# 

# CHAPTER ONE

# INTRODUCTION

# Background

In modern educational settings, the demand for effective instructional methods that enhance student comprehension and engagement, particularly in STEM (Science, Technology, Engineering, and Mathematics) education, has been steadily increasing. Traditional educational approaches often face challenges in conveying spatial or visual concepts, resulting in reduced comprehension and retention among learners (Smith et al., 2020).

Learning Management Systems (LMS) have emerged as vital tools in educational institutions, facilitating the management, delivery, and assessment of educational content. Over the years, LMS platforms have evolved from basic content repositories to comprehensive systems offering a wide range of features, including course management, collaboration tools, and assessment functionalities. Despite their widespread adoption, traditional LMS often lack the capability to effectively incorporate interactive and immersive learning experiences, particularly in disciplines that require visualization of complex spatial concepts (Parusheva & Bankov).

The integration of 3D model interaction into educational platforms has gained attention as a promising approach to address the limitations of traditional instructional methods. Research has shown that visualizing concepts in three dimensions can significantly enhance comprehension, engagement, and retention among learners, especially in STEM fields. By providing students with the ability to interact with 3D models within the learning environment, educators can create more immersive and impactful learning experiences (Holland et al., 2020).

The proposed project seeks to address the existing gap in educational technology by developing a prototype Learning Management System (LMS) with integrated 3D model interaction. By leveraging advancements in Web API, JavaScript Frameworks, 3D model export and integration technology, the project aims to enhance student comprehension of complex course content, particularly in STEM education. The integration of interactive 3D models into the LMS platform is expected to provide students with a more engaging, accessible, and effective learning experience, ultimately revolutionizing the way STEM subjects are taught and learned (Wenzel & Moreno, 2022).

# Project motivation

Learners' especially in STEM fields struggle to comprehend complex concepts due to the limitation in traditional instructional materials such as text and 2D visuals which often fail to convey certain spatial representation or understanding hindering comprehension and retention. Current learning management systems (LMS) often fail to utilize 3D models effectively. This project aims to develop an LMS platform that integrates 3D models to enhance the educational experience, empowering students to engage with course material more dynamically and effectively.

# Statement of problem

In modern educational environments, learners, especially in STEM fields, struggle to comprehend complex concepts due to limitations in traditional instructional materials. Textbooks and 2D visuals often fail to convey certain information effectively, hindering comprehension and retention. Existing learning management systems (LMS) lack the utilization of 3D models to enhance learning experiences. This project seeks to bridge this gap by creating an LMS platform that incorporates 3D models to improve comprehension, engagement, and retention among learners.

# Aim and objectives

The aim of this project is to develop a prototype LMS with integrated 3D model interaction to enhance comprehension of complex concepts especially in STEM (Science, Technology Engineering and Mathematics) fields, making learning more engaging and effective.

1. To design system architecture (flow charts, diagrams), UI/UX, database, API endpoints and technology stack and process to use for the LMS.
2. To develop a prototype of the LMS and integrate 3D models into the platform.
3. To test and evaluate software for requirements, and usability.

# Project organization

The project report is organized into five chapters, with chapter one giving a general introduction and overview of the project.

Chapter Two briefly discuss the relevant theoretical concepts and reviewed recent literature on Learning Management Systems (LMS) and the integration of 3D model interactions in educational platforms.

Chapter Three outlines the methodology and steps taken to actualize set objectives of the project.

Chapter Four presents results obtained from each step from methodology, and discuss them in context of the set project objectives.

Chapter Five concludes and gives a summary of project and the significance, limitations an area for future research and development.

# CHAPTER TWO

# LITERATURE REVIEW

# Introduction

This chapter provides an overview of existing research and developments on learning management systems (LMS) 3D models, interaction and integration. It outlines the current state-of-the-art technologies, explores their applications, and discusses the challenges and opportunities they present. By synthesizing relevant research, this review sets the stage for further exploration into the development of effective LMS with integrated 3D model interaction.

# Fundamental Concepts

This section discusses the fundamental concepts related to this work which includes LMS, 3D Models, WebGL, Web Programming, Web API, JavaScript (Next, React, Three).

* 1. **LMS**

The Learning Management System (LMS) serves as a centralized platform for organizing and delivering educational content, facilitating learning activities, and managing student progress and assessment. It streamlines the administration of courses, allowing instructors to create and share course materials, assessments, and resources, while students can access content, participate in discussions, and track their learning progress (Parusheva & Bankov).

## 3D Models

3D Models, created using software like Blender, Unity, Unreal, AutoCAD Maya, SolidWorks, etc. are virtual objects comprising geometric shapes, textures, and visual properties, serving diverse purposes in gaming, animation, architecture, and education. These models are seamlessly integrated into web applications using 3D model integration file export formats compatible with WebGL and other tools, such as glTF, OBJ, FBX, Collada, and STL, each optimized for efficient loading and rendering. Enabling 3D Model Interaction within web environments allows users to manipulate and engage with models through actions like rotation, zooming, and animations, enhancing user experience in e-learning, product visualization, and virtual tours (Ortiz et al., 2020).

## WebGL

WebGL (Web Graphics Library) is a JavaScript API for rendering 2D and 3D graphics in web browsers, leveraging GPU acceleration for high-performance rendering. It enables developers to create visually rich and interactive web experiences, including games, simulations, data visualizations, and virtual reality applications (MDN, 2024)

## Web Programming

Web Programming refers to the development of web-based applications, websites, and services using programming languages such as HTML, CSS, JavaScript, and server-side languages like Python, Ruby, PHP, and Java. It involves designing, coding, testing, deploying, and maintaining web solutions to address various needs, from simple websites to complex web applications. Web programmers use frameworks, libraries, and tools to build interactive user interfaces, implement business logic, process data, and manage server-side functionality, ensuring the creation of functional, user-friendly, and reliable web experiences (K, 2023).

## Web API

Web API (Application Programming Interface) defines interactions between different software systems over the web, allowing applications to communicate and exchange data. This enables integration with external services, access to web resources, and the creation of interactive web applications that interact with servers, databases, and other web services (Santoro et al., 2019).

## JavaScript (Next, React, Three)

JavaScript, a versatile language integral to web development, facilitates interactive and dynamic web experiences through client-side scripting, DOM manipulation, event handling, and asynchronous programming. Complementing JavaScript, Next.js and React are frameworks for building dynamic web applications; React offers a component-based UI architecture, while Next.js extends it with server-side rendering, static site generation, and routing, streamlining complex app development (Vercel, 2024). Additionally, Three.js, a popular JavaScript library built on top of WebGL, it simplifies 3D graphics creation and manipulation in web applications, providing a high-level API for rendering scenes, managing cameras, lights, materials, and animations, thereby enhancing developers' ability to work with 3D content on the web (Panchal et al., 2022).

## Software Development Life Cycle (SDLC)

The Software Development Life Cycle (SDLC) is a structured process used to guide the development of software applications from inception to retirement. It consists of several phases, including Requirements Analysis, Design, Implementation (Coding), Testing, Deployment, and Maintenance. Each phase of the SDLC has specific objectives and activities aimed at ensuring the successful delivery of high-quality software solutions. By following the SDLC, development teams can systematically plan, develop, test, deploy, and maintain software applications, ensuring they meet user needs, adhere to requirements, and align with business goals. The SDLC provides a framework for managing the software development process efficiently and effectively, resulting in the delivery of reliable and scalable software solutions (Khan et al., 2020).

# Review of similar literature

**(Li & Lin, 2022)** designed and evaluated a collaborative learning system for 3D model sharing in their chapter within "Research Anthology on Makerspaces and 3D Printing in Education." Their work addressed the growing use of 3D printing in educational settings and the limitations of existing platforms for collaborative learning with 3D models. They introduced the 3D Model Co-Learning Space (3D MCLS) system to address this gap. This system offered functionalities like storing, sharing, displaying, and discussing 3D models. It also provided teachers with flexible management options for student groups. Notably, the system offered features like automatic thumbnail generation for 3D models and tag-based organization for grouping models by attributes or class teams. Additionally, it included functionalities for anonymous peer review through blind assignments. Li and Lin implemented the system and conducted a pilot study to assess its usability, providing valuable insights into its effectiveness. This analysis provides a foundation for exploring potential improvements to enhance the learning experience.

**(Husár et al., 2021)** explored the development of a groundbreaking Learning Management System (LMS) that leverages augmented reality (AR) applications to address the educational needs of university students. Their work highlighted the advantages of directly overlaying knowledge interpretation and 3D model visualizations within a student's field of view. This innovative approach, achieved through the integration of the interactive LMS Moodle with Microsoft HoloLens 2 smart glasses, has the potential to revolutionize distance education by offering a more immersive and engaging experience. The authors meticulously detailed a step-by-step process for integrating LMS Moodle with the Windows Holographic Operating System display interface, ushering in a new era of learning. The Industry4School project served as a strong practical example, showcasing a curated database specifically designed for teaching robotics and manipulators through knowledge modules, tests, and 3D models. However, while the study demonstrates the potential of AR-integrated LMS, there's room for further exploration. The current focus on a single domain, robotics, presents an opportunity to investigate the LMS's adaptability to a wider range of disciplines. Future research could evaluate its effectiveness in various academic fields, assessing its ability to cater to diverse learning objectives. Additionally, the innovative feature of using multiple windows simultaneously, while offering flexibility, could potentially lead to information overload. Future studies could explore user interface design optimizations to manage this information effectively within the augmented reality environment, ensuring a clear and focused learning.

**(Nemtinov et al.)** delved into the implementation of software tools in the educational process and their impact on the formation of students’ professional competencies. Their article underscores the necessity of considering this influence in the scientific and methodological support of modern education systems. The primary aim of their research is to develop a technology for creating educational VR content that enhances teaching effectiveness through immersion into a virtual thematic space using a variety of software environments. The authors discuss the technology's process, which involves creating an electronic course using a complex of specialized software tools. This process begins with developing a course description, followed by the utilization of three-dimensional models of virtual objects from software like SketchUp, Blender, Solid works, and Compass-3D. The virtual space is then constructed in the Twin motion software package using these models, alongside photorealistic panoramas, images, and videos. Subsequently, the virtual tour is created in 3DVista Virtual Tour Pro and integrated into the LMS Moodle learning management system. The authors tested the technology's implementation in creating educational content for the course "History of the Tambov Region," which demonstrated high efficiency based on survey results and testing outcomes. The study revealed a 17% increase in correct answers among students who used the proposed electronic content compared to those who did not. This suggests that the integrated use of specialized software tools enhances students' learning experiences and achievements while fostering teamwork and interpersonal communication skills through interactive lectures and group discussions.

**(Hinojosa et al., 2021)** highlighted the growing importance of quality virtual education, particularly in areas where face-to-face instruction is challenging, such as engineering laboratories. To address this, they proposed an augmented reality (AR) application designed to simulate elements and devices typically found in engineering laboratories. Developed using Unity and Vuforia software, the application is compatible with devices running the Android operating system or HoloLens. The authors conducted a case study focusing on virtualizing elements from telecommunications engineering laboratories and tested the application's usability with random users. Surveys were conducted to assess the application's impact on learning. Additionally, the authors provided a link for readers to download and install the application (.apk file) on their own Android devices, enabling them to explore examples firsthand. Hinojosa et al.'s work demonstrates the potential of AR-based e-learning tools to enhance virtual

**(Elfakki et al., 2023)** underscored the potential of virtual reality applications in enhancing the education and training of students with learning disabilities, ultimately improving their quality of life. Traditional teaching methods often fall short in adequately supporting students with learning disabilities, such as dyslexia, dyscalculia, ADHD, and information retrieval disabilities, particularly in subjects like physics where experiments play a crucial role. These disabilities hinder students' ability to learn, visualize concepts, and process information effectively. To address these challenges, the authors developed and evaluated a 3D virtual physics laboratory tailored specifically for students with learning disabilities. The environment, designed based on specific criteria for disabled students, aimed to improve cognitive skills in physics experiments. The study demonstrated the effectiveness of the 3D virtual environment in enhancing cognitive skills related to physics among students with learning disabilities. Elfakki et al.'s research highlights the potential of virtual environments to provide tailored educational experiences for students with diverse learning needs and there is room for improvement to cover other science and engineering fields.

**(Amara et al., 2021)** proposed a web-based e-learning platform that utilizes Augmented Reality (AR) and Virtual Reality (VR) technologies to address the educational disruptions caused by the COVID-19 pandemic. Their platform aims to enhance the learning experience by leveraging immersive VR environments and interactive AR functionalities to visualize complex concepts, and integrate them to web-based education to aligning with the Algerian Ministry of Education's curriculum.

By incorporating VR and AR into education, Amara et al. aim to increase participation and improve understanding, particularly in abstract and complex subjects.

However, the effectiveness of this technology-driven solution in real-world educational settings remains unclear due to the inaccessibility of the technology used. Further evaluation through user testing and learning outcome analysis is necessary to determine its true impact on student learning.

**(Karagöz et al., 2023)** emphasized the critical role of student-content interaction in achieving successful e-learning outcomes. They argued that engaging content strengthens this interaction, and proposed leveraging the digital transformation in publishing to introduce Interactive Electronic Books (IEBs) as educational materials accessible on various smart devices.

IEBs integrate technologies like Augmented Reality (AR), 3D animation, and video files, offering interactive elements that enhance the learning experience. The study aimed to develop not only these IEBs but also a simple Learning Management System (LMS) capable of integrating them. This LMS would facilitate instructors in monitoring student activities within these digital resources.

The authors outlined the design and development processes for the IEBs, AR applications, and the LMS, all following the System Development Life Cycle (SDLC) approach. This comprehensive approach is expected to improve student engagement and interaction with the content, ultimately contributing to a more effective digital learning platform.

**(Pasha et al., 2022)** conducted a study to investigate the impact of virtual reality goggles (VRG) on students' acceptance of learning management systems (LMS) by employing a cross-sectional design and utilizing structural equation modeling (SEM) and machine learning techniques. The findings revealed that VR goggles significantly influenced expectation confirmation and knowledge acquisition among students. Moreover, both expectation confirmation and knowledge acquisition significantly influenced students' motivations, ultimately leading to LMS acceptance. The study also identified that behavioral intention partially mediated the relationship between students' motivation and LMS acceptance. In conclusion, the study emphasized the importance of integrating innovative technology, such as VR which can potentially overcome barriers associated with conventional learning systems by fostering a more engaging and effective learning experience, ultimately leading to greater student acceptance of LMS platforms. This can pave the way for a more technologically advanced and successful educational journey for students.

**(Selekos, 2024)** presented presented a fresh perspective on e-learning by proposing a 3D gamified learning management system (LMS) built on Unity3D and Spring Boot for the Open e-Class platform. This explored the potential of 3D visualization and gamification techniques to address the persistent challenge of student motivation in digital learning environments. While specifics regarding the implemented gamification mechanics are not explicitly mentioned, the research suggests that this approach can transform traditional LMS interfaces into more engaging and interactive platforms, potentially leading to increased student motivation and improved learning outcomes. This innovative project serves as a springboard for further research on the efficacy of immersive and interactive elements in enhancing the e-learning experience.

(Mouttalib et al., 2023) proposed a approach in their work titled "Revolutionizing engineering education: Creating a web-based teaching platform for immersive learning experiences." This research delved into the application of WebXR, a web-based technology that facilitates virtual and augmented reality (VR/AR) experiences, to create immersive learning environments specifically for Science, Technology, Engineering, and Mathematics (STEM) education.

The authors highlight the transformative potential of VR/AR in engineering education. This technology allows students to virtually explore and practice engineering concepts, fostering a learning experience that is geographically independent and more accessible. Mouttalib et al. suggest that VR/AR will significantly impact the roles of both educators and learners within these digital learning spaces.

The paper detailed the development of a WebXR platform specifically designed for engineering education. The platform showcases a virtual environment for training students on the Arduino board. This research significantly contributes to the field of educational technology by exploring the potential of WebXR to create engaging and interactive learning experiences for engineering students, with the potential to be applicable across the broader STEM disciplines.

# CHAPTER THREE

# METHODOLOGY

# Introduction

This chapter describes the steps taken to achieve the objectives of this project which aims to develop a prototype LMS with 3D model integration to enhance comprehension of complex concepts especially in STEM fields, making learning more engaging and effective.

.

# To design system architecture (flow charts, diagrams), UI/UX, database, API, endpoints, technology stack and process to use for the LMS

# To develop a prototype of the LMS and integrate 3D models into the platform

# To test and evaluate software for requirements, and usability

# References

Amara, K., Zenati, N., Djekoune, O., Anane, M., Aissaoui, I. K., & Bedla, H. R. (2021). I-DERASSA: E-learning Platform based on Augmented and Virtual Reality interaction for Education and Training. 2021 International Conference on Artificial Intelligence for Cyber Security Systems and Privacy (AI-CSP),

Elfakki, A. O., Sghaier, S., & Alotaibi, A. A. (2023). An efficient system based on experimental laboratory in 3D virtual environment for students with learning disabilities. *Electronics*, *12*(4), 989.

Hinojosa, C. J. T., Cabrera, J. J. F., Mora, H. R. C., & Garzón, N. V. O. (2021). An augmented reality based e-learning tool for engineering. 2021 IEEE colombian conference on communications and computing (COLCOM),

Holland, J. L., Lee, S., Daouk, M., & Agbaji, D. A. (2020). Higher education teaching and learning with augmented reality. In *Handbook of Research on Fostering Student Engagement with Instructional Technology in Higher Education* (pp. 229-248). IGI Global.

Husár, J., Knapčíková, L., Hrehová, S., & Trojanová, M. (2021). The concept of the lms system for teaching subjects from the field of industry 4.0 based on augmented reality. EDULEARN21 Proceedings,

K, E. (2023). A Comprehensive Review of Web Designing and Web Development:

Concepts, Practices and Trends. *International Journal of Research Publication and Reviews*, *Vol 4*. <https://ijrpr.com/uploads/V4ISSUE4/IJRPR11646.pdf>

Karagöz, E., Çavaş, B., Güney, L., & Dizdaroğlu, A. (2023). A design model proposal for digital learning platform based on interactive e-books. *Ukrainian Journal of Educational Studies and Information Technology*, *11*(3).

Khan, M., Shadab, S., & Khan, F. (2020). Empirical study of software development life cycle and its various models. *International Journal of Software Engineering (IJSE)*, *8*(2), 16-26.

Li, T.-Y., & Lin, I.-S. (2022). Design and Evaluation of a Collaborative Learning System for 3D Model Sharing. In *Research Anthology on Makerspaces and 3D Printing in Education* (pp. 165-188). IGI Global.

MDN. (2024, May 5, 2024). *WebGL: 2D and 3D graphics for the web*. Retrieved June 9, 2024 from <https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API>

Mouttalib, H., Tabaa, M., & Youssefi, M. (2023). Revolutionizing engineering education: Creating a web-based teaching platform for immersive learning experiences. *Journal of Smart Cities and Society*(Preprint), 1-12.

Nemtinov, V., Rodina, A., Borisenko, A., Morozov, V., Protasova, Y. V., & Nemtinov, K. Integrated Use of Various Software Environments for Increasing the Level of Visualization and Perception of Information.

Ortiz, J. S., Guevara, B. S., Espinosa, E. G., Santana, J., Tamayo, L. R., & Andaluz, V. H. (2020). 3D virtual content for education applications. 2020 15th Iberian Conference on Information Systems and Technologies (CISTI),

Panchal, S., Raval, P., Shetty, S., & Ambadekar, S. (2022). College 3D Model Rendering Using Three JS. 2022 5th International Conference on Advances in Science and Technology (ICAST),

Parusheva, S., & Bankov, A. P. D. B. Learning Management Systems as a Tool for Learning in Higher Education.

Pasha, S. A., Sharif, H., Ali, S., Al-Misfari, A., Elareshi, M., Ziani, A., & Habes, M. (2022). Perceptions of incorporating virtual reality of goggles in the learning management system in developing countries. International Conference on Business and Technology,

Santoro, M., Vaccari, L., Mavridis, D., Smith, R., Posada, M., & Gattwinkel, D. (2019). Web Application Programming Interfaces (APIs): General-Purpose Standards, Terms and European Commission Initiatives. *Eur. Commission, Louxembourg, Louxembourg, UK, Tech. Rep. JRC118082*.

Selekos, P. (2024). 3D visualization of learning management systems with gamification techniques to increase motivation of students.

Smith, D. W., Lampley, S. A., Dolan, B., Williams, G., Schleppenbach, D., & Blair, M. (2020). Effect of 3D manipulatives on students with visual impairments who are learning chemistry constructs: a pilot study. *Journal of Visual Impairment & Blindness*, *114*(5), 370-381.

Vercel. (2024). Next.js by Vercel is the full-stack React framework for the web. <https://nextjs.org/>

Wenzel, A., & Moreno, J. (2022). Designing and Facilitating Optimal LMS Student Learning Experiences: Considering students' needs for accessibility, navigability, personalization, and relevance in their online courses. *The Northwest eLearning Journal*, *2*(1).