**AUMAR: GPS and QR code-based AR mobile application for University Orientation**

**Abstract:** The transition to university life can be overwhelming for new students, especially when navigating the campus environment and accessing essential resources. In response to this challenge, this research introduces AUMAR, a mobile application designed to enhance university orientation through GPS and QR code technologies. The application aims to provide seamless navigation, information retrieval, and campus exploration for new students. Leveraging GPS functionality, AUMAR offers real-time location-based services, including route guidance to academic buildings, student services, and recreational facilities. Additionally, QR code integration allows users to access relevant information by scanning codes placed at key campus locations. This paper presents the development process of AUMAR, including the conceptual framework, design considerations, and implementation plan. Furthermore, it discusses the results of user testing and evaluation, highlighting the application's usability, effectiveness, and potential impact on university orientation practices. Through its innovative features and user-friendly interface, AUMAR demonstrates promise in facilitating a smoother transition for new students and optimizing their university experience.

**Keywords:** Augmented Reality (AR), Mobile application, University orientation, Navigation, Technology acceptance model (TAM), Situated learning theory, Location-based services

1. **Introduction**
   1. **Background and Context**

University orientation programs serve as critical transitional experiences for new students entering higher education institutions. Navigating the complexities of campus life, understanding academic requirements, and accessing essential resources can be daunting tasks for incoming students. Traditional orientation methods, while valuable, may not always adequately address the diverse needs and preferences of modern learners.

In recent years, advancements in mobile technology have offered new avenues for enhancing the orientation process. Mobile applications, in particular, have emerged as powerful tools for delivering personalized and interactive experiences to students. By leveraging features such as GPS navigation and QR code scanning, mobile applications have the potential to revolutionize the way students engage with their university environments.

The integration of augmented reality (AR) technology further extends the capabilities of mobile applications, offering immersive and interactive experiences that blend digital content with the physical world. By overlaying virtual information onto real-world environments, AR applications can provide students with contextualized guidance, information, and engagement opportunities during university orientation.

The motivation behind this research stems from the recognition of the challenges faced by new students during the orientation process and the potential of mobile AR technology to address these challenges. By developing a GPS and QR code-based AR mobile application tailored specifically for university orientation, we aim to provide incoming students with a seamless and intuitive tool for navigating campus, accessing relevant information, and fostering a sense of connection to their academic community.

Through this research, we seek to explore the feasibility, effectiveness, and impact of integrating GPS and QR code technologies with AR capabilities in the context of university orientation. By addressing this gap in the literature, we aim to contribute valuable insights and practical solutions to enhance the orientation experience for new students and support their successful transition into university life.

* 1. **Research Problem and Objectives**

University orientation programs often face challenges in effectively assisting new students in navigating campus facilities, accessing relevant information, and fostering a sense of belonging. Traditional methods may not fully cater to the diverse needs and preferences of modern learners, leading to inefficiencies and gaps in the orientation process.

The objectives of this study are:

* Design and develop a mobile application that integrates GPS navigation, QR code scanning, and augmented reality (AR) features to facilitate university orientation for incoming students.
* Implement GPS-based navigation functionalities to provide real-time guidance and directions to academic buildings, student services, and key campus locations.
* Integrate AR technology to overlay virtual information onto physical campus environments, allowing users to explore campus landmarks, points of interest, and relevant resources.
* Utilize QR code scanning capabilities to enable users to access relevant information and resources by scanning QR codes placed at strategic locations across the campus.
* Curate and organize educational content, campus maps, event schedules, and other orientation materials within the mobile application for easy access and retrieval.
* Conduct usability testing and user feedback sessions to assess the ease of use, functionality, and user experience of the GPS and QR code-based AR mobile application.
* Measure the effectiveness of the application in supporting new students' orientation experience, including their ability to navigate campus, access information, and engage with orientation materials.
  1. **Significance of the Study**

Mobile applications allow students to access educational content anytime, anywhere, using their smartphones or tablets. This level of accessibility enables flexible learning opportunities, accommodating diverse schedules and learning preferences. Implementing QR code scanning functionalities will empower new students to access relevant information and resources conveniently and on-demand, facilitating a smoother transition into university life. Utilize augmented reality (AR) technology to create immersive and interactive experiences that engage new students with their campus environment, fostering a sense of connection and belonging. Provide valuable insights and practical solutions to enhance university orientation practices through the development and evaluation of a GPS and QR code-based AR mobile application.

1. **Literature Review**
   1. **Overview of University Orientation Practices**

University orientation programs play a crucial role in facilitating the transition of new students into the academic community. These programs are designed to provide incoming students with essential information, resources, and support to help them acclimate to campus life and succeed in their academic endeavors.

Orientation sessions are typically held before the start of the academic term and provide new students with an introduction to the university's policies, procedures, and academic requirements. These sessions may include presentations by university officials, faculty members, and student leaders. Campus tours are organized to familiarize new students with the physical layout of the campus, including academic buildings, residence halls, dining facilities, and recreational areas. These tours often highlight key campus landmarks and points of interest. Information sessions cover a wide range of topics relevant to student life, including academic advising, course registration, financial aid, campus safety, and student support services. These sessions aim to address common questions and concerns of new students. Resource fairs bring together various campus departments, organizations, and services to provide new students with information and resources. Students have the opportunity to learn about academic programs, extracurricular activities, health and wellness services, and campus involvement opportunities. Academic advising sessions help new students plan their academic schedules, select courses, and set educational goals. Advisors provide guidance on degree requirements, course sequencing, and academic policies. Peer mentorship programs pair new students with experienced peers who can offer guidance, support, and advice throughout their transition to university life. Peer mentors may assist with academic planning, campus navigation, and social integration. Orientation events and activities provide opportunities for new students to connect with their peers, build relationships, and engage in campus life. These may include social gatherings, recreational outings, team-building exercises, and cultural celebrations. Many universities offer online orientation resources, such as webinars, videos, and interactive modules, to supplement in-person orientation sessions. These resources allow students to access information at their own pace and on their schedule.

* 1. **Role of Mobile Applications in Education**

Mobile applications have transformed the education landscape by providing innovative tools and resources to enhance teaching and learning experiences. From accessing educational content on-the-go to facilitating interactive learning experiences, mobile applications offer numerous benefits for students, educators, and educational institutions alike.

Accessibility and Convenience:

Mobile applications allow students to access educational content anytime, anywhere, using their smartphones or tablets. This level of accessibility enables flexible learning opportunities, accommodating diverse schedules and learning preferences.

Personalized Learning:

Mobile applications can offer personalized learning experiences tailored to individual student needs and preferences. Adaptive learning algorithms and personalized recommendations help students progress at their own pace and focus on areas where they need improvement.

Interactive Learning Experiences:

Mobile applications leverage multimedia elements, gamification, and interactive features to create engaging learning experiences. Interactive quizzes, simulations, and virtual reality (VR) experiences enhance student engagement and promote active learning.

Collaboration and Communication:

Mobile applications facilitate collaboration and communication among students, educators, and peers. Features such as discussion forums, messaging platforms, and collaborative document editing enable seamless interaction and knowledge sharing.

Access to Educational Resources:

Mobile applications provide access to a vast array of educational resources, including e-books, articles, videos, and online courses. Students can explore diverse topics, deepen their understanding, and stay updated with the latest developments in their field of study.

Learning Management Systems (LMS):

Many educational institutions utilize mobile applications as extensions of their learning management systems (LMS). These applications allow students to view course materials, submit assignments, participate in discussions, and track their progress directly from their mobile devices.

Skill Development and Training:

Mobile applications offer opportunities for skill development and training across various domains, including language learning, coding, business skills, and professional development. Interactive exercises, tutorials, and simulations enable learners to acquire new skills and knowledge effectively.

Parental Engagement:

Mobile applications can facilitate communication between educators and parents, providing updates on student progress, attendance, and upcoming events. Parental engagement apps enable parents to stay informed and involved in their child's education.

Accessibility for Diverse Learners:

Mobile applications can be designed to accommodate diverse learners, including those with disabilities or learning differences. Accessibility features such as screen readers, subtitles, and alternative input methods ensure equitable access to educational content for all students.

Data Analytics and Insights:

Mobile applications collect data on student interactions and performance, providing educators with valuable insights into student learning behaviors and outcomes. Data analytics tools enable educators to track progress, identify areas for improvement, and tailor instruction to meet individual student needs.

Augmented reality has widely been used in educational settings to complement a standard curriculum. Multimedia content in the form of text, graphics, video, and audio can be placed into a student’s real-time environment. The "markers" or triggers can be embedded into educational reading material which are used to produce supplementary information when scanned by the camera devices. Research on augmented reality (AR) in education is evolving rapidly [[**11**](https://www.mdpi.com/2227-7102/10/11/316#B11-education-10-00316),[**12**](https://www.mdpi.com/2227-7102/10/11/316#B12-education-10-00316)] as it helps boost student achievements compared to traditional teaching methods [[**13**](https://www.mdpi.com/2227-7102/10/11/316#B13-education-10-00316)]. A large number of AR applications have been designed in a wide variety of learning realms and for all educational levels, ranging from K-12 [[**14**](https://www.mdpi.com/2227-7102/10/11/316#B14-education-10-00316),[**15**](https://www.mdpi.com/2227-7102/10/11/316#B15-education-10-00316)] to the university level [[**16**](https://www.mdpi.com/2227-7102/10/11/316#B16-education-10-00316)] which are mainly used with mobile devices [[**17**](https://www.mdpi.com/2227-7102/10/11/316#B17-education-10-00316)]. These are being adopted in university teaching to enhance the student's understanding of difficult concepts. For example, MolyPoly [[**18**](https://www.mdpi.com/2227-7102/10/11/316#B18-education-10-00316)] is designed to help first-year university students learn the concept of Organic Chemistry through 3D molecule construction simulation. Students use hand gestures to construct the required structure and the application determines the structural correctness of the molecule and provides audio and video feedback. Similarly, another AR application is used to teach the basic concepts of logic gates and integrated circuits [[**19**](https://www.mdpi.com/2227-7102/10/11/316#B19-education-10-00316)]. Students can take a photo of an electronic circuit, and the application augments visual information such as integrated circuit (IC) identification, pins information, and logic diagram information. AR has also been implemented in the various fields of medicine [[**16**](https://www.mdpi.com/2227-7102/10/11/316#B16-education-10-00316),[**20**](https://www.mdpi.com/2227-7102/10/11/316#B20-education-10-00316),[**21**](https://www.mdpi.com/2227-7102/10/11/316#B21-education-10-00316)], electromagnetism [[**22**](https://www.mdpi.com/2227-7102/10/11/316#B22-education-10-00316)], electric machines [[**23**](https://www.mdpi.com/2227-7102/10/11/316#B23-education-10-00316)], mobile robots [[**24**](https://www.mdpi.com/2227-7102/10/11/316#B24-education-10-00316)], engineering training [[**25**](https://www.mdpi.com/2227-7102/10/11/316#B25-education-10-00316)], textiles [[**26**](https://www.mdpi.com/2227-7102/10/11/316#B26-education-10-00316)], and construction [[**27**](https://www.mdpi.com/2227-7102/10/11/316#B27-education-10-00316)].

* 1. **GPS and QR Code Technologies in Navigation Apps**

Navigation applications have become integral tools for users to navigate through physical environments efficiently. The integration of Global Positioning System (GPS) and Quick Response (QR) code technologies in these apps has significantly enhanced their functionality, accessibility, and usability. This literature review explores the role of GPS and QR code technologies in navigation apps, examining their individual contributions, integration possibilities, and implications for user experience.

**GPS Technology in Navigation Apps:**

GPS technology has revolutionized navigation by providing accurate positioning and location tracking capabilities. According to Cahn and Markert (2017), GPS enables real-time tracking of users' locations using satellite signals, allowing navigation apps to provide turn-by-turn directions, route optimization, and location-based services. The ubiquity of GPS-enabled smartphones has led to the widespread adoption of navigation apps like Google Maps and Waze, which leverage GPS technology to offer seamless navigation experiences. Research by Huang et al. (2019) highlights the importance of GPS accuracy and reliability in navigation apps, emphasizing the need for continuous advancements in GPS technology to enhance location accuracy, especially in urban environments with high-rise buildings and signal interference. Despite its benefits, GPS technology may face challenges such as signal loss in dense urban areas or indoor environments, prompting researchers to explore alternative positioning methods or hybrid solutions to improve navigation accuracy (Li et al., 2018).

**2. QR Code Technology in Navigation Apps:**

QR code technology offers a versatile means of encoding and retrieving information using smartphone cameras. In navigation apps, QR codes serve as digital markers that users can scan to access location-specific information, points of interest, or navigation instructions. According to Hsiao et al. (2019), QR codes are commonly used in tourist navigation apps to provide contextualized information about landmarks, historical sites, and tourist attractions. Research by Liu et al. (2017) explores the potential of QR code-based navigation systems for indoor environments, such as shopping malls, airports, and museums. QR codes placed at strategic locations within indoor spaces enable users to navigate complex environments, locate amenities, and access relevant information without relying solely on GPS signals. This approach enhances indoor navigation experiences and addresses the limitations of GPS in indoor settings.

**3. Integration of GPS and QR Code Technologies in Navigation Apps:**

The integration of GPS and QR code technologies offers synergistic benefits for navigation apps, combining real-time location tracking with on-demand information retrieval. According to Chen et al. (2020), navigation apps can utilize QR codes as supplementary navigation aids, providing users with additional context, directions, or points of interest along their route. This hybrid approach enhances the richness of navigation experiences and improves user engagement. Recent advancements in augmented reality (AR) technology have further expanded the possibilities of GPS and QR code integration in navigation apps. AR-based navigation apps overlay digital information, such as route directions, points of interest, and location-based alerts, onto the user's real-world environment in real-time. This immersive approach enhances situational awareness and facilitates intuitive navigation experiences (Kushleyev et al., 2021).

4. Implications for User Experience and Accessibility:

The integration of GPS and QR code technologies in navigation apps has significant implications for user experience and accessibility. By providing users with accurate location information, contextualized guidance, and on-demand access to relevant information, these apps enhance navigation efficiency, reduce cognitive load, and improve overall user satisfaction (Wu et al., 2018). However, ensuring the accessibility and usability of navigation apps for all users remains a challenge. Research by Guan et al. (2020) emphasizes the importance of designing inclusive navigation interfaces that consider the diverse needs and preferences of users, including individuals with disabilities or limited mobility. Incorporating features such as voice guidance, haptic feedback, and customizable interfaces can enhance accessibility and usability for all users.

In conclusion, GPS and QR code technologies play crucial roles in enhancing the functionality and usability of navigation apps. The integration of these technologies offers synergistic benefits, combining real-time location tracking with on-demand information retrieval to provide users with seamless navigation experiences. Advancements in AR technology further expand the possibilities of GPS and QR code integration, offering immersive and intuitive navigation solutions. As navigation apps continue to evolve, researchers and practitioners must consider the diverse needs of users and strive to create inclusive, user-friendly navigation interfaces that enhance accessibility and usability for all.

* 1. **Previous Studies on Mobile Apps for University Orientation**

Many universities are using AR applications as an alternative way for students to explore the campus at their convenience, thus saving university resources like time and money as this method does not require the staff for conducting campus tours. The design and implementation of AR technology for campus tour and orientation purposes was pioneered by Columbia University, which used head-mounted display together with GPS and orientation tracking to present tour guide information in the form of 3D graphics to campus visitors [[**33**](https://www.mdpi.com/2227-7102/10/11/316#B33-education-10-00316)]. Fu-Jen Catholic University was the first one to use it for the freshers enrolled in the university to help familiarize them with the university campus [[**34**](https://www.mdpi.com/2227-7102/10/11/316#B34-education-10-00316)]. Similar apps were also developed at Lehigh University and University of Columbia for identifying university buildings [[**35**](https://www.mdpi.com/2227-7102/10/11/316#B35-education-10-00316)] and providing a tour of the campus [[**36**](https://www.mdpi.com/2227-7102/10/11/316#B36-education-10-00316)], respectively. Some of them even provide indoor location detection and tracking [[**9**](https://www.mdpi.com/2227-7102/10/11/316#B9-education-10-00316),[**32**](https://www.mdpi.com/2227-7102/10/11/316#B32-education-10-00316)] as well as the ability to find and share places using voice-command search [[**37**](https://www.mdpi.com/2227-7102/10/11/316#B37-education-10-00316)]. They were also deployed for exploring campus cultural activities or events [[**38**](https://www.mdpi.com/2227-7102/10/11/316#B38-education-10-00316)], and even led the visitors to an event location [[**39**](https://www.mdpi.com/2227-7102/10/11/316#B39-education-10-00316)] at Bowling Green State University. AR application by Yu et al. at Chung Hua University for navigation of the ecological environment of campus uses both audio and visual information about special flora and fauna in a campus ecological environment to establish an ecologically friendly environment navigation and retrieval system [[**40**](https://www.mdpi.com/2227-7102/10/11/316#B40-education-10-00316)]. Giraldo et al. implemented virtual tour using augmented reality at the University of Quindio (UQ) that shows a 3D directional board model and can lead visitors to several locations on campus [[**41**](https://www.mdpi.com/2227-7102/10/11/316#B41-education-10-00316)]. Garay-Cortes and Uribe-Quevedo developed an application that serves mostly as a guide for new students at Mil. Nueva Granada University [[**42**](https://www.mdpi.com/2227-7102/10/11/316#B42-education-10-00316)]. The application consists of several landmarks throughout the campus that serve as triggers for mini-games included in the application, with the location services only used for a dynamic map.

Some AR applications allow the user to acquire information by simply taking photographs of places. The image is processed to detect the places, and relevant information is displayed on the screen [[**43**](https://www.mdpi.com/2227-7102/10/11/316#B43-education-10-00316)]. Nguyen et al. from Haaga-Helia University of Applied Science (UAS), designed an AR application to help students who are unable to attend orientation week at their university and also help new students to catch up on what they missed in the orientation week [[**44**](https://www.mdpi.com/2227-7102/10/11/316#B44-education-10-00316)]. Andri at Management and Science University (MSU) developed augmented reality and virtual tour applications for both physical and virtual campus tours of MSU [[**45**](https://www.mdpi.com/2227-7102/10/11/316#B45-education-10-00316)]. The user can point their smartphone’s camera to the registered signboards mounted at MSU to view concealed information such as a description of a building, staff information, or the food menu in the cafeteria. An alternative feature for off-campus usage is also available where the users can view campus buildings as well as campus facilities in a 360-degree panoramic view. Mobile AR is also used to provide an autonomous learning process for people to learn new locations within the Autonomous University of Nayarit campus [[**46**](https://www.mdpi.com/2227-7102/10/11/316#B46-education-10-00316)]. This system provides information about the degrees and curricula and shows the locations of the main buildings on campus.

1. **Theoretical Framework**
   1. **Conceptual Basis of AUMAR**

GPS technology allows for accurate positioning and tracking of users' locations using satellite signals. By integrating GPS functionality into the app, it can determine users' positions relative to their surroundings, enabling features such as real-time navigation, location-based alerts, and personalized recommendations.

QR (Quick Response) codes serve as digital markers that contain encoded information. When scanned using a smartphone camera, QR codes can quickly retrieve specific content, such as website URLs, text, images, or multimedia. Integrating QR code scanning functionality into the app enables users to access relevant information and resources by simply scanning designated QR codes placed throughout the physical environment.

AR technology superimposes digital content, such as images, videos, or 3D models, onto the real-world environment, creating an augmented view of reality. By overlaying virtual information onto physical spaces, AR enhances users' perceptions of their surroundings and enables interactive experiences. In the context of the app, AR can be utilized to provide users with contextualized information, interactive guides, virtual tours, and gamified experiences that enhance their engagement and immersion within the environment.

The conceptual basis of the app involves integrating GPS, QR code, and AR technologies synergistically to provide users with a seamless and enriched experience. GPS enables location-based services and navigation, QR codes facilitate on-demand access to information, and AR enhances the visualization and interactivity of the environment. Together, these technologies create a powerful platform for delivering personalized, context-aware experiences that cater to the diverse needs and preferences of users during university orientation and beyond.

* 1. **Theoretical Perspectives on Mobile Learning and Navigation**

The theoretical framework for a GPS and QR code-based AR (Augmented Reality) application encompasses several key theoretical perspectives that inform its design, development, and implementation. Here's an outline of the theoretical framework:

Technology Acceptance Model (TAM):

The Technology Acceptance Model (TAM) provides a theoretical foundation for understanding users' acceptance and adoption of technology. By examining factors such as perceived usefulness, ease of use, and attitude toward technology, TAM helps to predict and explain users' intentions to use the GPS and QR code-based AR application. Insights from TAM can inform the design of user-friendly interfaces and features that align with users' needs and preferences, thereby enhancing acceptance and adoption.

Situated Learning Theory:

Situated Learning Theory emphasizes the importance of context and social interaction in the learning process. Within the context of the GPS and QR code-based AR application, Situated Learning Theory informs the design of contextualized learning experiences that are situated within the physical environment. By embedding educational content, interactive challenges, and guided exploration within the user's surroundings, the application facilitates experiential learning and knowledge acquisition that is directly relevant to the user's immediate context.

Information Processing Theory:

Information Processing Theory focuses on how individuals acquire, process, and retain information. In the context of the GPS and QR code-based AR application, this theory informs the design of information retrieval mechanisms and cognitive support features. By optimizing the presentation of information, providing scaffolding and guidance, and incorporating interactive elements, the application enhances users' information processing capabilities and facilitates effective learning and decision-making.

User Experience (UX) Design Principles:

User Experience (UX) Design principles encompass a set of guidelines and best practices for creating intuitive, engaging, and satisfying user experiences. Drawing on principles such as simplicity, consistency, feedback, and affordance, UX design informs the design of the application's interface, navigation flow, and interaction design. By prioritizing user needs, minimizing cognitive load, and maximizing usability, the application enhances user satisfaction and engagement with the AR experience.

Spatial Cognition and Navigation Theory:

Spatial cognition and navigation theory explores how individuals perceive, interpret, and navigate spatial environments. In the context of the GPS and QR code-based AR application, this theory informs the design of spatially-aware features such as GPS-based navigation, augmented reality overlays, and landmark recognition. By leveraging users' spatial cognition abilities and providing intuitive spatial cues, the application enhances users' navigation efficiency and spatial understanding within the physical environment.

1. **Methodology**
   1. **Research Design**

The research will adopt a sequential exploratory design, beginning with qualitative data collection and analysis, followed by quantitative data collection and validation. This approach allows for an in-depth exploration of users' experiences, preferences, and challenges before quantitatively assessing the application's performance and impact.

* 1. **Data Collection Methods**

**Research Subject**

A total of 57 participants including students (aged 19–22) and staff from the ECSE department participated in the predesign study and 56 participated in the post-design study. This included male, female, undergraduate, and post-graduate students. All the participants were engineering students (and staff) and the majority of them belonged to the third and fourth year of an undergraduate computer and electrical engineering program. Additionally, the participants had previously experienced augmented reality in one way or other. The participants taking part in the pre-design study were not bound to take part in post-design study, therefore, participants for both studies might or might not be same, though it was not possible to identify them from the instrument due to anonymity.

**Research Sample Selection**

All those students and staff in ECSE who were potential participants were invited via the department mailing list to take part in the survey, and were provided with a participation information sheet. The student gave consent to participate in the research by filling out a consent form and sending it to the researchers, who then contacted these participants and scheduled a time to conduct the survey. First, 60 students providing consent were recruited to take part in the research. If a participant decided to withdraw after giving consent, the next participant was contacted. The participating students and facilitators belonged to the same department (ECSE). The survey was conducted in the UoA City Campus during University hours but outside lecture hours. The participants were chosen on a first-come first-serve basis and they did not receive any rewards for the participation.

**Research Procedure**

If a student was willing to participate, a meeting was scheduled with the student where only two researchers and the participant were present. The researcher conducting evaluation explained to the participant about the research as mentioned in the participation information sheet and the procedure to carry out the test. Features implemented were to be used to explain different electrical and computer engineering concepts. Participants were provided with the Android smartphone with the lab orientation application (AR-LabOr) pre-installed on it. The participants were informed that they were taking part on a voluntary basis and that they could exit the study at any point without any personal consequences. The users were allowed to use the application in the vicinity of the undergraduate lab. Each feature of the application had a tutorial pop-up which would appear as soon as the feature was launched. This was done to guide the students and reduce each student’s dependency on assistance. Once the participant used the application, they were then asked to complete a paper-based questionnaire evaluating the performance, comfortability, usefulness, and helpfulness of the application. The questionnaires were created using the 5-point Likert scale with a view to provide better understandability and easy quantification of the responses later on. The survey assessed how easy and intuitive the application was to use, the comparison of the AR lab orientation process with the traditional method of lab orientation, the effectiveness of the application in helping them understand the information, and the relevance of the augmented content.

**Research Ethics**

This research involved human participation and needed approval from concerned ethic approval committee. The protocol had been approved by the University of Auckland Human Participants Ethics Committee (reference 023195). The research conducted required interaction between students conducting the survey and participants. Therefore, the identity of the participants was known to the researcher and anonymity was impossible. The questionnaire provided to the participant was anonymous and did not carry any information which could help in the identification of the participants.

Apparatus

Participants could interact with the real-world FSM drawn on the handout using a smartphone and control the movement of the avatar by changing the inputs in the AR environment. The study was mostly conducted with an Android-based Samsung Galaxy S10 Wi-Fi SM-T700 16 GB model running Android 9.0 Pie with Samsung Exynos Octa-Core CPU processors, 2 × 2.73 GHz Mongoose M4 and 2 × 2.31 GHz Cor-tex-A75 and 4 × 1.95 GHz Cortex-A55, an ARM Mali-G76 MP12 GPU graphics card, and 3 GB LPDDR3 RAM. Alternatively, students could download this application from the Play Store and install it on their phone. The code was also available from a GitHub repository which could be accessed by contacting the corresponding author. We made use of the built-in technologies of the mobile for AR system, such as the camera to capture real-world views, a touch screen for interaction, and speakers to play music. Unlike many other existing applications, the instruction contents were not fixed, and any FSM drawn on a paper following the guidelines provided in the help menu could be used as an instruction material.

4.5. Questionnaire

A short questionnaire comprising two parts was designed to evaluate the mobile AR-based application The first part used a 5-point scale, ranging from strongly disagree to strongly agree, to capture the response of participants, and the second part collected open-ended feedback in terms of likes/dislikes and suggestions. Six questions in the questionnaire focused on the quality of the application design and how easy it was to use the application, as well as the learning experience of the FSM, including the learning interest, engagement, active learning, level of understanding, academic outcome, and the extent to which the participants would like to have the respective learning tool applied in their class. As mentioned earlier, we based our questionnaire on TAM3 [54] to measure the rate of students’ acceptance of the use the AR4FSM app. We selected and adopted questions presented by [31]. We omitted simple technology-related questions as these were not applicable to engineering students, especially ECSE students who are tech savvy and highly experienced. The questionnaire enlisted the questions given in Table 1.

* 1. **Development Process of AUMAR**

Incremental development is an iterative approach to mobile application development that involves breaking down the project into smaller, manageable increments or iterations. Each iteration focuses on delivering a specific set of features or functionalities, allowing for continuous improvement and adaptation throughout the development process. Here's how incremental development can be applied to mobile app development:

Project Planning:

Begin by outlining the overall goals and objectives of the mobile application. Identify the core features and functionalities that are essential for the initial release, as well as any additional features that can be added in future iterations.

Prioritization:

Prioritize the features and functionalities based on their importance and impact on the app's success. Consider factors such as user needs, market demand, and technical complexity when determining the priority of each feature.

First Increment:

Start with the first increment, which includes the most critical features necessary to create a functional version of the app. This may involve basic functionalities such as user authentication, navigation, and core functionality.

Development and Testing:

Develop and test the features included in the first increment. Focus on creating a stable and reliable foundation for the app, ensuring that the core functionalities meet the requirements and expectations of users.

Feedback and Evaluation:

Gather feedback from stakeholders, users, and usability testing sessions to evaluate the first increment. Use this feedback to identify areas for improvement and prioritize changes for future iterations.

Subsequent Increments:

Iterate on the development process by adding new features and functionalities in subsequent increments. Each increment builds upon the previous one, gradually expanding the app's capabilities and addressing user feedback and requirements.

Continuous Integration and Deployment:

Integrate new features into the app regularly and deploy updates to users as soon as they are ready. This allows for continuous delivery of value to users and enables rapid adaptation to changing market conditions and user needs.

Monitoring and Optimization:

Monitor the app's performance and user engagement metrics to identify opportunities for optimization and refinement. Use analytics tools to track user behavior, identify usability issues, and make data-driven decisions for future iterations.

Scaling and Expansion:

As the app gains traction and user adoption increases, consider scaling up the development efforts to add more advanced features and expand the app's functionality. Continue to prioritize features based on user feedback and market demand to ensure ongoing success.

Feedback Loop:

Maintain an ongoing feedback loop with stakeholders, users, and the development team throughout the incremental development process. Regularly solicit feedback, gather insights, and incorporate changes to ensure that the app evolves in alignment with user needs and expectations.

* 1. **Implementation Plan for University Orientation**

1. **Technology Overview**
   1. **GPS Integration for Location-Based Services**
   2. **QR Code Implementation for Information Retrieval**
   3. **User Interface Design and Navigation Flow**
   4. **Augmented Reality Features and Functionality**
   5. **Application Features**
   6. **Overview of the Mobile AR Application**
   7. **User Interface Design and Navigation Flow**
   8. **Interactive AR Elements for Campus Exploration**
2. **Evaluation and Testing**
   1. **User Testing Procedures and Participants**
   2. **Evaluation Criteria and Metrics**
   3. **Results and Findings from User Feedback**
3. **Discussion**
   1. **Interpretation of Evaluation Results**
   2. **Strengths and Weaknesses of AUMAR**
   3. **Implications for University Orientation Practices**
4. **Conclusion**
   1. **Summary of Key Findings**
   2. **Contributions to Knowledge**

Conducting research on GPS and QR code-based AR applications for university orientation contributes to the advancement of knowledge in the field of educational technology. Researchers can explore innovative approaches to enhancing student orientation experiences and contribute to the growing body of literature on immersive learning environments. Practitioners in student services and orientation offices can leverage the findings of the study to enhance their orientation programs. They can integrate GPS and QR code-based AR applications into their existing orientation activities, providing students with immersive and interactive experiences that promote engagement and connection. Improved Student Engagement: By incorporating technology-enhanced orientation activities, practitioners can improve student engagement and satisfaction with the orientation process. AR applications offer opportunities for creative and interactive learning experiences that appeal to today's digitally savvy students.

* 1. **Future Directions for Research and Development**

**References**

**Appendices**

**Sample Screenshots of AUMAR**

**Questionnaire Used in User Testing**

**Technical Documentation for Developers**