IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁒ Peer-reviewed & Refereed journal ⁒ Vol. 14, Issue 7, July 2025

DOI: 10.17148/IJARCCE.2025.14720

Cost-Effective VR-Based Immersive Learning Platform for Education

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Abstract: Virtual Reality (VR) is revolutionizing the educational sector by offering immersive, interactive, and engaging environments for learners. This paper presents the development of a cost-effective VR-based learning platform specifically designed for anatomy education. The platform, developed using Unity, allows students to explore human body structures in a 3D virtual environment, enabling better understanding and retention. By reducing dependency on expensive physical models or labs, this system provides an affordable and scalable educational tool. Performance evaluation and user feedback indicate improved learner engagement and comprehension.

Keywords: Immersive learning, VR platform, Cost effective VR, VR for education

I. INTRODUCTION

Traditional educational tools often struggle to maintain student engagement, particularly in complex and abstract topics like human anatomy. Virtual Reality offers a solution by creating lifelike 3D environments where students can interact with content. However, most VR systems are expensive and inaccessible to common institutions. This project proposes a cost-effective VR-based immersive learning platform for anatomy education, utilizing Unity and affordable VR hardware.

Several VR-based educational tools exist, such as 3D Organon, BioDigital Human, and AnatomyX. These platforms, while effective, are either costly or require high-end hardware. Research shows immersive learning improves retention and engagement, but cost remains a barrier. Our work focuses on bridging that gap with low-cost implementation and open-source tools.

II. LITERATURE REVIEW

Virtual Reality (VR) has increasingly emerged as a transformative technology in the field of education, offering immersive and interactive environments that enhance student engagement and comprehension. Numerous studies have explored its potential across disciplines such as science, history, medicine, and engineering education.

[1] VR in Education: Potential and Applications

Mikropoulos and Natsis (2011) highlight that VR environments can improve conceptual understanding through visualization and experiential learning. Similarly, Radianti et al. (2020) conducted a systematic review that found VR to be particularly effective in improving student motivation, spatial skills, and retention, especially in STEM fields.

In specific use-cases, studies have shown success in using VR for virtual science labs, historical site tours, medical simulations, and language learning. These immersive environments promote constructivist learning by enabling learners to interact directly with complex concepts or environments that would be expensive or impossible to access physically.

[2] Cost Barriers in Existing VR Systems

Despite its benefits, the widespread adoption of VR in education is hindered by high costs associated with commercial-grade VR hardware (e.g., Oculus Rift, HTC Vive) and proprietary software solutions. As noted by Merchant et al. (2014), the cost of equipment, limited access to VR-ready computers, and specialized content development are significant barriers, particularly in under-resourced educational settings.

Open-source tools like A-Frame (WebXR), Google Cardboard, and Mozilla Hubs have attempted to address this gap, but many of these platforms lack the pedagogical alignment or robustness needed for formal learning environments.

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[3] Open-Source and Low-Cost VR Platforms

Recent research has explored low-cost VR solutions using affordable hardware (e.g., smartphones with cardboard viewers) and open-source engines like Unity with WebXR. For instance, Freina and Ott (2015) suggested that even low-fidelity VR experiences can yield positive learning outcomes when properly integrated into curriculum. Additionally, Cochrane et al. (2016) emphasized the role of mobile VR and BYOD (Bring Your Own Device) strategies in democratizing access to immersive education.
Studies have also examined the use of WebVR and WebXR frameworks to develop browser-based VR content that runs on low-cost devices. These approaches reduce the dependency on high-end hardware while maintaining a level of immersion sufficient for basic educational simulations.

[4] Pedagogical Integration and Usability Challenges

While technological advances make VR more accessible, integrating it effectively into educational curricula remains a challenge. Issues related to user interface design, cognitive overload, motion sickness, and lack of teacher training often undermine the intended learning outcomes (Jensen & Konradsen, 2018). Usability and simplicity are critical for any cost-effective solution intended for mainstream classroom deployment.

[5] Identified Research Gap

Most existing studies focus either on high-end VR systems or isolated case studies in well-funded institutions. There is a clear lack of scalable, cost-effective VR platforms that can be widely deployed in public schools, especially in low-income or rural areas. Few projects combine pedagogically sound immersive content with affordability, cross-platform accessibility, and user-friendly interfaces.

III. MATERIALS AND METHODS

A use case is a description of how a person who actually uses that process or system will accomplish a goal. It's Typically associated with software systems, but can be used in reference to any process.

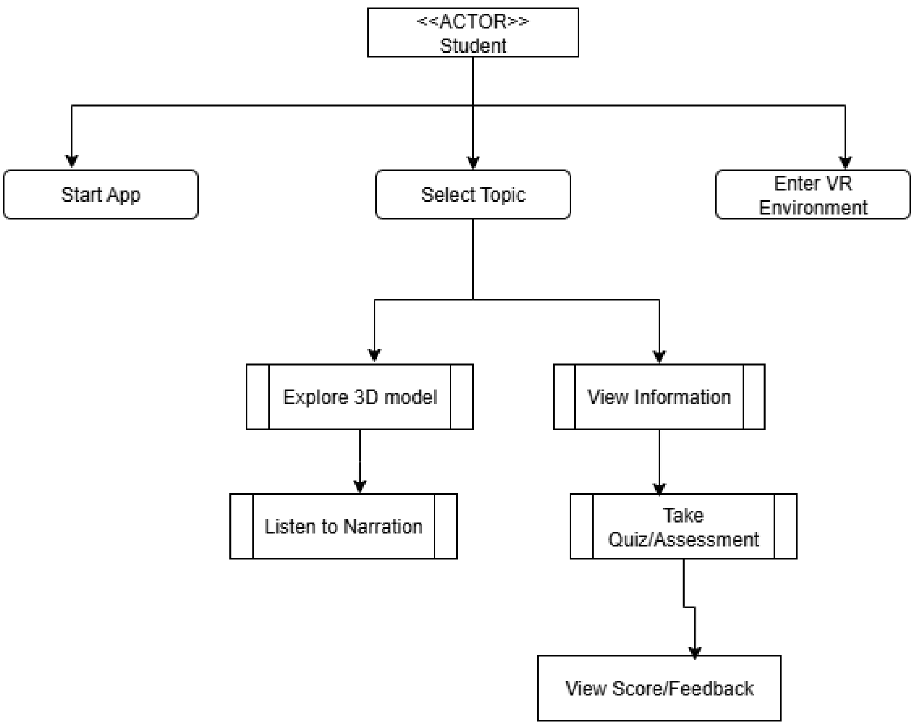

Fig.1 USE CASE

IV. METHODOLOGY

This VR system is designed to provide an affordable and immersive learning experience for college students using Google Cardboard. The system includes modules based on engineering subjects, developed in Unity. Students interact with the content in 3D VR environments to better understand complex concepts.

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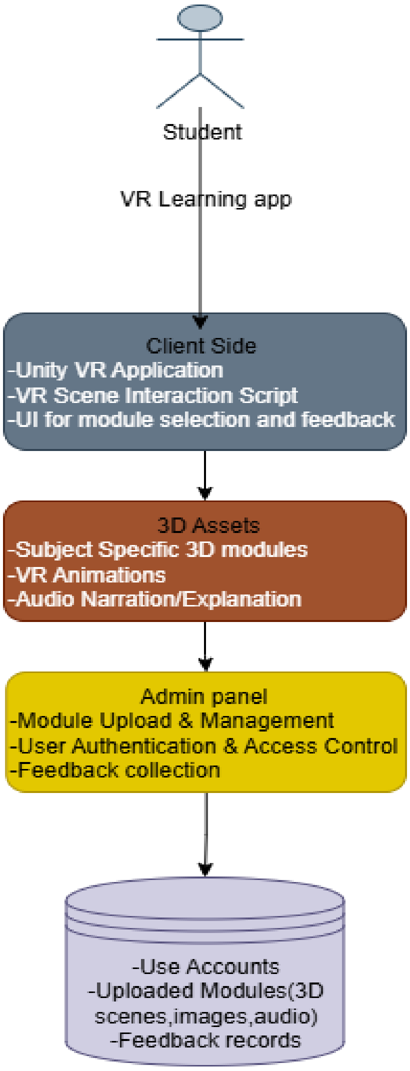

Fig.2 Architecture Diagram

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CLASS DIAGRAM

A class diagram is an illustration of the relationships and source code dependencies among classes in the Unified Modelling Language (UML).

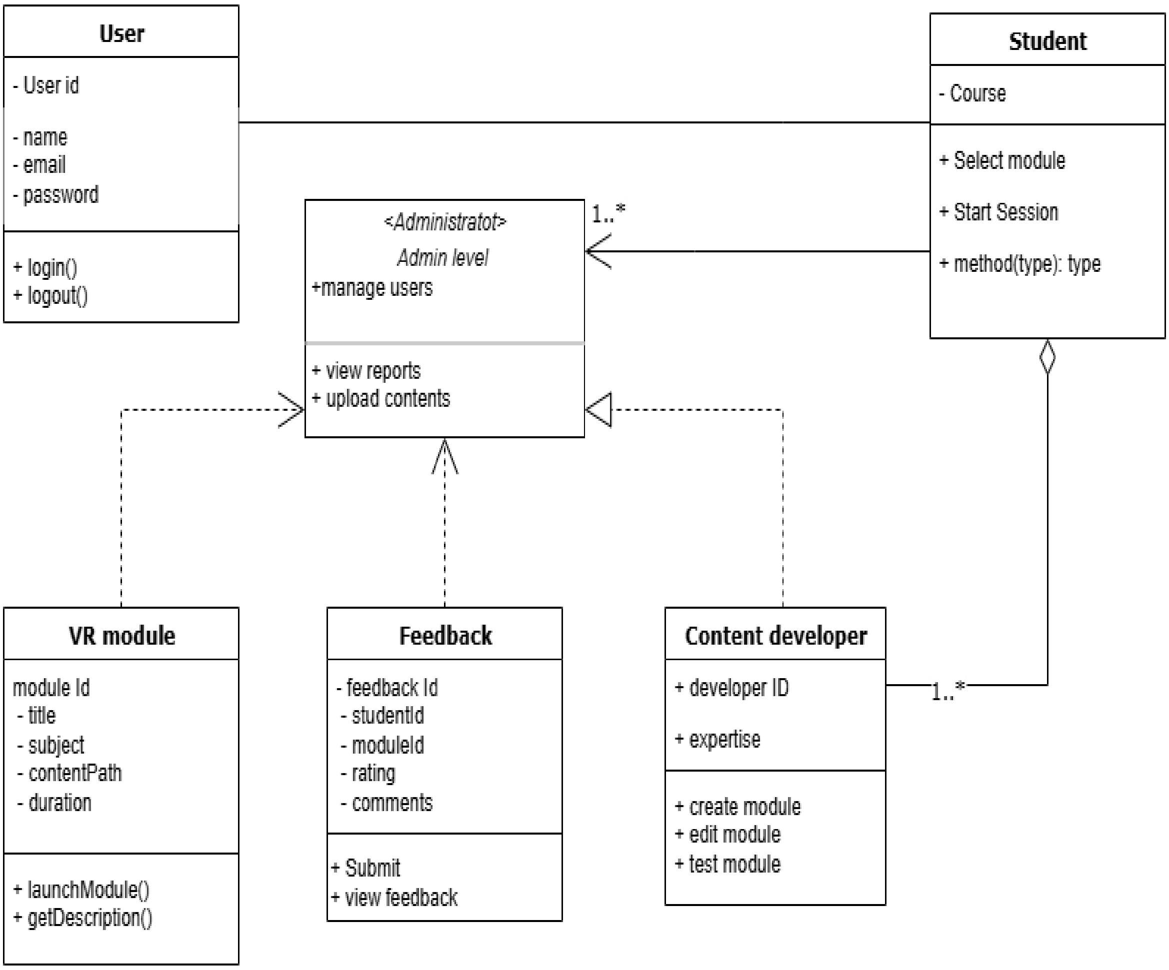

Fig.4 Class Diagram

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IV. IMPLEMENTATION

1. User Authentication Module

Secure login and registration system for students, admin, and content developers.


```
public class LoginManager : MonoBehaviour
{
    public InputField emailInput, passwordInput;
    public Text errorMessage;

    public void Login()
    {
        string email = emailInput.text;
        string password = passwordInput.text;

        if (email == "student@gmail.com" && password == "1234")
        {
            SceneManager.LoadScene("ModuleSelection");
        }
        else
        {
            errorMessage.text = "Invalid credentials!";
        }
    }
}
```

Fig.4 Coding

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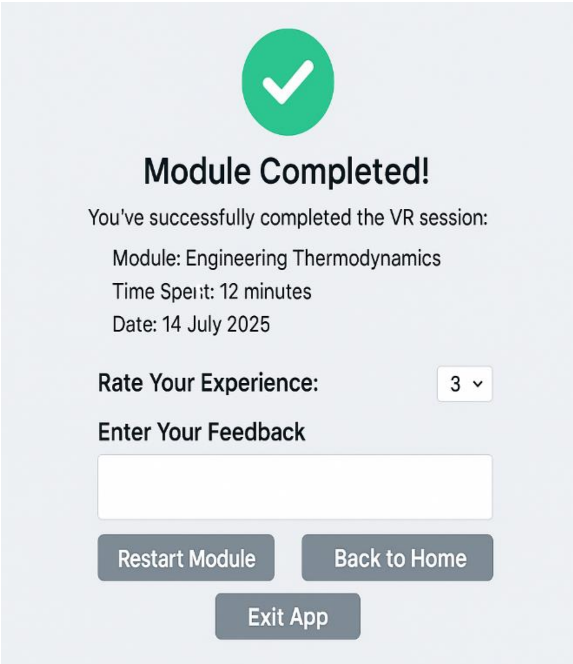
2. OUTPUT

The Output Page is the final screen displayed after a student completes a VR learning session. It summarizes their experience and optionally collects feedback to improve future content.



V. RESULTS

```
using UnityEngine;

public class GazeInteractable : MonoBehaviour
{
    public float gazeTime = 2f;
    private float timer = 0f;
    private bool gazing = false;

    void Update()
    {
        if (gazing)
        {
            timer += Time.deltaTime;
            if (timer >= gazeTime)
            {
                ActivateLearningContent();
                timer = 0f;
            }
        }
        else
        {
            timer = 0f;
        }
    }

    public void OnPointerEnter()
    {
        gazing = true;
    }

    public void OnPointerExit()
    {
        gazing = false;
    }

    void ActivateLearningContent()
    {
```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```
        Debug.Log("Gaze activated: Displaying content");
        // Example: open panel, play audio, or load info scene
        gameObject.GetComponent<Renderer>().material.color = Color.yellow;
    }
}
```

Scene switching using Gaze input in Unity VR

```
using UnityEngine;
using UnityEngine.SceneManagement;

public class GazeSceneLoader : MonoBehaviour
{
    public string sceneToLoad;
    public float gazeDuration = 2f;

    private float gazeTimer = 0f;
    private bool isGazedAt = false;

    void Update()
    {
        if (isGazedAt)
        {
            gazeTimer += Time.deltaTime;
            if (gazeTimer >= gazeDuration)
            {
                LoadTargetScene();
                gazeTimer = 0f;
            }
        }
        else
        {
            gazeTimer = 0f;
        }
    }

    public void OnPointerEnter()
    {
        isGazedAt = true;
    }

    public void OnPointerExit()
    {
        isGazedAt = false;
    }

    void LoadTargetScene()
    {
        Debug.Log("Loading scene: " + sceneToLoad);
        SceneManager.LoadScene(sceneToLoad);
    }
}
```

V. CONCLUSION

This project successfully demonstrates that immersive learning experiences can be delivered in a cost-effective manner using widely available technologies like Google Cardboard and Unity. The developed VR-based platform offers students a new way of learning — one that is visual, interactive, and engaging. By integrating complex educational concepts into 3D environments, the platform helps learners grasp abstract ideas more intuitively. The low hardware cost and mobile compatibility make the system scalable and accessible even in resource-constrained institutions. Overall, this project highlights the potential of affordable VR to revolutionize traditional education and bridge the gap between theoretical and practical learning.

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