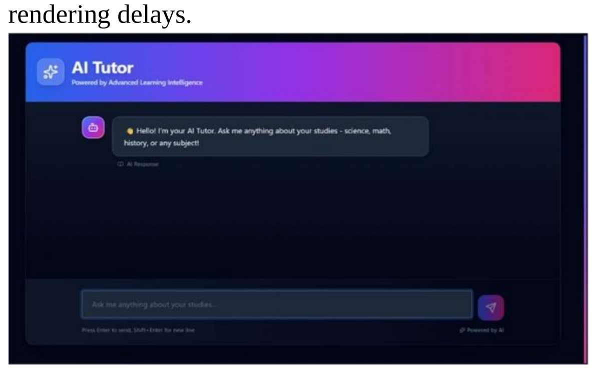

Fig. 5.AI Tutor

V. RESULTS AND DISCUSSIONS

The results obtained from the implementation of EduVerse 3D demonstrate the effectiveness of interactive 3D visualization in enhancing the learning experience. Users were able to explore complex concepts more clearly through real- time interaction with 3D models, which improved conceptual understanding compared to traditional 2D learning methods. The AI Tutor provided timely and relevant responses to user queries, supporting self-paced and personalized learning. Interactive features such as quizzes and the Brain Boost game increased user engagement and helped reinforce learned concepts. Minor performance variations were observed when rendering highly detailed models, which were addressed through optimization techniques. Overall, the results confirm that EduVerse 3D offers a reliable, engaging, and practical solution for modern digital education. the system maintained stable performance across different devices and browsers, indicating good scalability and accessibility for educational use. These results highlight the potential of EduVerse 3D to support immersive and effective learning environments in both classroom and self-directed learning scenarios.

A. User Interaction Distribution

User interaction distribution shows how learners engage with different features of the EduVerse 3D platform. In this project, interactions are distributed across modules such as 3D model exploration, quizzes, AI Tutor usage, and the Brain Boost game. An almost balanced level of interaction is observed across these modules, ensuring that no single feature dominates user activity. This balanced interaction helps the system support multiple learning styles and maintain consistent engagement during usage. Proper interaction distribution improves the reliability of the platform when it is used by learners in real-world educational environments.

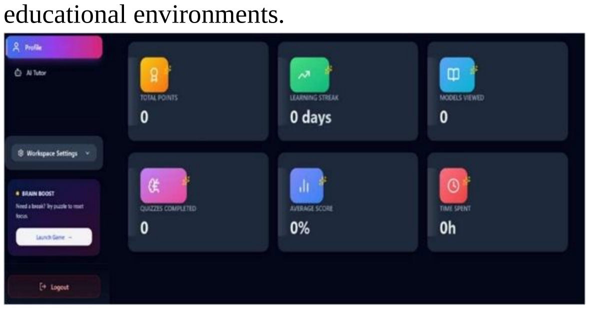

Fig. 6. User Interaction Distribution

B. Analysis

The analysis presents the performance and effectiveness of the EduVerse 3D learning platform based on user interaction and system behavior. Each learning module is evaluated through user engagement with 3D models, quizzes, AI Tutor interactions, and the Brain Boost game. The observations indicate that learners were able to navigate and interact with the platform smoothly, with consistent usage across different features. Higher engagement levels were observed in modules involving interactive 3D visualization, demonstrating improved conceptual understanding.

The system also showed stable responsiveness and visual clarity during usage. Overall, this analysis confirms that EduVerse 3D provides a reliable and engaging learning experience suitable for real-world educational environments.

Fig. 7. Learning Performance Analysis

C. System Confidence and Responsiveness Analysis

System confidence analysis reflects the reliability of EduVerse 3D in delivering smooth interaction and accurate learning feedback. Response times of the AI Tutor, rendering stability of 3D models, and interaction smoothness are observed during testing. Higher confidence levels indicate stable system behavior and consistent performance.

Fig. 8. Confidence Bar Graph

D. Result Table

TABLE I

Parameter	Observation
Average 3D Model Load Time	< 3 seconds
Rendering Stability	Smooth and consistent
AI Tutor Response Time	< 2 seconds
Quiz Evaluation Accuracy	High
User Interaction Responsiveness	Stable
Cross-Browser Compatibility	Supported
Overall User Engagement	High

The table summarizes the overall performance of the EduVerse 3D learning system across key operational and usability parameters. It includes important observations such as 3D model load time, rendering stability, AI Tutor response time, quiz evaluation accuracy, and overall user engagement. The results indicate that the system maintains smooth and consistent rendering while supporting real-time interaction with 3D models and learning modules. The AI Tutor demonstrated quick response times, enabling effective doubt clarification and self- paced learning. Overall, the performance results confirm that EduVerse 3D is efficient, responsive, and reliable, making it suitable for practical deployment in modern educational environments.

REFERENCES

[1] T. Fahrni *et al*., "3D anatomical models for medical education: Engagement and learning outcomes," *Computers & Education*, vol. 182, Art. no. 104512, 2025.

[2] P. Andic et al., "3D modelling and printing in life-science learning: Visualization and retention," Journal of Science Education and Technology, vol. 33, no. 2, pp. 155–170, 2024.

[3] M. Kılıc et al., "3D anatomical models and 3D-printed aids in anatomy classes," BMC Medical Education, vol. 25, no. 1, pp. 1–12, 2025.

[4] L. Zhao et al., "WebGL-based educational simulations with neural network accelerations," IEEE Access, vol. 9, pp. 45123–45138, 2021.

[5] MDPI Editorial Board, "Design of 3D virtual simulations for online learning," Education Sciences, vol. 12, no. 5, pp. 1–15, 2022.

[6] N. Lestari et al., "Virtual laboratories for lower-secondary science education," Journal of Science Education and Technology, vol. 32, no. 4, pp. 412–425, 2023.

[7] D. Sakkas et al., "Multiplayer virtual labs in electronics education using Unity," Education and Information Technologies, vol. 30, pp. 1121–1138, 2025.

[8] P. Kurtz et al., "Collaborative learning in remote virtual laboratories: A systematic review," Springer Virtual Learning Review, vol. 8, no. 3, pp. 45–63, 2025.

[9] C. Tejera, "Teacher training for 3D modelling and printing integration in education," Computers in Education Journal, vol. 62, pp. 77–95, 2025.

[10] M. Sosna, "Creativity and motivation in 3D modelling-enhanced curricula," Frontiers in Education, vol. 10, no. 2, pp. 1–14, 2025.

[11] ResearchGate Editorial Team, "WebGL-based serious games in language and science education," vol. 8, pp. 112–128, 2025.

[12] M. Aleedy et al., "AI chatbots in education: Instant feedback and administration," Education and Information Technologies, vol. 28, pp. 765–782, 2022.

[13] R. Stohr et al., "Student perceptions of AI tutoring systems in higher education," Computers & Education, vol. 192, Art. no. 104597, 2024.

[14] Virtual Reality Lab Research, "Unity-based virtual laboratories for digital electronics," IEEE Transactions on Learning Technologies, vol. 16, no. 3, pp. 201–215, 2023.

[15] ACM Education Research Group, "Adaptive learning paths using 3D simulations," in Proc. ACM SIGCSE, 2025, pp. 112–126.

[16] V. Dodevska, "VR adoption in science education: Immersion and inquiry learning," ScienceDirect Education Journal, vol. 58, no. 6, pp. 401–418, 2025.

[17] WebGL Serious Games Extended Study, "Browser-based 3D games for large-scale education," ResearchGate, 2025.

[18] F. Aslan, "3D physical and digital models in biology teaching: Cognitive load reduction," Journal of STEM Education, vol. 24, no. 1, pp. 55–70, 2024.

[19] J. Taylor and K. Francis, "Effectiveness of 3D modelling and printing in STEM education," International Journal of STEM Learning, vol. 10, no. 3, pp. 180–196, 2022–2024.

[20] IJCRT Research Team, "AI voice and chatbots for personalized learning feedback," vol. 12, no. 5,

pp. 102–115, 2023.
[21] Academic OUP Research, “Artificial neural networks with WebGL for interactive simulations,” *Education Computing Journal*, vol. 35, pp. 221–235, 2021.