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**DEVELOPMENT OF A LEARNING MANAGEMENT SYSTEM (LMS) WITH INTERGRATED 3D MODEL INTERACTION**

**BY**

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**CERTIFICATION**

This project report by **Erasmus E Obeth** meets the regulation governing the award Bachelor of Engineering (B.Eng.) Degree in Computer Engineering of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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# 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 Compass3D. 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 eLearning 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 eLearning platform that utilizes Augmented Reality (AR) and Virtual Reality (VR) technologies to address the educational disruptions caused by the COVID19 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 eLearning 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 eLearning by proposing a 3D gamified learning management system (LMS) built on Unity3D and Spring Boot for the Open eClass 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 eLearning experience.

**(Mouttalib et al., 2023)** proposed an 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 outlines the methodology used to achieve the objectives of this project, which focuses on developing a prototype Learning Management System (LMS) with integrated 3D model interaction. The aim is to simplify the comprehension of complex concepts, particularly in STEM fields, by making learning more engaging and effective. This chapter will detail the design of the system architecture, the development of the prototype, and the testing and evaluation procedures used to ensure that the final product meets the intended requirements.

# Materials

**Next.js:** Was used for both frontend and backend development. It supports server-side rendering (SSR) and static site generation (SSG), providing fast page loads and improved SEO.

**React.js:** A JavaScript library for building user interfaces, particularly single-page applications, using a component-based architecture. Was employed to create dynamic and interactive user interfaces with a component-based architecture, allowing for reusable UI components.

**Three.js:** Wasutilized for rendering and interacting with 3D models within the web environment, essential for integrating spatial or interactive learning materials.

**PostgreSQL:** Was selected and used for database management system because of its robustness, scalability, and support for complex queries. It stores user data, course content, assessments, and interaction logs.

**Prisma** is a modern ORM for Node.js and TypeScript. It simplifies database interactions by providing a declarative schema, type-safe queries, and automatic migrations. Was used for model-based interaction with the PostgreSQL database.

**Git:** Was used for version control to keep track of changes throughout the development process and facilitate easy deployment.

**Tailwind CSS:** A utility-first CSS framework for rapidly building custom user interfaces with minimal custom CSS for styling the frontend.

**Visual Studio Code:** A popular source-code editor developed by Microsoft, offering support for debugging, syntax highlighting, intelligent code completion, and more. The development environment was used for writing and testing code on both Windows and Linux Ubuntu machines.

**Chrome and Firefox Development Tools:** This was used as the browsers for testing the LMS during development.

**Vercel:** The hosting platform was used for deploying the LMS, ensuring it is accessible to users and supports scalable operation.

**PC and Laptop:** Was **u**sed as the development hardware device for running the software

# Methodology

The LMS was designed iterative agile methodology with a modular architecture separated into the frontend, backend, and data persistence layers. This separation ensures scalability, maintainability, and ease of integration with other systems or tools. The system’s core components include the User Interface (UI), Application Programming Interface (API), assessments, discussion forums, a 3D model viewer, course management tools, content delivery mechanisms, database and file storage for persistence. The LMS architecture also incorporated authentication and authorization mechanisms to manage user access and data security. Features was taken and developed individually and incrementally using sprints which allowed faster development and room for improvement in the front end, backend and persistent data layers.

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

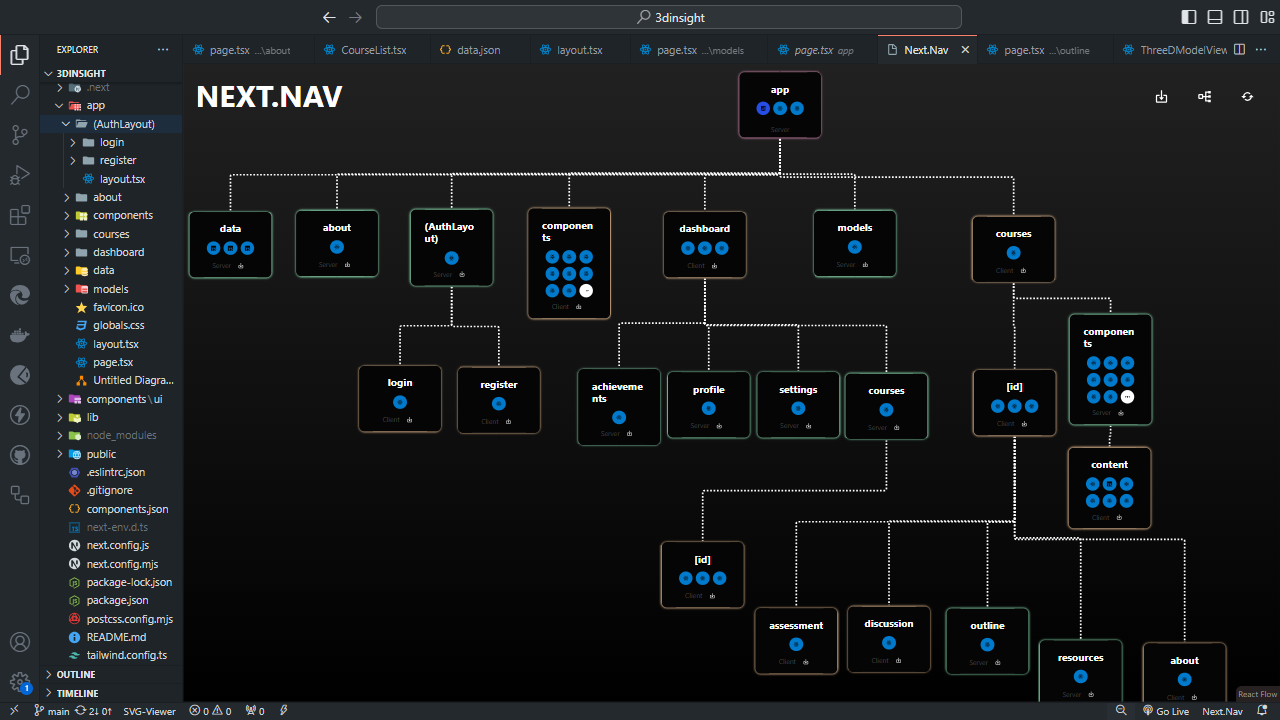
The LMS architecture was designed to support the seamless integration of 3D models into the learning content. The system was divided into three main layers: The Frontend Layer, the Backend Layer, and the Persistence and Data Layer. These layers interact to provide a robust and scalable platform for delivering educational content and easy plug and play of the three layers.

**3.3.1.1 Frontend Layer**

The Frontend Layer is the user facing side of the LMS, where learners and instructors interact with the system. It includes several components that was designed to provide a seamless and intuitive user experience across various devices the process used to design them was to look at the pages common in most LMS currently famous, how they look and the considerations put into the design. Then base on those designs a draft of how 3dInsights will look was drawn and directly coded and adjusted to fit a pleasant user view.

**User Interface (UI):**

The UI is where users interact with the LMS directly. It includes visual elements like menus, buttons, forms, navigation tools and pages, all designed based on industry patterns for easy use. The UI is responsive, ensuring accessibility on desktops, tablets, and smartphones.



**Home:** The home page is the LMS's entry point. It offers users the ability to explore available courses, explore models, or learn more about the platform. New users can sign up, while returning users can sign in.

**Sign In/Sign Up:** This page handles user authentication. New users can create an account, while returning users can log in to access their dashboard and enrolled courses. Security measures protect user data during this process.

**Dashboard:** The dashboard is the central hub for users after logging in. It summarizes the user's courses, achievements, and recent activities, allowing navigation to profiles, settings, or direct access to courses.

**Profile:** The profile section allows users to manage personal information, such as their name, email, and password. Users can also view their achievements and track their progress.

**Settings:** This page enables users to customize their LMS experience by adjusting notification preferences, changing language settings, and managing other personalization options.

**Explore:** The explore section allows users to try interacting with samples of 3d models, and also resources to open source 3D models that can be used in creating courses.

**Courses:** This page lists all the courses a user is enrolled in. Users can access course content, view the course outline, and participate in assessments and discussions.

**Course/[id] /About:** Each course has a dedicated page where users can enroll or continue learning, access the Information (description, duration, level, instructors, timeline) outline and content, resources, assessments, and discussions. The [id] represents the specific course identifier that loads the corresponding course content.

**Course Content:** This is where the core learning materials are accessed, including video lectures, reading materials, and 3D models. Users can participate in assessments or discussions related to the content directly from this page.

**Course Resources:** This section provides additional materials related to the course, such as downloadable PDFs, external links, and reference documents, supplementing the main content.

**Course Assessments:** The assessments page lists quizzes, tests, and assignments associated with the course. Users can take assessments, submit assignments, and view their grades from this section.

**Course Discussion:** The discussion forum allows users to engage in course related conversations, supporting both threaded discussions and direct messaging for collaborative learning.

**User Flow**

The user flow diagrams illustrate the paths that a teacher and a student take when interacting with the LMS. These flows highlight the different functionalities available to each user role and how they navigate through the system to achieve their goals.

**Student Journey**

**Home → Sign In/Sign Up:** The student begins at the home page, where they either sign in (login) or sign up (create an account).

**Dashboard:** After signing in, the student accesses their dashboard, showing enrolled courses, recent activity, and achievements.

**Courses:** Students can browse available courses via the "courses" page, using search filters to find courses of interest.

**Enroll in a Course:** Once a course is found, the student can enroll, with the course appearing on their dashboard under "Enrolled Courses."

**Access Course Content:** Clicking on a course directs the student to the course's main page, where they can view the outline, access content, and interact with the 3D model viewer.

**Participate in Assessments:** The student navigates to the "Assessments" section to complete and view status of quizzes assignments exams, and their grades.

**Engage in Discussions:** The "Discussion" section allows enrolled student and teachers in a course to discuss via chat with peers for more understanding of the course or course notifications.

**Track Progress:** Progress is monitored via the dashboard, showing completed modules, scores, and discussion participation.

**Teacher Journey**

**Home → Sign In/Sign Up:** Teachers start at the home page and either sign in or sign up to access their accounts.

**Dashboard:** The teacher's dashboard summarizes courses they teach or manage, along with recent activities.

**Create a Course:** Teachers can create a new course, setting up the structure, adding an outline, and uploading content and 3D models.

**Manage Courses:** Existing courses can be managed, including editing content, scheduling assessments, and organizing resources.

**Add/Update Course Content:** New lectures, resources, and 3D models can be added or updated to keep materials current and relevant.

**Create Assessments:** Assessments are designed in the "Assessments" section, linked to course modules, and can be set to auto grade where applicable.

**Facilitate Discussions:** Teachers moderate discussions, respond to student queries, and foster an interactive learning environment.

**Monitor Student Progress:** Student performance is monitored through progress tracking tools, helping identify students needing additional support.

**Students:** Focus on course enrollment, content consumption, assessments, and discussions.

**Teachers:** Responsible for course creation, content management, assessment design, and student support.

These flows ensure that both students and teachers have a simple and easy experience, tailored to their specific needs and objectives.

**3D Model Viewer:**  
The 3D Model Viewer is an integral component of the frontend, allowing users to interact with 3D models embedded within the course content. This viewer supports operations such as rotating, zooming, and dissecting models, providing an interactive learning experience. The integration of 3D models is particularly beneficial for explaining complex concepts in STEM fields, where visualizing structures and processes in three dimensions can enhance comprehension. It was designed with three.js iteratively.

* + - 1. **Backend Layer**

**Purpose**: The backend server is the core component responsible for handling business logic, managing data, and serving the content requested by the frontend.

**Functionality**: The backend processes requests from the frontend (UI) and interacts with the database to perform operations like user authentication, course management, and retrieval of 3D models. It also handles session management, security protocols, and data validation.

**Interaction with Other Components**: The backend server communicates with the database to store and retrieve data, and with the API to send and receive data to/from the frontend. It also processes and serves 3D models to the UI, integrating them into the learning environment.

**API (Application Programming Interface)**

The API acts as a bridge between the frontend and backend, allowing the two to communicate efficiently. It exposes endpoints that the frontend can call to retrieve or update data. For example, when a user submits an assessment, the frontend sends the data to the backend via the API, which then processes and stores the results.

**Authentication & Authorization Module**

This module ensures that only authorized users can access certain features of the LMS. It manages user roles (e.g., student, instructor, admin) and permissions, ensuring that sensitive data is protected and that users can only access the resources they are entitled to.

**User Management Module**

This module handles user creation, deletion, update, and serves as identification source to the Authentication & Authorization Module.

**Course Management Module**

This module manages the creation, updating, and deletion of courses within the LMS. It handles the organization of course content, including lectures, assignments, and assessments. Instructors use this component to upload materials, schedule sessions, and monitor student progress.

**Content Management and Delivery Module**

This module interacts with the backend server to store and retrieve course content, which is then made available to users through the UI. The CMS also interacts with the database to manage the content and with the 3D model integration and file storage to include interactive models in course materials.

**3D Model Management** **Module**

This module handles the storage, retrieval, and integration of 3D models within the LMS. It ensures that models are accessible and can be rendered appropriately in the 3D Model Viewer. The system supports various 3D file formats and provides tools for managing these assets within courses.

**Assessments Module**

The assessments module is responsible for creating and managing quizzes, tests, and other evaluative tools within the LMS. It allows instructors to design assessments that align with course objectives and automatically grades certain types of questions (e.g., multiple-choice).

**Discussion** **Module**

This module is responsible for handling discussion and announcement chats of the different courses and keeping track of each course chats.

**Progress Tracking** **Module**

The progress tracking system monitors and records the learner's journey through the course. It tracks completed modules and courses, assessment scores, and participation in discussions.

* + - 1. **Persistence and Data Layer**

The Persistence and Data Layer is responsible for storing all the data generated and used by the LMS. This includes user information, course content and information, assessment and results, discussions, resources and 3D models.

**Database**

The database is structured using a relational schema to ensure data integrity and efficient querying. It supports CRUD (Create, Read, Update, Delete) operations for all data within the LMS. The data is organized into tables such as users, courses, course enrolment, resources, 3DModels, discussions rooms, resources, progress tracking, sessions, and assessments file storage.

**Interaction with Other Components**: The backend server interacts with the database to perform all data related operations. The data retrieved is then sent to the UI or used internally by the backend to perform logic operations.It is designed to handle concurrent access by multiple users, ensuring data consistency and integrity

**File Storage**

The file storage system handles unstructured data such as video, image, documents, images, and 3D model files. It ensures that these files are stored securely and can be retrieved efficiently. The system supports large file sizes and provides mechanisms for organizing and managing these resources within the LMS.

**3.3.1.4 Technology Stack**

The technology stack for the Learning Management System (LMS) was chosen with careful consideration to meet the system's requirements, ensuring scalability, performance, and ease of maintenance. The selected stack includes:

**Frontend**

**Next.js**: The LMS frontend is built using Next.js, a React based framework that allows for server-side rendering (SSR) and static site generation (SSG). This ensures fast page loads and improved SEO, making the platform highly responsive and performant.

**React.js**: React.js was chosen for creating a dynamic and interactive user interface. React’s component-based architecture facilitates the development of reusable UI components, enhancing development efficiency and maintainability.

**Three.js:** Integrated into the frontend, Three.js is used for rendering and interacting with 3D models within the web environment. This library allows for sophisticated 3D visualizations, making it ideal for courses that involve spatial or interactive learning materials.

**Tailwind CSS:** A utility-first CSS framework for rapidly building custom user interfaces with minimal custom CSS for styling the frontend.

**Prisma** is a modern ORM for Node.js and TypeScript. It simplifies database interactions by providing a declarative schema, type-safe queries, and automatic migrations.

**Backend**

The backend of the LMS is developed using **Next.js** a framework with support for backend and frontend development also a JavaScript runtime that allows for building fast and scalable server-side applications. Node.js is well-suited for handling the asynchronous nature of the LMS, which involves Realtime updates, such as course progress tracking and discussion forums. The backend manages all business logic, including user authentication, course management, and data processing. It also handles interactions with the database, ensuring smooth data retrieval and storage.

**Database**

**PostgreSQL** was selected as the database management system due to its robustness, scalability, and support for complex queries. As an opensource, SQL based relational database, PostgreSQL offers reliable data storage with strong ACID (Atomicity, Consistency, Isolation, Durability) compliance. The database is responsible for storing user data, course content, assessments, and interaction logs. PostgreSQL’s support for advanced data types and indexing makes it well-suited for handling the complex data relationships and large datasets required by the LMS.  
**3D Model Integration**

**Three.js** is a JavaScript library that enables the rendering of 3D models directly within the web browser. This library is integrated into the LMS frontend, allowing students and teachers to interact with 3D content as part of the course materials. Whether it’s exploring anatomical models in a biology course or viewing architectural designs, Three.js provides the necessary tools for creating immersive learning experiences.

# Development of prototype LMS with integrated 3D models Interaction

The LMS prototype was developed in iterative stages, with each iteration refining the features and functionality. The development process involved:

**Agile Iterative Methodology**: An agile approach was adopted to allow for flexibility and continuous feedback, with sprints focusing on implementing specific features such as user management, course creation, and content delivery.

**Version Control**: Git was used for version control, for keeping track of changes throughout the development process and easy deployment.

**Development Environment: Visual Studio Code on both a windows and Linux ubuntu machine was used throughout the development and Chrome and Firefox browser for testing during development**

**3D Model Integration:** The integration of 3D models into the LMS was achieved by developing a 3D model viewer using Three.js and Next.js that allows users to interact with models in a meaningful way. The viewer supports manipulation of models (such as rotation and zoom) and is embedded into the course content. The backend manages the storage and retrieval of these models, ensuring they are seamlessly integrated into the learning experience

**Model Selection and Preparation**: 3D models relevant to the subject matter were selected and optimized for web use, ensuring they load quickly and run smoothly on

**Interaction with Other Components**: 3D models are stored as files in the file storage with URLs in the database and retrieved by the backend server. The frontend uses WebGL or similar technologies to render these models within the browser.

**Project Setup**

1. Install Git:

**Install Git:** [Download Git] (<https://git-scm.com/downloads>)

**Configure Git:**

*git config --global user.name "Your Name"*

*git config --global user.email* [*your.email@example.com*](mailto:your.email@example.com)

***2.* Set Up Version Control:**

**Initialize Git and connect to remote:**

*cd path/to/your/project*

*git init*

*git add .*

*git commit -m "Initial commit"*

*git remote add origin https://github.com/username/repository.git*

*git branch -M main*

*git push -u origin main*

**3. Install and Configure VSCode:**

**Install VSCode:** [Download VSCode] (https://code.visualstudio.com/Download)

**Install Extensions:**

Next.js Nav: `next.js nav`

Prettier: `prettier`

ESLint: `eslint`

**Configure settings (`settings.json`):**

"editor.defaultFormatter": "esbenp.prettier-vscode",

"editor.formatOnSave": true,

"eslint.format.enable": true,

"editor.codeActionsOnSave": {

"source.fixAll.eslint": true

}

**4. Install Node.js and npm:**

**Install Node.js:** [Download Node.js] (https://nodejs.org/)

**Verify installation:**

*node -v*

*npm -v*

**5. Set Up Next.js with React and TypeScript:**

**Create a Next.js project:**

*npx create-next-app@latest your-project-name --typescript*

*cd your-project-name*

*npm run dev*

**6. Set Up PostgreSQL and Prisma:**

**Install PostgreSQL:** [Download PostgreSQL] (https://www.postgresql.org/download/)

Create database using `pgAdmin` or terminal.

**Install Prisma:**

*npm install @prisma/client*

*npm install prisma --save-dev*

*npx prisma init*

**Configure `.env`:**

*DATABASE\_URL="postgresql://user:password@localhost:5432/your-database-name"*

**Apply schema:**

npx prisma migrate dev --name init

**7. Integrate Three.js:**

**Install Three.js:**

*npm install three*

Create and use a Three.js component in Next.js.

8. **Set Up CI/CD with Vercel:**

**Using Vercel GUI:**

**Connect to GitHub:**

Go to [Vercel](https://vercel.com/), log in or create an account.

Click "New Project" and import your GitHub repository.

**Configure Project:**

Vercel will automatically detect your project settings.

Select the correct project framework (e.g., Next.js) and click "Deploy."

**Automatic Deployments:**

Vercel will automatically build and deploy your project on each push to the main branch.

**Using Vercel CLI:**

**Install Vercel CLI:**

*npm install -g vercel*

**Login and Link Project:**

*vercel login*

*vercel link*

**Deploy Project:**

*vercel deploy --prod*

9. **Clone the Repository on Another System:**

**Clone the repository:**

*git clone https://github.com/cyber330d/3DInsights.git*

*cd 3DInsights*

**Install dependencies and start the project:**

*npm install*

*npm run dev*

**All detailed instructions and configurations can be found in the README file in the repository** <https://github.com/cyber330d/3DInsights>**.**

**Deployment and Hosting**

The deployment and hosting component ensure that the LMS is accessible to users at all times, hosted on a secure, scalable platform. The source code was hosted on GitHub on this URL <https://github.com/cyber330d/3DInsights> and configured to allow vercel to access and redeploy the LMS whenever the main branch changes. The LMS is available life on this URL [3dinsights.vercel.app](file:///C:\Users\cyber330d\Desktop\ACAD\project\FINAL_YEAR_PROJECT\docs\3dinsights.vercel.app). The hosting and deployment environments support the backend, database, and 3D model rendering engines, ensuring they operate efficiently and are scalable based on user demand. It also manages the security components and integrates with monitoring tools to ensure the LMS is running smoothly.

# Testing and evaluating software for requirements, and usability

The testing phase focused on ensuring the system meets the functional requirements and provides a user-friendly experience. Usability testing was conducted to evaluate the effectiveness of the UI/UX design, while performance testing assessed the system’s response time and reliability, particularly when rendering

**3.3.3.1 Requirements Testing**

The LMS prototype was tested against the initial requirements to ensure all functionalities were correctly implemented. This included:

**Functional Testing**: Each feature was tested to ensure it worked as intended, including user authentication, course management, content delivery, discussion, progress, assessment and 3D model interaction.

**Integration Testing**: Tests were conducted to ensure all components (frontend, backend, database, and 3D models) worked seamlessly together.

**3.3.3.2 Usability Testing**

Usability testing involved real users interacting with the LMS to identify any issues or areas for improvement. The feedback was used to refine the UI/UX and enhance overall user satisfaction

**User Testing**: A group of users representing the target audience was selected to interact with the LMS. Their feedback was collected to identify any usability issues or areas for improvement.

**Performance Testing**

Performance testing was conducted to measure the system's ability to handle multiple users and render 3D models without significant lag. The results ensured that the LMS performs well under typical usage scenarios. Key performance metrics, such as load times, responsiveness, and ease of navigation, were observed to assess the LMS's overall efficiency and user-friendliness.

**3.3.3.3 Evaluation and Iteration**

Based on the results from testing:

**Bug Fixing and Improvements**: Identified bugs were fixed, and user feedback was incorporated to enhance the LMS’s design and functionality.

**Final Review**: A final evaluation was conducted to ensure the LMS met all project objectives and was ready for deployment and further development.

This chapter detailed the methodology used to design, develop, and test the LMS prototype with 3D model integration. By following a structured approach, the project aimed to create a user-friendly and effective learning platform that meets the needs of modern STEM education. The subsequent chapter will discuss the results and findings from the testing and evaluation process.

# References

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

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 elearning 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. 229248). 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 ebooks. 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), 1626.

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. 165188). IGI Global.

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

Mouttalib, H., Tabaa, M., & Youssefi, M. (2023). Revolutionizing engineering education: Creating a webbased teaching platform for immersive learning experiences. Journal of Smart Cities and Society(Preprint), 112.

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., AlMisfari, 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): GeneralPurpose 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), 370381.

Vercel. (2024). Next.js by Vercel is the fullstack 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).

Cabello R. (2024). *Three.js*. Retrieved 26/07/2024 from https://threejs.org