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ARia: Empowering Education through Immersive Experiences

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ABSTRACT: True Learning comes from understanding a topic and it can become hard when the explanation is just plain text or images, the learner has to visualize the concept with limited data, but ARia, focuses on boosting that visualization of the user by providing immersive Augmented Reality models to navigate by the user. With the help of AR, learning can be made easier and fun. Students can explore complex concepts interactively, improving engagement and understanding. With increasing use of technology in education, ARia addresses the limitation of traditional learning methods by offering engaging and interactive experience. The app's architecture ensures scalability and smooth performance, ensuring access to everyone without excessive compute and gpu usage. This paper presents the development of ARia, its underlying architecture, the challenges faced, and the solutions implemented to create a robust learning tool that harnesses the power of AR technology.

KEYWORDS: Understanding, Visualization, Augmented Reality (AR), Interactive Learning, Student Engagement, Complex Concepts, Engaging Experience, Scalability, Smooth Performance, Architecture, Robust Learning Tool

I. INTRODUCTION

Traditional educational methods, such as textbooks and offline learning are constantly being supplemented with digital education such as websites, educational videos, and applications. And since the global COVID-19 pandemic, the use of technology in education and various fields have increased a lot. This lead to Teachers and Educational Institutes come up with various strategies to overcome the issue, (Sir John Daniel, 2020) [1], and since then the role of technology in education has played a huge role. But, technology if not used in a proper direction can have negative effects on the development of the children (Rüstem Mustafaoglu, Emrah Zirek, Zeynal Yasacı & Arzu Razak Özdingler, 2018) [2]. One such transformative technology is Augmented Reality (AR), allowing us to overlay virtual content onto the real world. Various strategies in the past have been applied in Mobile Augmented Reality (MAR) (Fabrício Herpich1, Felipe Becker Nunes2, Giani Petri3, Liane Margarida Rockenbach Tarouco, 2019) [3] as learning approaches can be virtually accessed using the ubiquitous mobile devices, in which, learners can access learning materials and contents anywhere, anytime on their mobile devices. However, limitation in the application of mobile augmented reality in education is that the best practices for the use of these resources in education are still being established and that leads to the idea of ARia.

This paper focuses on the design and development of an AR-based education application called ARia, created using React Native for cross platform application development focusing a rich user driven User Experience, Firebase for real-time database management and backend services like user authentication, OpenAI's API for AI driven features like interaction with the objects and prompting the AI for more information, and Blender for designing the 3D models which would then be animated inside the application using the rich libraries of React. The app aims to enhance the learning experiences of students by making concepts more interactive and visually engaging to an audience whose attention span is already getting affected due to short form videos such as reels or shorts (HS Varshaa, Shreya K & MS Ghosh).

II. BACKGROUND

The Role of AR in Education: As cited by (Dorota Kamińska ,Grzegorz Zwoliński ,Anna Laska-Leśniewicz ,Rui Raposo ,Mário Vairinhos ,Elisabeth Pereira ,Frane Urem ,Martina Ljubić Hinić ,Rain Eric Haamer and Gholamreza Anbarjafari, 2023) [4], The educational landscape is an environment prone to change due to the volatile and ever-changing nature of digital society, and that the use of augmented reality solutions as teaching and learning tools can improve teacher and student learning outcomes by increasing engagement and interactivity. The volatile state of technology and the mind of a student goes hand in hand and having a solution like augmented reality to keep their attention span intact can prove to be very efficient in teaching and learning.

AR found its origin in 1960's, when computer scientist Ivan Sutherland developed the 'Sword of Damocles' (see Figure 1) at the University of Salt Lake City in the United States. The device was a head-mounted three-dimensional display functioning as a pair of glasses to view images in 3D.

Augmented Reality is continuously growing in the field of educational setting and according to (Juan Garzón, 2021) [5], 23 years have been passed since the first AR application was designed exclusively for educational purposes. Ever since, this technology has been successfully being enriching the educational contents to boost the learning gain, motivation and enjoyment amongst the learners.

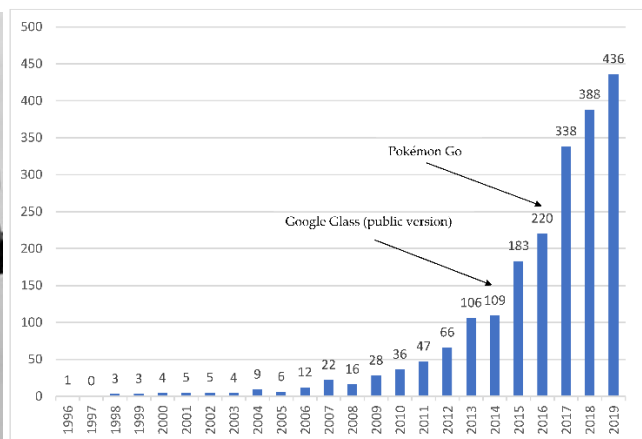


Figure 1. Sword of Damocles – Head Mount Figure 2. Number of studies in AR in education per year in WoS

Benefits of AR in Learning: Again as stated by (Juan Garzón, 2021) [5], AR technology in education helps enrich the learning gains, keeps the users motivation and enjoyment. These supplemented with other benefits such as Improved Engagement, Enhanced Understanding and Personalized Learning can be given as some major benefits of AR in learning.

Improved Engagement: AR creates interactive environment for the learner to experience first-hand visually, where they can manipulate the objects on command, this increases the user engagement and keeps the learning fun. Learning like this is after all rooted deep into us, since childhood we used to play with LEGO's and interactive toys to enhance our problem solving skills and having something similar accessible to us anywhere can trigger those senses and make learning more easy to understand.

Enhanced Understanding: The main focus of using AR is to be able to visualize the complex or abstract subjects, such as scientific models or anatomy of human, which becomes easy with the help of AR and this helps the learner to understand the concepts in a different light from what they might've imagined. Having a second brain to visualize and then compare our own imagination with it can help fill in the gaps and make the learner retain the content easily.

Personalized Learning: Every person is different, with different learning habits and different speeds at which they cover a certain topic, with the help of AR application, one can take on a subject on their preferred pace, hence proving to be tailored to users need.

Overview of Technologies: ARia is being developed using some of the most popular technologies to keep up with the fast paced, ever changing and volatile digital society.

The technologies being used are – React Native: A JavaScript-based framework for building mobile applications that run on both iOS and Android, allowing cross-platform application development having a single codebase. This will help generate the skeleton of the whole application.

Firestore: Any good application needs a backend and storage service and for ARia, Firestore has been chosen, it is a Google-backed platform providing backend services such as Realtime databases, user Authentication, and most importantly the cloud storage, allowing it to synchronize the educational content across the servers and end user applications.

AI APIs: Artificial Intelligence is the current trend in the market and as cited by (Banya Arabi Sahoo, 2021), AI is being used to make discoveries, generating new ideas, conduct experiments, similarly not having AI in an educational application would be just unfair hence, with the help of OpenAI's API and Claude's API integration would provide the power of AI to ARia.

Blender: The 3D models which would be used in ARia would be sculpted/created with the help of an open-source 3D modelling software, Blender, which supports animation, modelling, and rendering. It is used to develop high quality animated and wireframes for 3D models and AR content.

III. APP DESIGN AND ARCHITECTURE

The AR-based educational application is designed with a modern architecture that leverages popular technologies to ensure scalability, smooth performance, and ease of maintenance. This architecture, structured to cater to a dynamic and interactive learning environment, ensures that users can access AR content effortlessly while interacting with intuitive user interfaces.

App Architecture: The application is built using a multi-layered architecture, ensuring that each component is dedicated to a specific responsibility. The architecture is divided into three distinct layers:

Presentation Layer: This layer is the face of the application. It consists of the User Interface (UI), responsible for all user interactions, including the launch screen, navigation menus, AR content display, interactive 3D models, and user input forms. Users can customize their experience by accessing settings for preferences like themes and AR configurations, ensuring a personalized and engaging learning environment.

Application Layer: The heart of the application lies here. It handles the core logic such as AR scene management, model rendering, and interaction with ARKit/ARCore, ensuring smooth AR experiences. This layer also manages content by downloading models and updating educational curricula. Additionally, user authentication and settings configuration are handled here, enabling secure access and tailored app settings for each user.

Database Layer: This is where all the user data and content is stored. The User Database stores user profiles, bookmarks, and preferences, ensuring personalized experiences. Meanwhile, the Content Database holds 3D model files and educational content, allowing for easy retrieval of the required resources during the learning sessions.

This modular architecture allows for independent development and maintenance of each layer, making the app both robust and flexible.

System Flow: The system flow is designed to offer a seamless interaction between the user and the app's underlying logic. It starts with the Presentation Layer, where users can navigate through the app, interact with AR content, and

modify their preferences. These user interactions are sent to the Application Layer for processing and handling business logic.

When a user selects a 3D model to interact with, the Application Layer takes control by managing the AR scene and rendering the model using ARKit or ARCore. The content management module ensures that the correct 3D models and educational materials are retrieved from the Content Database, which stores various model files and curriculum-related data.

If user-specific information is required, such as saved bookmarks or personalized settings, the User Database is queried to provide this data. For example, if a user has customized their app theme or bookmarked specific content, the app will fetch these preferences from the database, applying them instantly to the interface.

Throughout the interaction, the Application Layer remains the central point, coordinating between the user interface and the database. By separating data storage from the core logic and presentation, this flow ensures the app remains responsive and efficient, providing users with dynamic, real-time content updates without sacrificing performance.

This structured flow allows for a smooth user experience, ensuring that educational content is delivered quickly and accurately in augmented reality, while also allowing users to personalize and manage their learning experience effectively.

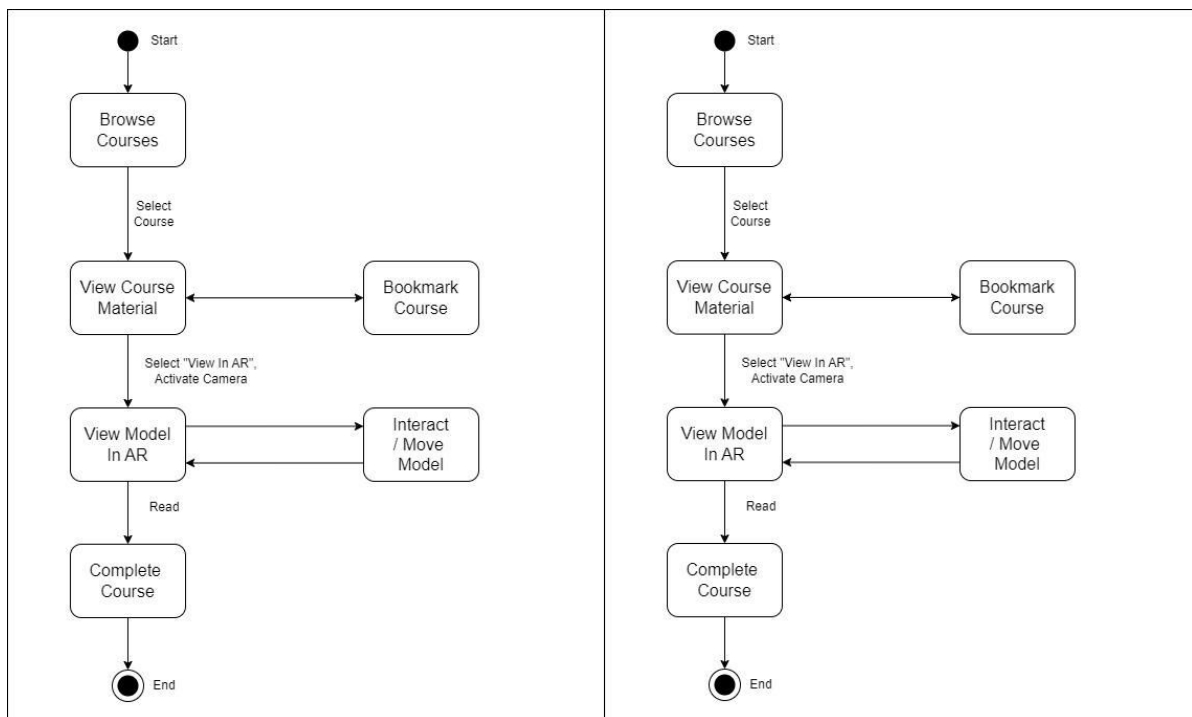


Figure 3

Figure 4

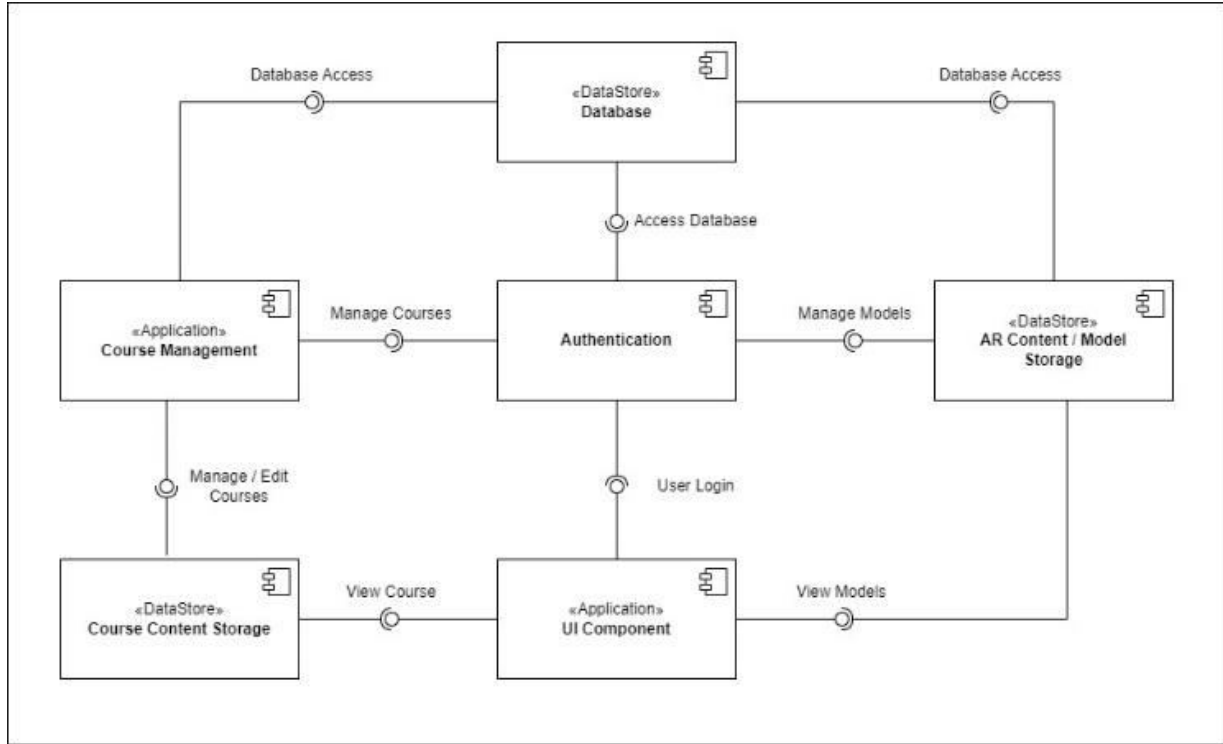


Figure 5

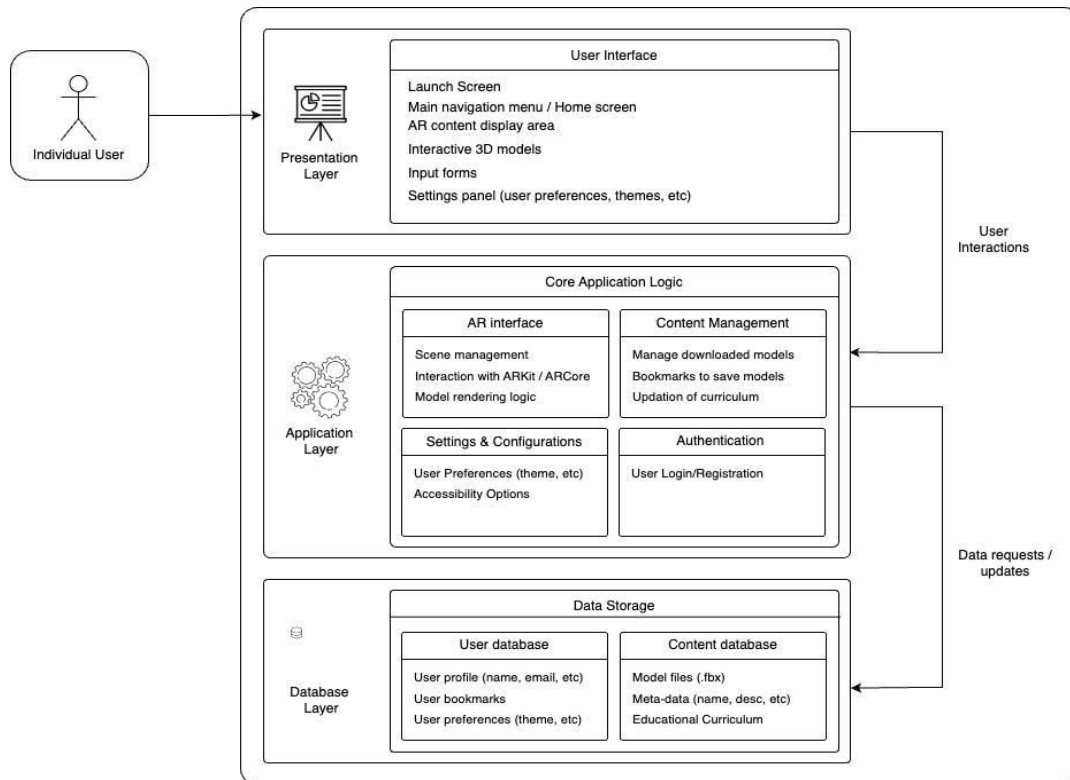


Figure 6

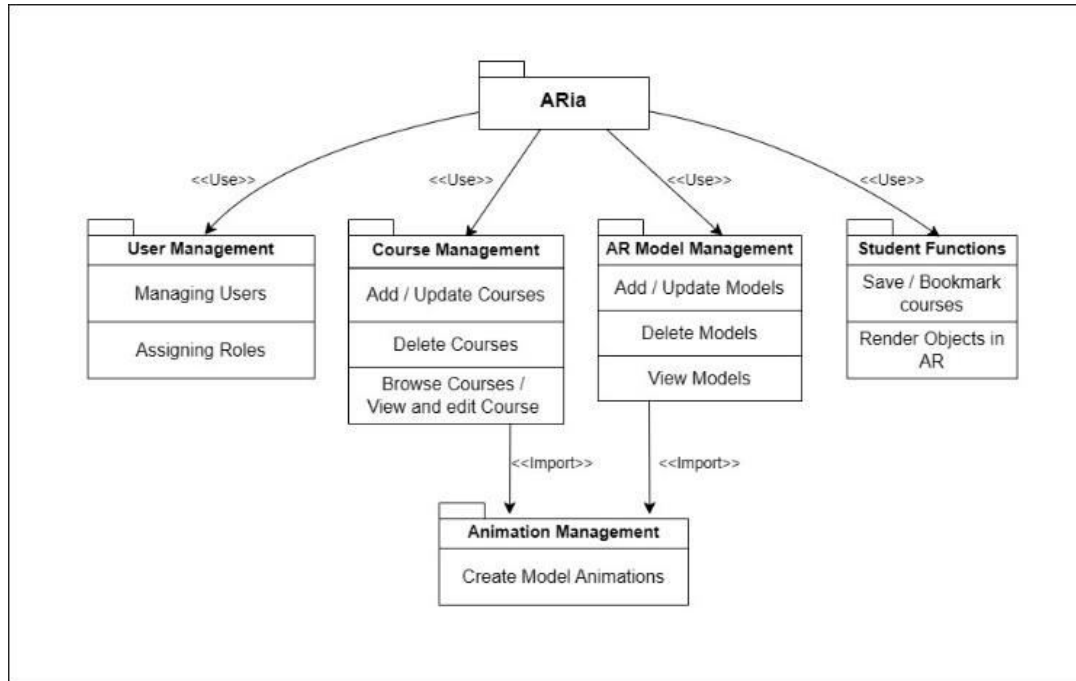


Figure 7

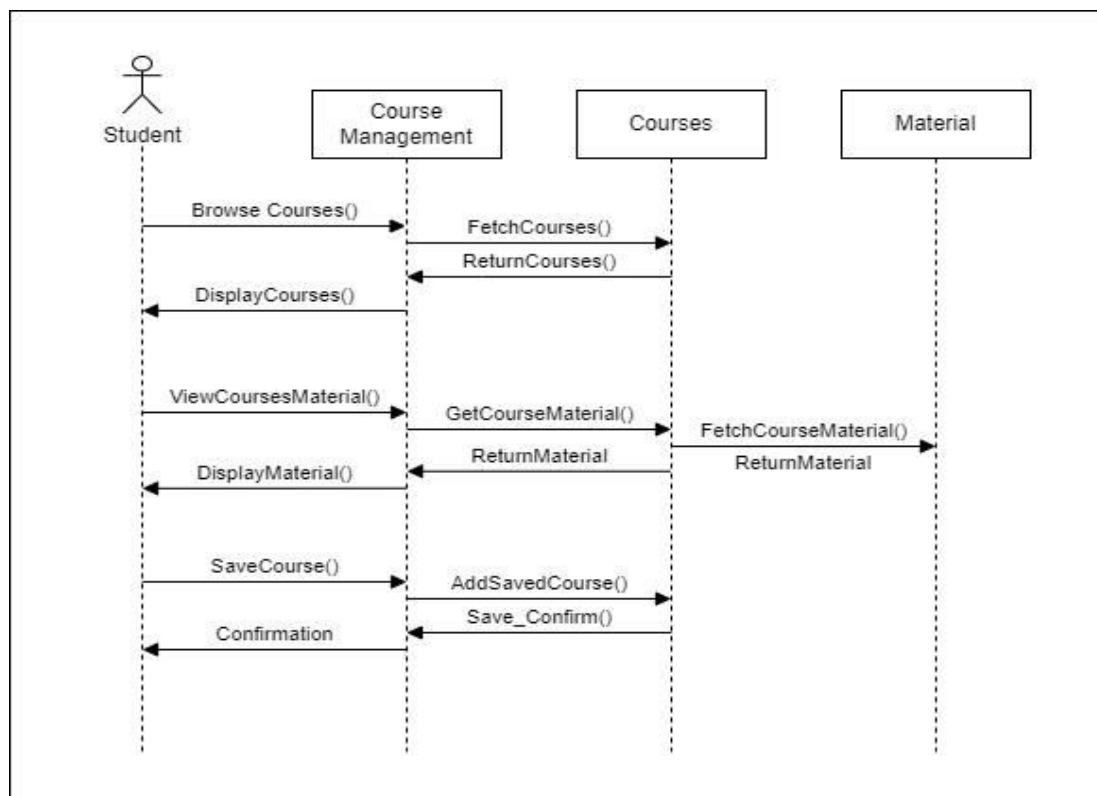


Figure 8

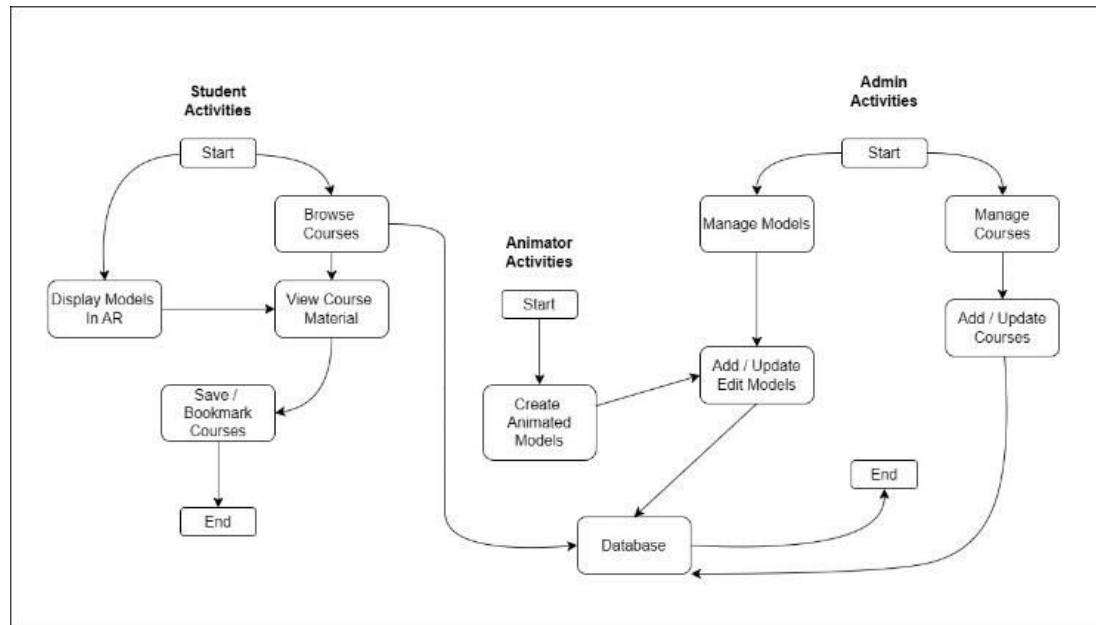


Figure 9

IV. TECHNICAL IMPLEMENTATION

React Native for Cross-Platform Development: React Native (also known as RN) is a popular JavaScript-based mobile app framework that allows you to build natively-rendered mobile apps for iOS and Android. The framework lets you create an application for various platforms by using the same codebase. Having same codebase enables Cross-Platform development and makes the work of developers easier. This ensures reduced development time and more time focused on creating the content for the application. React Native has a rich variety of libraries which are constantly getting updated thanks to its massive community. Libraries such as ViroReact, which is used in the development of ARia is essential to extend the base application with the features of Augmented Reality.

Key considerations in the React Native implementation:

Component-Based UI: React Native supports reusable components which is very useful to program applications which used a lot of repetitive components. A basic component structure can be made for each module which can then with the help of props be populated for different lessons and load relevant 3D models.

Platform Consistency: There are some navigation and design differences between iOS and Android, which – in cross-platform development – are dealt with by default, thanks to the shared codebase. This helps with creating a consistent app brand identity on both platforms with less effort than if built on two separate native apps.

Reduced costs: Building cross platform applications can be 30% cheaper than building native applications, and react supporting cross-platform directly impacts the cost.

Integration with AR Libraries: ViroReact library integrated in ARia enables the AR functionality of the application, allowing the students to interact with the virtual objects in their physical environments.

Integration of APIs: React Native being a JavaScript framework supports integration of various APIs, such as OpenAI's API can be used to enable the Artificial Intelligence features to the application which would further enhance the student's learning curve.

Firestore for Real-Time Data Management

Firestore is a Platform as a Service (PaaS) by Google which helps developers to build, manage, and grow their applications easily. It is a fast and secure method for developing applications for android, ios, web, and other services. It is a cloud storage featuring NoSQL database for storage.

Firestore has 3 categories in which it provides its services (see Figure 10)

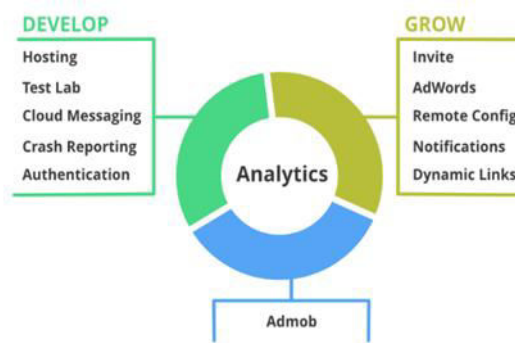


Figure 10. Three Categories of Firestore Services

Why Firestore was chosen for ARia? User Authentication: Firestore provides easy to implement authentication thanks to it's easy to navigate UI and SDKs for the developers to use without much effort. It allows users to sign up, log in, and have their learning stored onto the cloud with the help of private user sessions to continue displaying the progress of each user separately.

Real-Time Database: Firestore supports Real-time Database which is cloud based NoSQL database. Data is stored as JSON (see Figure 5.) and synchronized in Real-time to every connected client at superfast speeds. React Native Firestore provides native integration with the Android & iOS Firestore SDKs, supporting both Real-time data sync and offline capabilities.

Cloud Storage: 3D models are heavy on memory consumption and if stored locally on the application, can cause performance issues and strain the device storage, hence utilizing the online database to store the high quality 3D models and allowing user to load the content on demand would help reduce this strain.

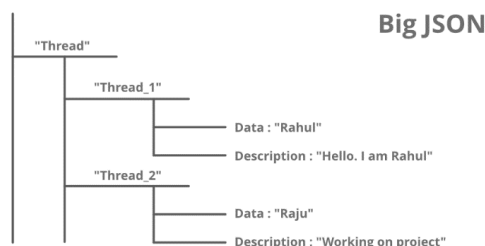


Figure 11. Big JSON File

Blender for 3D Modelling and Animations: Blender is a free and open source 3D creation suite which uses OpenGL to provide a consistent user experience. ARia uses models designed using blender with educational objectives in mind, allowing for student to interact with the content in meaningful ways.

For example:

Biology Module: A 3D animated heart model that users can rotate, view in cross-section, and watch in action as it pumps blood through body.

Physics Module: Simulations of mechanical systems and parts, such as gears, shafts, pendulums, that show how machine work on a more detailed level, the principles of motion, force, viscosity, stress, strain and many such concepts in clear detail.

Blender allows us to export the created models into formats which are compatible with React Native's AR libraries, ensuring the pipeline, animations and textures are preserved in production and can be viewed in AR mode

V. CHALLENGES AND SOLUTION

The most important step of creating an application or any software in general is not just understanding the problem statement or coming up with solution, but it's also understanding the challenges that the application might face and then finding solution to those. Similarly ARia has its own set of challenges which it needs to overcome to become a successful application which can then be used for learning.

Below are some challenges which ARia might face during its software lifecycle and their solutions.

Performance Optimization: One of the major challenge of AR-based application is its performance, and maintaining a consistency in the performance, especially on lower end devices require expertise in developing highly efficient mobile applications, hence developers need to focus more on optimization to get the required results. Certain practices that the developers can follow are –

Optimized 3D Models: Blender uses polygons to render models(see Figure 6), and depending upon the use case the polygon count on the models can be reduced such that not much visual quality is sacrificed in the process, ensuring the model doesn't strain the application while being rendered and providing the user with optimized viewing experience.

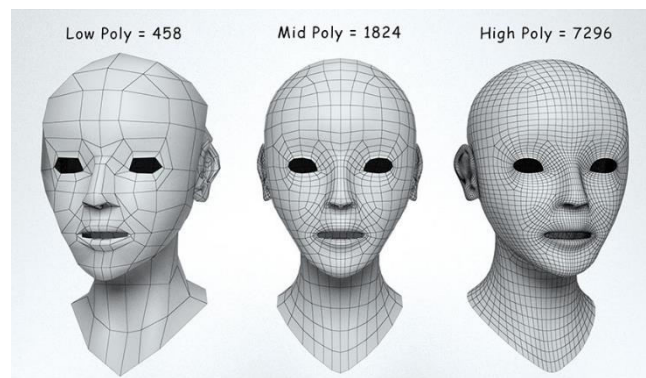


Figure 12. Image Showcasing three major modelling styles

Lazy Loading: High quality assets are bigger in size and downloading them from firebase cloud storage will affect the loading time on the application, this can be fixed by caching the data on local storage for faster loading of the same asset again and again. The initial loading would be dependent on the connection speed of the user, but due to faster data transfer rates of firebase storage servers, a lot of time can be saved.

User Interaction and UX Design: As cited by (Mudita Sandesara, Umesh Bodkhe, Sudeep Tanwar, Mohammad Dahman Alshehri, Ravi Sharma, Bogdan-Constantin Neagu, Gheorghe Grigoras & Maria Simona Raboaca, 2022) [6], many applications fail to serve the purpose of getting attention of intended users, which is determined by their User Interface (UI) and User Experience (UX), this leads developers questioning which UI/UX would work best for their application and leads them to spend extensive time and money on finding the perfect UI/UX. Then again companies spend huge resources on understanding their customers and their requirements to devise the perfect User Interface and User Experience.

ARia focuses on a rich UI, keeping the current design trends into mind and UX featuring seamless AR interaction such that transitioning between subjects or topics would keep the user engaged.

Here are some steps taken to enhance the User Experience in ARia:

Glassmorphism UI: Taken inspiration from one of the most successful company in the world, Apple, the glassmorphism UI provides a clean and minimal User Interface to the user which is easy to look at and navigate without efforts.

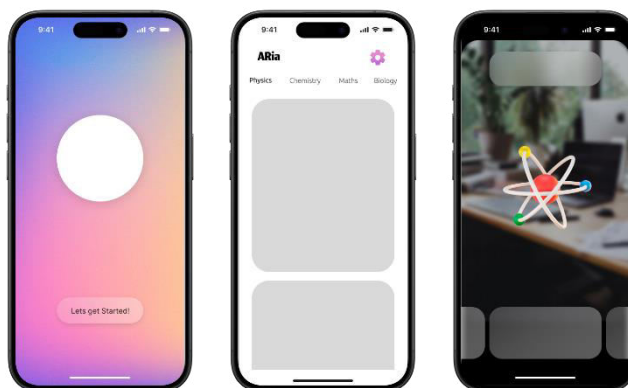


Figure 13. Design Draft of ARia

Gesture-Based Control: The application supports common touch gestures, like pinch-to-zoom, swipe-to-rotate and hold-to-prompt, to make the interaction with the 3D object interactive and engaging to the user.

Interactive Feedback: The application provides real-time feedback to the user's interactions such as hold-to-prompt would enable AI features for the displayed model, triggering animations when play animation button is pressed and many more.

VI. EDUCATIONAL IMPACT AND POTENTIAL

We started this paper discussing about how in recent years, the AR technology has grown and made its way into Educational Field, showing consistent growth on how AR has supplemented Education of the students into understanding complex topics by visualizing them into reality.

Augmented Reality in educational application has a lot of potential to transform traditional learning through the way we peruse our learning completely changing it by letting us interact with our subjects and understand the topic in greater depths. This simple shift in the methods can impact greatly in learning. Some anticipated Impacts include:

Improved Retention: As cited by (HS Varshaa, Shreya K & MS Ghosh), the retention of current generation is depleting due to short video content such as reels or YouTube shorts and this leads to troubled focusing on a topic which requires good retention from the student. But due to Interactive 3D models, students can better understand and remember the complex concepts compared to traditional textbook diagrams which are static.

Increased Engagement: The immersive nature of AR would encourage active participation by the user and would keep the curiosity flowing. Increased participation paired with easy understanding of the concepts would increase the motivation and interest of the user on the topic and motivate them to learn more

VII. CONCLUSION

ARia successfully showcases the transformative potential of augmented reality (AR) in the educational field, bridging the gap between traditional learning methods and modern interactive technologies. By integrating cutting-edge tools like React Native for cross-platform development, Firebase for real-time data handling, and Blender for 3D model creation, the app creates an enriched, engaging learning experience that caters to today's digitally inclined generation. The ability to visualize and interact with complex concepts through 3D models elevates user engagement, retention, and comprehension, addressing the limitations of conventional textbooks and static diagrams.

Throughout the development process, significant challenges were faced, including performance optimization, handling large 3D assets, and ensuring smooth user interaction. However, by implementing strategies such as lazy loading for 3D models, caching, and UI/UX enhancements like gesture-based controls, these challenges were mitigated, allowing the app to perform consistently across various devices and platforms.

ARia not only meets the current demands of immersive learning but also lays a strong foundation for future advancements in AR-based educational applications. Its modular architecture allows for easy scalability, enabling future integration of more advanced AI-driven features and expanded curriculum content. The app's flexibility in handling different learning styles and pacing, through personalized settings and interactive models, makes it an adaptable tool in diverse educational settings.

Looking ahead, ARia can continue to evolve by incorporating more sophisticated AI for personalized tutoring, expanding subject coverage, and improving AR capabilities with newer technologies. This positions ARia as a leading example of how AR can reshape the future of education, providing a blueprint for future AR-driven applications that aim to make learning more engaging, accessible, and effective

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