AR-LabOr: Design and Assessment of an Augmented Reality Application for Lab Orientation

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Abstract: Lab orientation is a vital part of learning for new students entering the university, as it provides the students with all the necessary and important information about the lab. The current orientation is manual, tedious, suffers from logistical constraints, lacks engagement, and provides no way to assess that outcomes have been achieved. This is also supported by the results of a student survey which revealed students' dissatisfaction with current process of orientation. This study presents the design and development of a sample augmented reality mobile application, AR-LabOr, for the lab orientation that helps students in a quick and easy adaptation to the lab environment by familiarizing them with the lab equipment, staff, and safety rules in a fun and interactive manner. This application makes use of marker-less augmented reality technology and a blend of multimedia information such as sound, text, images, and videos that are superimposed on real-world contents. An experiment with 56 students showed that they found the novel method of orientation using the application more engaging than the traditional instructor-led method. Students also found the application to be more supportive, motivating, and that it helped them in better understanding the lab equipment.

Keywords: augmented reality; higher education; lab orientation; teaching and learning; educational technology

1. Introduction

The early days on campus can be a chaotic and stressful experience for freshers as they are made to absorb a lot of information in a packed schedule. Although universities take many measures to ease their transition, provide directions, and make students feel comfortable, new entrants can still be overwhelmed by the amount of information poured on them. Orientation offers a great opportunity for students to collect the information and gel through an extensive agenda of special events, outings, presentations, games, and more. This information helps student to develop learning skills and fulfil the academic requirements stipulated by the university programs [1]. The design of orientation program impacts students' performance and participation as there exists a positive correlation between well-designed orientations and student academic performance [2]. This makes lab orientation an important component of the orientation process for new students and increases the chances of their success. In many universities, it is compulsory for the students to attend the lab orientation program before they are allowed to work in the lab. In addition to familiarizing the students with the staff and equipment, the intent of the lab orientation is also to provide the students an overview of the policies and procedures within department laboratories. This orientation phase helps students to sketch a model outline in order to formulate their initial understanding of the engineering labs by providing

an instructional environment preliminary to them. The lab orientation is normally conducted using manuals, videos, or physical visits to the lab facilities accompanied by an expert.

The emergence of new technologies such as augmented reality (AR) has revolutionized the ways tasks are carried out in academia and industry, and has found widespread use almost in every walk of life [3]. Augmented reality is the superimposition of virtual objects onto the real-world, augmenting the real-world with computer-generated virtual objects in real-time [4]. AR technology has three main requirements: amalgamation of virtual and real objects in a real environment, alignment of real and virtual objects with each other, and interaction of both in real-time [5,6]. Figure 1 shows Milgram's mixed reality continuum which is a taxonomy of the manners in which real and virtual features may be mixed [6]. In other words, AR does not replace the reality but supplements it.
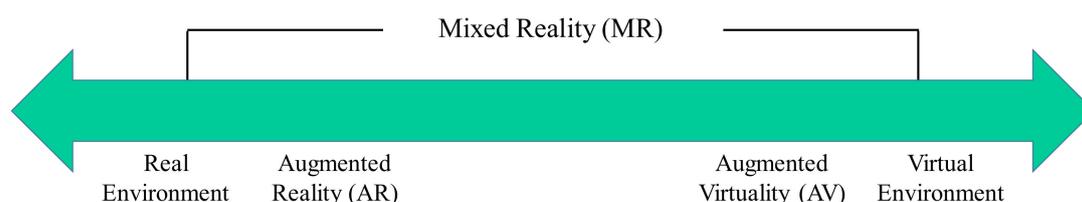

Figure 1. Milgram's mixed reality continuum.

1.1. Augmented Reality Applications

Lab orientation typically involves three main tasks, namely the lab tour, educating the students, and training the students on specific issues/aspects. AR is used in many areas, but we are interested in certain related fields. The relevant fields include tourism, education, orientation, and training.

1.1.1. Augmented Reality in Tourism

Tourism is a growing field requiring highly dynamic and immersive interaction in order to provide better tour experience to tourists [7] and AR applications have such potential and these are expected to play a more vital role in navigation, travel, and city life in the future. This trend has already been embraced by many modern cities to attract tourists to explore the history of the city using AR applications such as TimeWarp [8]. It creates an environment where the user feels immersed in the reality and allows experience of the city in the spatial and the temporal dimensions. AR is becoming popular for providing guided tour to visitors, helping them in navigation and provides more details about the hotspots, names of streets, and buildings spontaneously when roaming around. These apps also help overcome limitation of delayed information update in the tourist booklets and newspapers by instantly updating information in one go [9]. In order to make it more fun and engaging, gamification is merged with the AR, as is the case with Oracle of Delphi [10], which is an AR game designed to help the user explore the outdoor archaeological site called Delphi. It is a story-based treasure hunt game and tourists are required to follow the story presented to them using digital characters and answer quizzes related to the site in order to proceed.

1.1.2. Augmented Reality in Education

Augmented reality has widely been used in educational settings to complement a standard curriculum. Multimedia contents 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 the supplementary information when scanned by the camera devices. Research on augmented reality (AR) in education is evolving rapidly [11,12] as it helps in boosting student achievements compared to traditional teaching methods [13]. 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 [14,15] to the university level [16] which are mainly used with mobile devices [17]. These are being adopted in university teaching to enhance the student understanding of the difficult

concepts. For example, MolyPoly [18] 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]. 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 [16,20,21], electromagnetism [22], electric machines [23], mobile robots [24], engineering training [25], textiles [26], and construction [27].

1.1.3. Augmented Reality in Training

Training is an essential component for developing necessary performance skills in humans [28] and this is an expensive practice due to the cost incurred by the training materials (printed guidebooks, instruction manuals, etc.), training personnel, and equipment. AR can provide an easier and inexpensive way of training new employees as well as existing staff and helps them to get information about a company's products, services, and facilities quickly without any assistance, thus empowering workers to have state-of-the-art, accurate information available in context when they need it most. There is a wide range of AR training tools available in different industries, such as maintenance training of automobile as proposed by Lima et al. [29] as well armored vehicle [30], teacher training in higher education [31], and training medical personnel to perform endotracheal intubation (ETI) in a safe and rapid sequence [32]. Only few cases are quoted here, but there are numerous examples where AR has been successfully deployed for training workers in all fields of life.

1.1.4. Augmented Reality in 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]. 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]. Similar apps were also developed at Lehigh University and University of Columbia for identifying university buildings [35] and providing a tour of the campus [36], respectively. Some of them even provide indoor location detection and tracking [9,32] as well as the ability to find and share places using voice-command search [37]. They were also deployed for exploring campus cultural activities or events [38], and even led the visitors to an event location [39] 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]. 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]. Garay-Cortes and Uribe-Quevedo developed an application that serves mostly as a guide for new students at Mil. Nueva Granada University [42]. 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]. 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]. Andri at Management and Science University (MSU) developed augmented reality and virtual tour applications for both physical and virtual campus tours of MSU [45]. 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]. This system provides information about the degrees and curricula and shows the locations of the main buildings on campus.

It is apparent from the literature review that there have been noteworthy advances in the deployment of AR in learning and teaching. However, there is a lack of applications targeting laboratory orientation in an efficient and effective manner. To the best of our knowledge, no lab orientation application has been deployed and its effect has not been investigated. This paper presents a mobile phone-based augmented reality application, AR-LabOr, developed by the authors to replace the traditional method of lab orientation at the Department of Electrical, Computer, and Software Engineering (ECSE) at The University of Auckland (UoA). The final version of the application will be developed after incorporating the feedback received during the post-design survey which will be made freely available to students through Google Store in the near future. It will help students improve their knowledge of the department facilities, available resources, staff, equipment, and safety rules in an enjoyable way. As wireless communication technology proceeds to develop rapidly, smartphones as of 2020 display high-quality graphics of that can offer realistic and immersive AR experiences. The application will not only help in quick and easy adaptation to the educational environment but also save the department resources. This will also aid in simplifying the process to assess students' proficiency and instantly update the lab-related information as opposed to the current paper-based method.

1.2. Augmented Reality Background

A typical AR system comprises sensors, input devices, a processor, and a display. In all types of AR applications, the user should feel that the augmented object is a part of the real world, and high accuracy and little latency at a reasonable cost are the main requirements of a good tracker, thus the choice of tracking technique has a huge impact.

1.2.1. Tracking

Wikipedia defines tracking as "the problem of estimating the trajectory of an object in the image plane as it moves around a scene. In other words, a tracker assigns consistent labels to the tracked objects in different frames of a video. Additionally, depending on the tracking domain, a tracker can also provide object-centric information, such as orientation, area, or shape of an object."

In many AR applications, digital world contents are superimposed on real-world contents. In other words, the digital contents are anchored to real-world objects, which requires the device to be able to sense the environment and the movement of the user in real-time. This phenomenon of recognizing the object or scene is called tracking. Once the scene or object is tracked, the virtual objects are overlaid onto the real objects. There are mainly three methods of tracking: marker-based, marker-less, and hybrid tracking. Marker-less AR is mostly used in navigational applications, but marker-based AR has more diverse uses.

A marker-based AR uses a camera to capture the image of the object or environment, track the position of the marker, and superimpose the video or text over the image which is shown on a screen. Marker-based tracking makes use of camera and a visual marker to find out the orientation, center, and range of its coordinate system [47,48]. The use of fiducial (artificial) markers makes it easy to locate coordinate points for use in augmenting the object [49]. The visual markers are made of black and white squares or rectangles with distinct features, thus making it easier to identify the position of the objects in the real world. Once the marker is identified, the characteristics of the marker are extracted and compared with the image of the marker, which is pre-loaded in the system. This techniques suffers from the drawback that it is requires the positioning of the markers on the object which should be visible and cannot be obscured by any other objects throughout the process of augmentation. The use of fiducial markers can be avoided by using the natural featured tracking (NFT) method which uses the natural cues of the objects such as edge, surface texture or other such features as markers. This technique can be applied to any image and an NFT-based AR application can recognize an object and identify it by comparing it to similar images, as this method relies on natural objects in the scene instead of artificial patterns. Model-based tracking is another developed form of marker-based tracking which uses the outline of a computer-aided design (CAD) model or 2D template of the object based on distinct features as a reference for image recognition. Model-based trackers mostly use lines or edges as a feature to estimate the pose (position and orientation) of a camera [50].

Marker-less tracking is a method of positional tracking which uses a mobile's built-in sensors to determine the position and orientation of an object within its environment. The mobile components such as accelerometer, gyroscope, compass, and GPS allow determination of direction and orientation of the device in the environment. Hybrid tracking is an amalgam of both marker-less and marker-base tracking. This method fuses the data obtained from multiple built-in mobile sensors to calculate the actual position and orientation.

1.2.2. Platform

The AR platform/display position of AR is a fundamental property of AR, which results in different kinds of experiences. There are three distinct AR platforms, namely Head-Worn, Hand-Held, and Spatial [51]. In Head-Worn the visual displays are attached to the head like a Head-Mounted Display (HMD). Popular examples are Google Lens and Microsoft HoloLens [52]. The hand-held is the most popular platform due to an increase in AR applications targeting smartphones. A smartphone has all the essential hardware needed to implement a consumer-grade AR application; these include a large touchscreen, fast processor, camera, GPS, compass, and accelerometer. This makes it easier to experience the application both indoors and outdoors. The spatial display is placed in a fixed location within the environment and used for large presentations. An example of this type of display is a Heads-Up Display (HUD), used by pilots in a cockpit. A HUD contains a projector, a viewing glass, and a computer.

Our platform of choice for the AR lab orientation application was hand-held smartphones as these are already available to students, and they do not need to buy specialized hardware to use the developed application.

1.2.3. Display

A key aspect of AR is the type of display technology used to experience the AR content. Display technology is how the user experiences the AR content. There are usually three types of display technology used, Video See-Through, Optical See-Through, and Projective [53]. Video See-Through technology swaps the real world for a video feed of real life, and the AR content is overlaid upon the video feed. This makes it easy to remove or replace fiducial markers. In Optical See-Through, the AR overlay is displayed over the real world utilizing transparent mirrors and lenses. This technique has the resolution of the real-world. Therefore, users are not restricted by the screen quality. In Projective

technology, AR overlay is projected onto real objects themselves. Therefore, it can cover large surfaces for a wide field-of-view.

2. Theoretical Framework

AR is a well-integrated technology in education research, and many studies have reported that the use of AR resulted in boosting of motivation and, as a result, learning performance. Motivation is referred to as the student's willingness to engage in the learning environment and a person should be motivated enough to pay attention to learning [54]. The AR-based orientation activities are designed in line with the ARCS model of motivation proposed by Keller [55], where ARCS stands for Attention, Relevance, Confidence, and Satisfaction, as shown in Figure 2. Keller argued that more attention should be paid on motivating students intrinsically to learn, instead of applying external stimuli as suggested by other models. In order to enhance the learning performance of the students and achieve increased stimulation, ARCS emphasizes that the teaching activities and materials must be matched with these four factors.
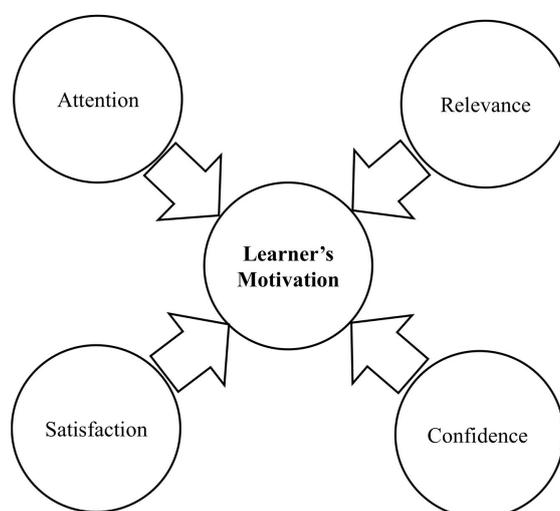

Figure 2. ARCS model of motivational design.

2.1. Attention

Attention is the first element of ARCS model of motivational design which is related to inculcating the interest of a student and stimulating their enthusiasm during the learning process. This can be obtained in different ways. Innovative AR technology does have an element of surprise for the students which can be helpful for attracting students and capturing their interest. After getting success in grabbing students' attention, the next challenge is to sustain their attention. Mobile-based AR applications allow instruction materials to be incorporated in a variety of formats which can be offered using different modalities of learning such as audio, video, and text thus keeping learners interested and sustaining their attraction. Mobile AR applications also provide students with full control of the learning material and learning pace, which can keep them interested during the learning process. Lastly, the best way of boosting the student's attention is to use real-world examples and AR is tailor made for this purpose as it amalgamates the real-world with virtual world and this interaction with real-world may keep the learners interested for prolonged periods of time, thus enhancing their attention spans and boosting their learning performance.

2.2. Relevance

The second of element of the ARCS model is relevance, which is related to teaching design and methods. It is about students' development of relevant personal recognition founded on the learning of novel material and past experiences. This allows the students to perceive the present worth of the material or future usefulness and students want to know how this information is going to help them in solving problems in real life. This can be achieved by incorporating the activities and exercises into application which are not only closely related to the contents of the orientation, but also focus on showing application of the skills developed in order to solve the problems which they may face when actually working in the lab, and to convince them that this application will be helpful for them in future. Additionally, short quiz activities can be used to identify gaps in students' learning, and the application can then motivate them to fill those gaps.

2.3. Confidence

Confidence is the third element of the ARCS model of motivational design, which is related to student behavior. It is meant to provoke students' prospects of achieving success by scaffolding meaningful tasks and fostering positive attitudes towards students which help them in building their self-confidence. This can be achieved by setting learning requirements, creating success opportunities, and encouraging personal control. This application will set clear goals for the students and scaffolds their learning through audio, video, and textual tutorials and hints. It can provide personal agency to students, since they can start doing any tasks, any time, and in any order. Students can be asked to solve a simple quiz at the end of each activity and solving it successfully will help in boosting their confidence. Confirmatory feedback is provided for each correct answer and corrective feedback may be provided if the questions are answered incorrectly.

2.4. Satisfaction

Satisfaction is the last element of the ARCS model of motivational design, which is related to building students' sense of success and achievement. It is compulsory for the students to complete the orientation process before they start working in the lab. Although this is an extrinsic factor, it will create a sense of achievement. Confirmatory feedback at the end of each correct answer also produces a satisfactory feeling for the students. Solving real-world problems will also bring a lot of personal satisfaction for students. This AR-based application is all about interacting in the real-world and empowers them to find the solution to the problem they have encountered. This will satisfy the students' lust for reward and keep them motivated.

3. Methodology

3.1. Research Objective

The objective of this research is to find the gaps in the existing method of orientation and make use of modern technology to fill these gaps for enhancing the learning performance of the students and evaluate its efficacy for achieving these goals. The main goal was to design and develop an application comprising a number of versatile features to help fresher students before they begin working in the lab. Furthermore, the application would engage learners emotionally by applying design aspects and ease students' adaptation to the lab environment.

3.2. 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.

3.3. 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.

3.4. Research Problem

The existing method of lab orientation involves a hands-on approach where the students are required to attend a lab session led by an instructor, who takes them for a lab tour, educates them about health and safety rules, and provides information about the lab equipment. It is compulsory for the students to attend a lab induction session in order to be eligible to work in the lab. The students register in one of the many lab induction sessions scheduled throughout the week. Every year, there are many students who have shown their discontent with this method of orientation and there are complaints from students which are resolved by the staff, and sometime students suffer as a result. This gives rise to our first research question (RQ) as given below:

- RQ1: What is the students' perception towards the existing method of lab orientation? The students' feedback is presented below.

Apart from the above findings, this method also suffers from the drawback that it is instructor led, costly and creates logistical constraints as it requires conducting multiple sessions for hundreds of students. The lab-technicians spend extra working hours in conducting these lab orientation sessions. The calculated working hours do not take into account additional lab sessions needed by students who were unable to attend the lab orientation on the set dates. Therefore, the existing method of orientation should be improved to overcome the aforementioned drawbacks. We need an instruction method that could engage the students in an effective way and create deep learning; which will help students assimilate information in an effective way and retain it for a longer period. This gives rise to our second research question:

- RQ2: How can lab orientation experience be enhanced and used to complement the existing method?

In this context, availability of new-generation pedagogical tools has come to the forefront which help in assimilating the complex concepts in an easier way and eliminate misconceptions because it is seen that existing teaching environments lack the capability of meeting the differentiated expectations of today's students, popularly referred to as generation Z [56,57]. Therefore, it is important to reformat the teaching environments to accommodate the use of innovative technologies [57]. This has led to an integration of intelligent systems in virtually every aspect of academia and has become an important focus of many education projects in recent years [58,59], resulting in development of "smart learning environments", in particular, focusing on tools and techniques. These systems are based on a centralized or distributed model where the centralized model saturates the environment with an active role in both adapting to and shaping the behavior of its occupants, and the distributed

model focuses on independent objects that enrich a static environment with dynamic behaviors and interaction [5]. In both models the augmented reality technologies are widely applied, for example as reported in References [60–62], and are among the most common recent trends in daily life, being used for entertainment purposes and many other fields. Augmented reality bridges the gap between the virtual and physical world thus making learning more exciting. There exist a plethora of mobile augmented reality based applications used in education, university orientation, training, and tourism. To the best of our knowledge, no application has been designed targeting lab orientation. The use of novel technology for orientation captures students' interests, engages them by providing interaction with the real-world and motivates them intrinsically to engage with the learning environment without caring for external rewards.

The final step is to find out the efficacy of the AR-LabOr by exploring students' perspective of the application. This gave rise to our third research question:

- RQ3: Explore students' perception towards use of AR-LabOr for lab orientation purpose and its impact on their motivation.

3.5. Study Design

This project is a descriptive research with a quantitative approach to validate the methodology and tools chosen for the planned activities, with the aim of establishing whether the use of AR was helpful for the students in conducting lab orientation. A prototype AR application was tested among a group of undergraduate students. All the participants had given their informed consent for inclusion before they participated in the study.

3.6. Materials

The study was mostly conducted with an Android-based Samsung Galaxy S10 WiFi SM-T700 16 GB model, running Android 9.0 Pie with a Samsung Exynos Octa-Core CPU processors: 2x2.73 GHz Mongoose M4 and 2x2.31 GHz Cortex-A75 and 4x1.95 GHz Cortex-A55 and having ARM Mali-G76 MP12 GPU graphics card and 3GB LPDDR3 RAM. The instrument used to know the level of acceptance that the usage of AR has aroused in students was a questionnaire answered by students enrolled in the discipline. The questionnaire incorporated four questions to characterize the student, 9 Likert scale questions with 5 options, and 3 open-ended question.

3.7. 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.

3.8. 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.

4. Application Design

Before commencing with the development process, it was essential first to understand the requirements of the user and choose the base software development platform to make crucial decisions about the application features. We followed the software development practices to ensure best outcome of the effort.

4.1. Application Development Methodology

We chose the Agile development method to develop this application in a prototyping manner justified by the time constraint as well as the user involvement, which was an important principle of this methodology. The developers of the AR-LabOr were involved in prioritizing new user requirements and evaluating the iterations of the system throughout the development phase. The first phase of development, analysis and design phase, involved the processing of the initial user requirements prior to designing the functionalities of the application. Analysis of requirements was performed and suitable programming language, hardware and software requirements, and 3D model designing engine to meet user specifications were determined. During the prototyping phase, an initial prototype of the application was developed which included all vital components and users experienced the prototype to provide feedback. During the Improvement Phase in Future Iterations, the feedback from students was analyzed and modifications to systems were made. In the final Implementation Stage, the most stable and improve prototype was compiled into a final product and implemented as a working application.

4.2. Software Development Platform

The choice of software development platform was important for application design as it could affect the integration of the application with other tools largely depending on the main platform. The available options included: Flutter, C#, Swift, React Native, Java or Kotlin. Flutter and React Native have the benefit of being cross platform. However, they had the issue of being behind under native frameworks and not beneficial for specialized applications. C# had the benefit of integrating easily with the largest augmented reality provider, Vuforia; however, Java was chosen due to its widespread use and ease of integration with other tools for model and text recognition, and cross-platform development.

4.3. System Architecture

The AR-LabOr comprises a mobile client app on Android OS platform and remote data server; connection between them is provided through a wireless network, as evident from the system architecture shown in Figure 3a,b. After submitting a request from a client, the server receives and responds to this request by returning the processing results to client. For application development, we used Google's Firebase mobile platform which provides various tools in a single package to help develop applications. Firebase authentication was used to build a user authentication system, by only developing for client-side code which can support multiple login providers such as Facebook, GitHub, Twitter, and e-mail. We integrated Facebook Login into the app the option which allowed users' authentication with Firebase using their Facebook accounts as most users already have a Facebook account. In order to differentiate among the users with the same name, a unique token is provided

to each user. Upon launching application, the user is asked to log in with Facebook or continue as a guest. If the user is logged in with Facebook, completed quiz result in their name and quiz completion data is stored in a real-time database, Firebase, hosted on a cloud. Data is stored on server in JSON (JavaScript Object Notation) format and synchronized in real-time to every connected client which can be accessed directly from the mobile device even if it is offline. It uses data synchronization—every time data changes, any connected device receives that update within milliseconds. Real-time syncing makes it easier to access the list of students who completed the quiz from any device. If the user is offline when they completed the quizzes, the real-time database stores it on a local cache on the device, and once the user has Internet access, the data is automatically synced to the cloud-hosted database thus making it convenient for the teachers to find all the students who have completed the quiz.
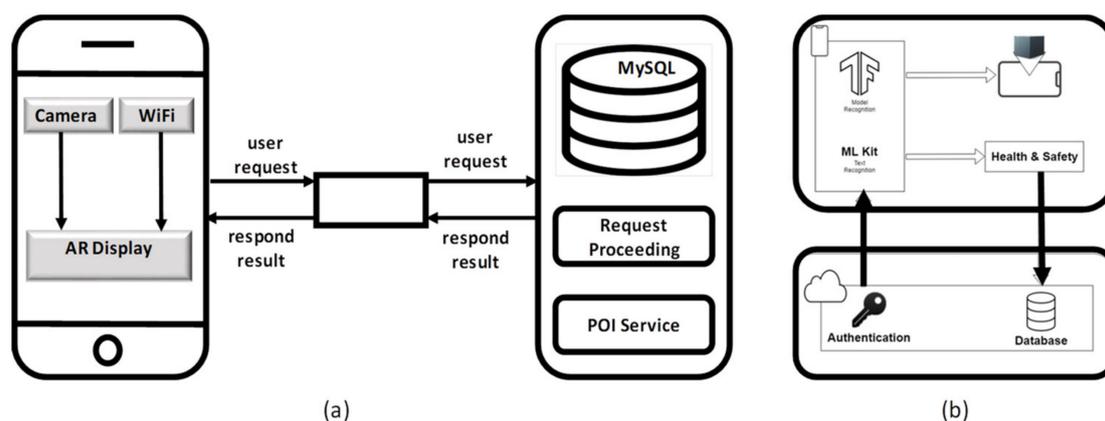

Figure 3. System Architecture: (**a**) Interaction between smartphone app and remote server (**b**) Firebase toolset.

In order to realize AR experience in our smartphone application, we used Google's ARCore platform. It uses the smartphone's camera and other sensors to sense and interact with the environment. The app is capable of tracking motion, understanding the environment, and estimating the light intensity essential for integrating virtual content with the real world in an effective way. Motion tracking allows the smartphone to understand and track its position relative to the real world. Environmental understanding allows the smartphone to detect the size and location of all type of surfaces. Light estimation allows the phone to estimate the environment's current lighting conditions for determining both the position and the orientation of the smartphone. Once position and orientation are determined, it looks for a flat surface. Upon the recognition of a flat surface, clicking on the flat surface results in an overlay of information. This information depends on what the model recognition recognized in the image.

We used object detection to identify different lab equipment and this process started with the video capture using the device camera. The video frames were analyzed in real-time to detect the objects using Azure Custom Vision service [63], an image classifier that applies labels (which represent classes) to images using machine learning technique, according to their visual characteristics. The functionality is divided into image classification and object detection. Image classification applies one or more tags to an image and object detection is similar but it also returns the coordinates in the image where the applied labels can be found. The model is trained with various images of the lab equipment which were labeled and submitted in groups. Once the algorithm is trained, we exported the model for offline use on a smartphone. We used ML Kit's Object Detection and Tracking APIs to identify the object in an image and then track it in real time. This allows text recognition, image labeling, and object recognition. We used ML Kit's text recognition APIs to recognize texts from images. Text recognition is used in the "Staff Information" to detect the name of the staff in an image and load their information.

4.4. Application Features

The results of the user design study framed the main feature of the application are discussed below:

- A database that presents a Login-Register mechanism;
- Equipment identification;
- Staff information;
- Health and Safety.

4.4.1. Sign up and log in

This is a task-based application where the student is required to complete a task by interacting with it. When a user launches the application for the first time, they are asked to create an account and register themselves.

In order to create a new account, the users are required to enter their details such as name, surname and email address. This information is used to create a new profile for the user. After the registration process is complete, the user may log in by using the login screen as shown in Figure 4a. If a user is not logging in for the first time, they are taken to welcome screen where they are provided with the application features to select the feature of choice. The image in Figure 4b shows the screen of the mobile app where user can make five distinct choices.
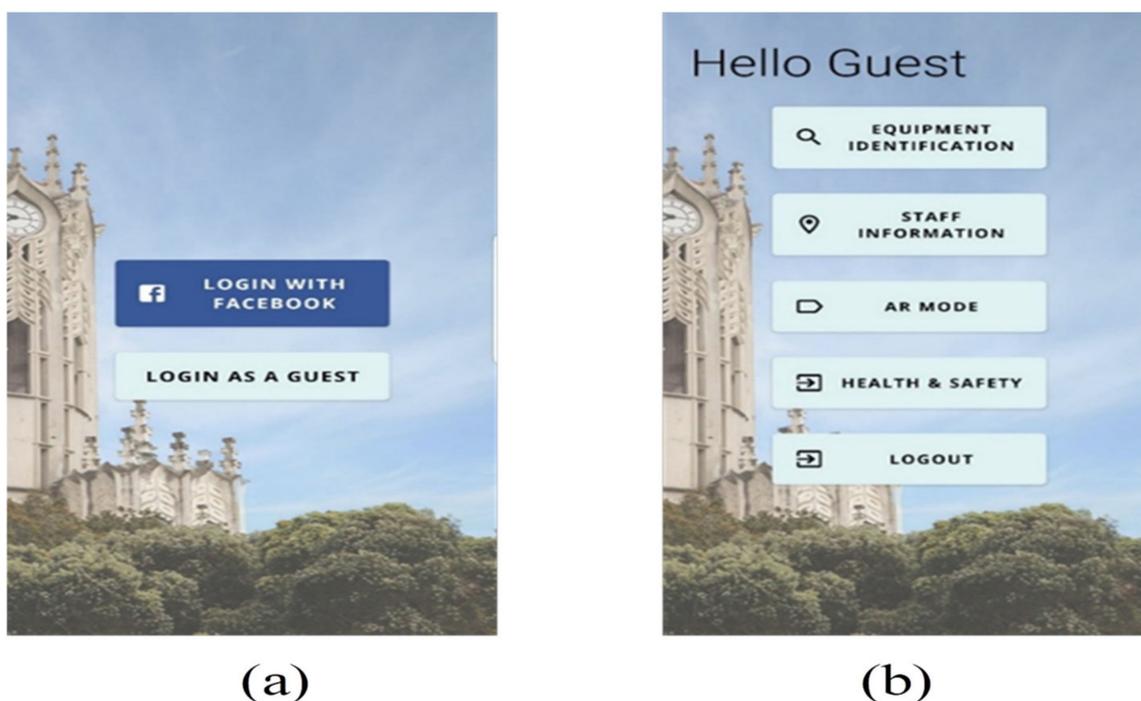
Figure 4. (**a**) Log-in, (**b**) Main Screen.

4.4.2. Equipment Identification

Lab equipment are tools of daily use throughout ECSE students' degree tenure as well as later in their professional careers. The variety of equipment can be overwhelming for new students, and they can be intimidated to ask for help from the teaching assistants. Equipment identification feature is used to identify and familiarize students with the most frequently used equipment in the lab, which includes: oscilloscopes, power supplies, waveform generators, and multi-meters. Once the user starts the equipment identification activity, the application turns on the mobile device camera. Users can take a photo of a physical piece of equipment; the application recognizes the equipment and superimposes

the virtual name of the equipment on a real object as shown in Figure 5a. Furthermore, a dialog box pops up which offers the information in multiple ways such as Video, Quiz, PDF, and Interactive material, as shown in Figure 5b. The range of different tasks allows students to educate themselves in a lot of different formats and supports a variety of different learning styles.
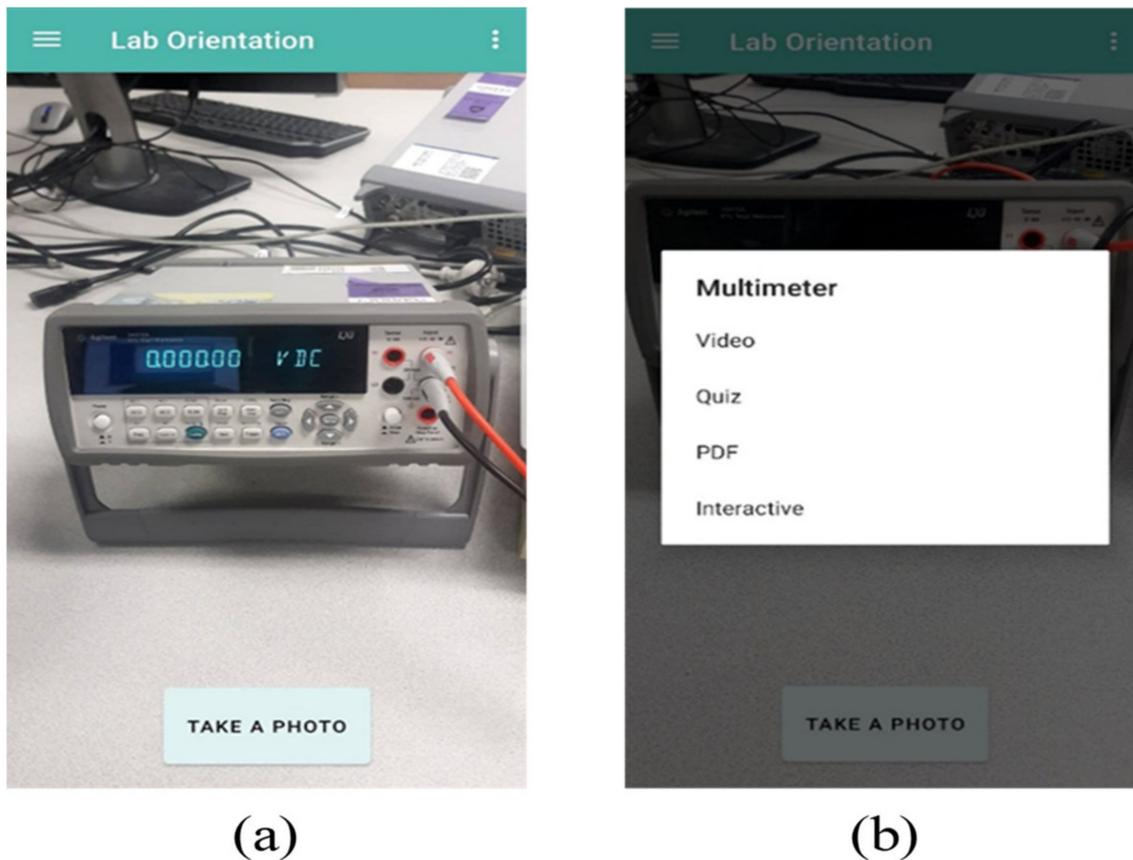
Figure 5. Equipment identification (**a**) equipment image acquisition, (**b**) information dialog box.

Clicking on the video option opens an informative video of the identified equipment which plays a short video tutorial for users on how to use the lab equipment. This option allows the students to learn about the equipment at their leisure, without any assistance.

The interactive mode presents the information in an interactive and compelling way, thus enhancing student learning performance. It provides the student with an experiential learning model where users can interact with the equipment by clicking on its various parts and learn about the functionality of the equipment. Interactive mode can be used by the students to quickly get information about the functionality of the different buttons and other components of the equipment, without the need for any assistance from the teaching assistants and at their convenience. An example of interactive activity with the oscilloscope and socket are shown in Figure 6a where one can see that after pressing a specific section of the image, information pops up detailing the functionality of the button. This activity gives the student a hint if they are unsure of how to use the specific part of the equipment.
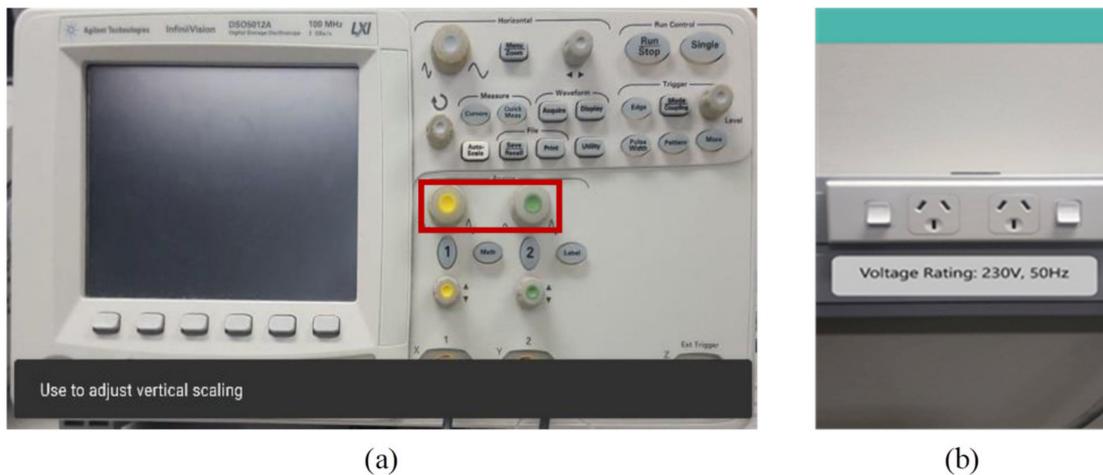
Figure 6. (**a**) Interactive Equipment (**b**) Power socket.

The AR Mode helps the students to identify the equipment in the labs in an AR experience. This mode also uses model recognition to identify the equipment. Once the model is recognized, clicking on a flat surface overlays information on the selected surface. To use this mode, the user needs to point the camera to the equipment they want to identify and select the flat surface which will then overlay the name of the identified equipment, component, or a button. For example, if the recognized model is a power socket, the application will overlay the name and as well as the voltage rating of the power socket, as shown in Figure 6b.

4.4.3. Activities

The central part of this section of the application is the quiz. After taking part in the other activities, the quiz assesses students on their understanding of the equipment. Figure 7 shows the layout of quiz activity. There are three quizzes for each equipment and each quiz comprises up to three multiple choice questions as recommended by students during predesign phase. The user is provided with immediate feedback in the form of affirmation upon attempting each question. If the student is able to answer all the questions correctly, a message pops up congratulating the student on finishing the orientation process. Information about the student's performance in the quiz is updated in the database for lab supervisors to track the progress of the student. There is no limit on attempting the quizzes.
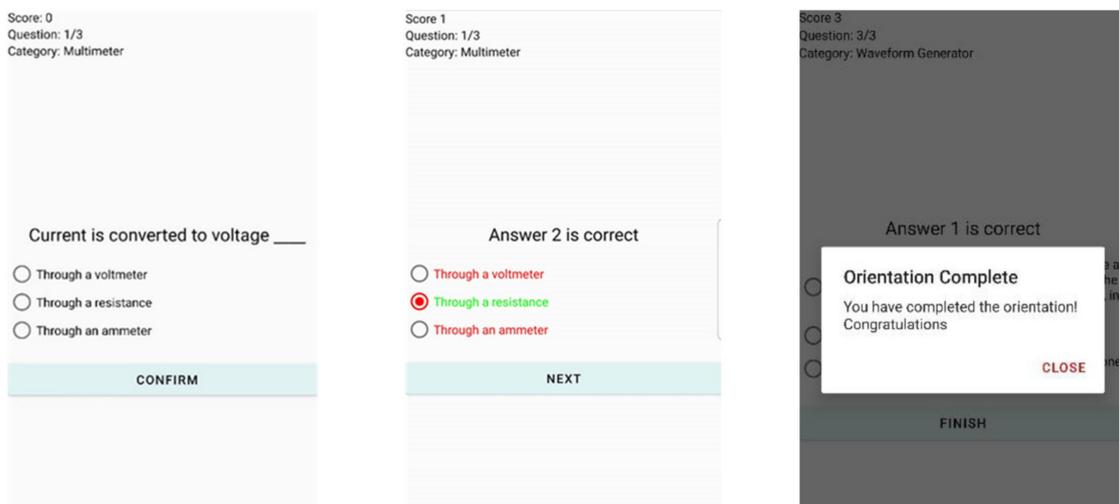
Figure 7. Quiz activity.

The PDF activity provides textual information showing step-by-step instructions on how to use the equipment and offers a variety of different tasks that the user can do to understand the working of the equipment, thus supporting the kinesthetic learner. A sample of this activity is shown in Figure 8. This part of the application is activity driven, supporting kinesthetic learners.

Figure 8. Pdf activity.

4.4.4. Staff Information

The traditional method of getting information about a lecturer is tedious. To get the information, the user needs to go to the Auckland University website, go to the staff directory page, and then enter the name of the lecturer they are looking for. This method takes a long time and is not readily available to the students. Therefore, to solve this issue, we created a feature in the application called "Staff Information." Staff Information mode is an easy way for the students to access details of the lecturers. It allows users to issue keyword-based or image-based queries and return web pages with static images that match users' queries. The users can either enter text manually or take a photo of text. The application recognizes the image and takes it to the personal webpage of the concerned faculty member where it contains all the information about them. The information about the lecturers is stored in the university's database, and this feature redirects to the university staff directory. The layout of the staff information page is shown in Figure 9.
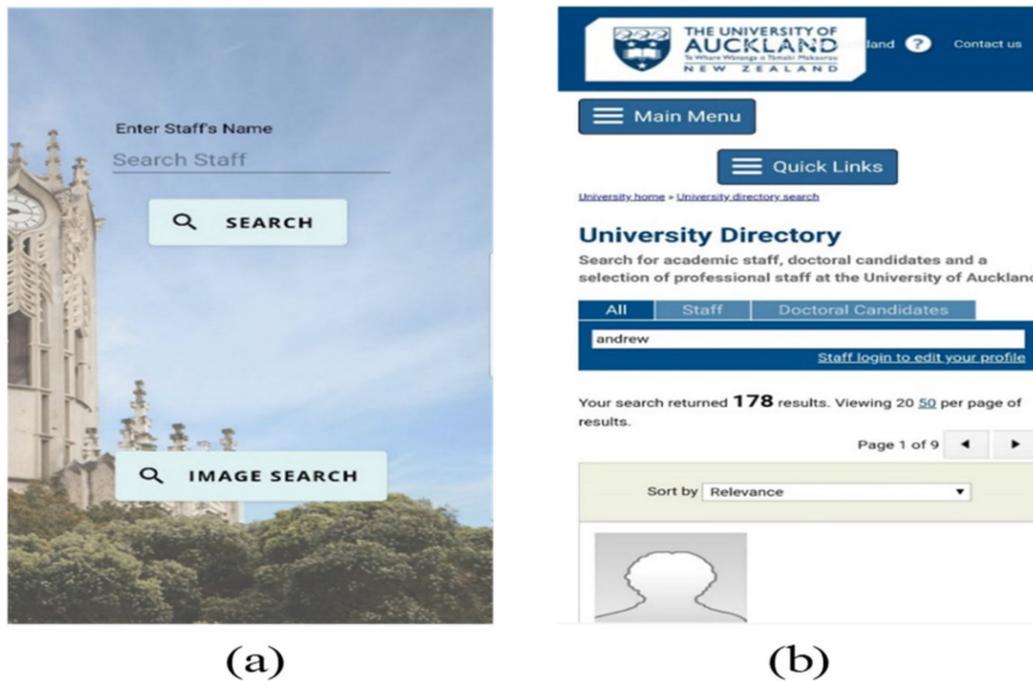
Figure 9. Staff Information (**a**) query screen (**b**) university directory page.

4.4.5. Health and Safety

The health and safety mode uses text recognition to recognize the health and safety posters around the lab, as shown in Figure 10. This then provides the students with the full list of health and safety rules in the lab. The posters around the lab do not provide with all the rules, this mode includes all the lab rules that students need to follow. All the functionalities available in the equipment identification mode are also available in this mode as well.
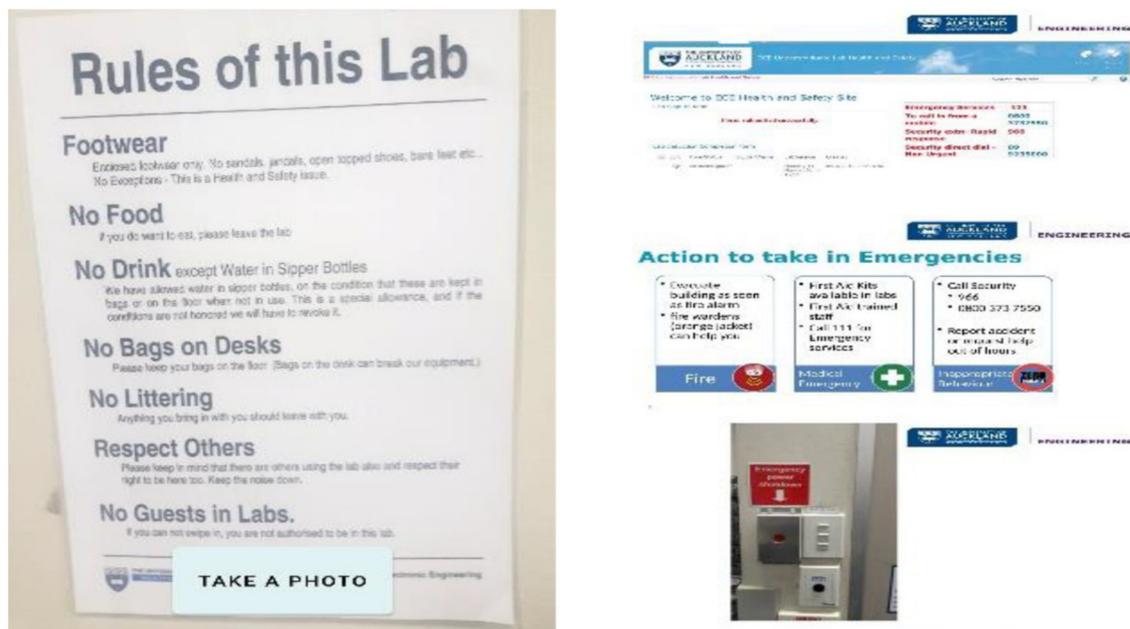
Figure 10. Health and Safety.

5. Results

A total of three surveys were conducted in total during this research and two of them were conducted before the design and implementation of AR-LabOr to find out the students' perception of existing method of orientation as well user interface requirements. The participants were asked to fill these questionnaire at the same time. Therefore, the number of students in the first two studies were the same. The third survey was conducted after the implementation of the AR-LabOr to explore students' experiences with the application. The number of participants for the post implementation was different from the pre-design survey.

5.1. Research Question 1

In order to answer RQ1 and explore students' perception towards existing method of the lab orientation, we conducted a paper-based survey during the first semester of 2019. A total of 57 students (aged 19–21) and staff members from the Department of Electrical, Computer, and Software Engineering participated in the study, with more demographic details provided in Table 1. The majority of participants had previously experienced augmented reality in one way or other. It is evident from the table that the majority of the participants were undergraduate local male students with a considerable portion of female students also participating in the study. The reason for low participation of post-graduate students and staff is their locality as they were located far from the undergraduate labs. A total of 15.8% students were international students as UoA is a reputed university and very popular among the local students.

Table 1. Participants Demographics.

	Male	Female	Total
Participants Gender Recount % of Total	42	15	57
	73.7%	26.3%	100%
	Students	**Staff**	**Total**
Designation recount % of total	55	2	57
	96.4%	3.6%	100%
	Undergraduate	**Post-graduate**	**Total**
Degree recount % of total	55	2	57
	96.4%	3.6%	100%
	Local	**International**	**Total**
Residency recount % of total	48	9	57
	84.2%	15.8%	100%

The results of students' responses are shown in Figure 11 and it can be seen that more than 50% of the students did not agree that the current lab orientation method is helpful, less than 40% students were satisfied with existing method of orientation, and only 30% of the students found it engaging. An overwhelming majority of the students were of the view that the current orientation method needs improvement (only 4% disagreed). Additionally, it was observed during the survey that students struggled to recall the lab orientation session indicating under-learning and low retention of the information which, together with the survey outcome, indicates that the current orientation is not effective.
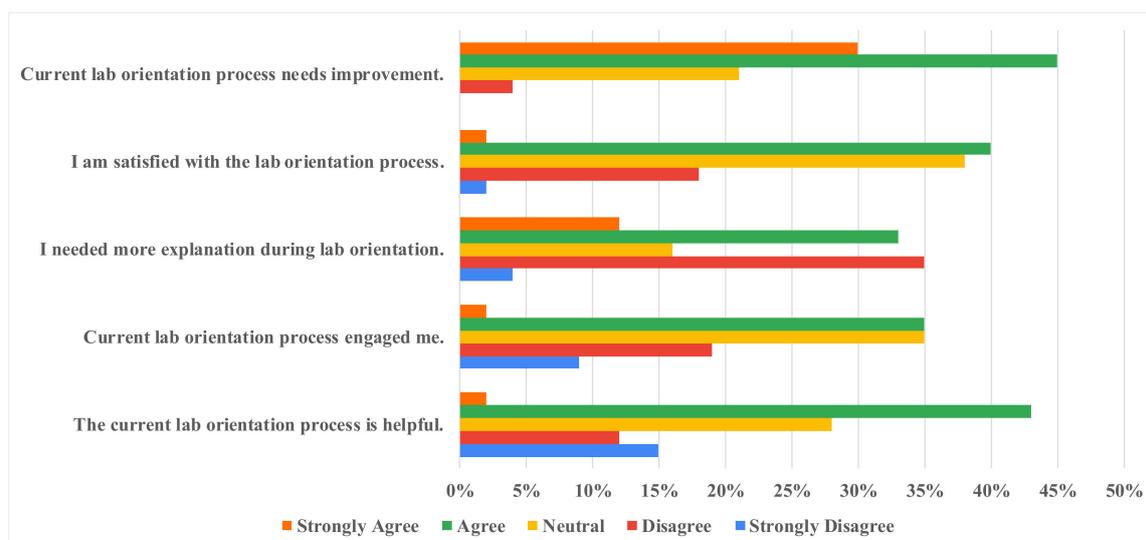
Figure 11. Students' perception of existing method of orientation.

The breakdown of the responses is provided in detail in Table 2, where a vast majority of the students, and in particular females and international students, were of the view that the current method of orientation needs improvement as it is not inclusive as they might feel shy to ask questions due to a communication barrier or for some other reason [64]. Similarly, lack of engagement is also highlighted by a majority of the students, international and female students in particular. A portion of the local students were satisfied with the existing method of orientation as they are used to such methods, and a majority of them being local students know the rules of games. They could interact with the instructors and extract required information.

Table 2. Participants' response breakdown.

Question	Answer	Male	Female	Local	Inter-national	Under-grad.	Post-grad.
Lab orientation process needs improvement.	A+SA	30 (52.5%)	13 (22.8%)	36 (63.2%)	7 (16.7%)	42 (74.7%)	2 (3.5%)
	DA+SDA	1 (1.8%)	1 (1.8%)	2 (3.5%)	0 (0.0%)	2 (3.5%)	0 (0.0%)
	N	11 (19.3%)	1 (1.8%)	10 (17.5%)	2 (3.5%)	12 (21.1%)	0 (0.0%)
Satisfied with the lab orientation process.	A+SA	19 (33.3%)	5 (8.8%)	20 (35.1%)	4 (7.0%)	23 (43.3%)	1 (1.7%)
	DA+SDA	7 (16.7%)	4 (7.0%)	10 (17.5%)	1 (1.7%)	10 (17.5%)	1 (1.7%)
	N	16 (28.1%)	6 (10.5%)	18 (31.6%)	4 (7.0%)	22 (38.6%)	0 (0.0%)
Needed more explanation during lab orientation.	A+SA	18 (31.6%)	8 (28.1%)	20 (35.1%)	6 (10.5%)	26 (45.6%)	2 (3.5%)
	DA+SDA	16 (28.1%)	6 (10.5%)	20 (35.1%)	2 (3.5%)	20 (35.1%)	0 (0.0%)
	N	8 (28.1%)	1 (1.7%)	8 (28.1%)	1 (1.7%)	9 (15.8%)	0 (0.0%)
Lab orientation process engaged me.	A+SA	15 (26.3%)	6 (10.5%)	17 (29.8%)	3 (5.3%)	19 (33.3%)	2 (3.5%)
	DA+SDA	11 (19.3%)	3 (5.3%)	16 (28.1%)	0 (0.0%)	16 (28.1%)	0 (0.0%)
	N	16 (28.1%)	4 (7.0%)	15 (26.3%)	6 (10.5%)	20 (35.1%)	0 (0.0%)
Lab orientation process is helpful.	A+SA	26 (45.5%)	5 (8.8%)	27 (47.4%)	4 (7.0%)	29 (50.9%)	0 (0.0%)
	DA+SDA	7 (16.7%)	2 (3.5%)	10 (17.5%)	0 (0.0%)	11 (19.3%)	2 (3.5%)
	N	9 (15.8%)	7 (16.7%)	11 (19.3%)	5 (8.8%)	15 (26.3%)	0 (0.0%)

Based on the responses to the questions in Figure 11 and responses to open-ended questions, the existing method was found to be suffering from obvious drawbacks summarized as follows.

- Lab orientation session had conflict with regular lecture
- The session was not inclusive for students with communication barrier
- Documents were not updated with the latest information
- No feedback was providing on students' understanding
- Lacks engagement and passive in nature
- Creates many hassles for students

5.2. Research Question 2

After the identification of the problem to be solved, the next step was to decide the technology to be used for improving this method. Based on the findings from our literature review, we had decided to use AR technology. The next step was to decide the platform and features that should be included in the application. The aim was to provide the students with tangible benefits including enhanced student experience, improved delivery of contents, learning enhancements, and reduced cost. Therefore, we conducted a pre-design study to make sure that the input of all stockholders is obtained at the outset before getting the process of design and development of the application underway ensuring a better final prototype. The study explored the requirements of students, and what methodologies students believed were most beneficial in understanding of the concepts taught in the lab orientation. A paper-based survey was conducted for students and staff of ECSE department at The University of Auckland. The survey comprised different types of questions which included four demographic questions, five Likert scale questions, five multiple choice questions (MCQs), and one open-ended question.

A total of 57 participants completed the survey and all these participants also completed the questionnaire exploring student perception about the existing method of the orientation. The responses to the demographic questions have been given above in Table 1, and responses to Likert scale and multiple choice questions are given in Table 3 and Table 4, respectively.

Table 3. Application predesign questionnaire.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. Do you think an augmented reality application would help the lab orientation process?	4%	7%	23%	46%	20%
Q2. Do you think videos would be helpful in an augmented reality application?	1%	2%	16%	20%	61%
Q3. Would a tutorial be useful to explain how does the application work?	0%	0%	11%	44%	45%
Q4. Do you think an interactive screen explaining the uses of buttons in equipment would be helpful?	0%	1%	9%	45%	45%
Q5. Do you think a short quiz after each activity would help enhance your understanding?	0%	2%	9%	44%	45%

Table 4. Application predesign survey responses to MCQs and open-ended questions.

Statement	Responses
Q6. Would you be more likely to use this application if it was on your phone or if it was using an alternative tool (e.g. Hololens)	Phone: 75%, Wearable: 16%, Alternative Tool: 9%
Q7. If we had videos in our applications, what do you think would be the optimum length of the videos?	< 1 Minute: 32%, 1 Minute: 27%, 2 Minutes: 41%, > 3 Minutes: 5%
Q8. How do you want your App to be displayed: only in a vertical position, only in landscape or both?	Landscape: 16%, Vertical: 25%, Both: 59%
Q9. How many questions do you think would be good if there was a quiz?	1:5%, 3:75%, 5 +: 20%
Q10.Do you think the questions in a quiz should be multiple choice or short answer questions?	MCQ: 95%, Short answer:5%
Q11. Do you have any ideas for the application that you would suggest would be beneficial?	• Should be usable outside of the lab orientation (for refreshing memory) • Make sure its accessible to everyone as not every person has the same phone/laptop/equipment • Similar to how learning activities are presented online, with quiz and instructional activities • Make it like an interactive game or something so it doesn't feel like an orientation • Easy and straight forward to use

Based on the above predesign survey results, the following critical decisions were made:

- Application targeting smartphones;
- Flexible orientation usage depending on the activity;
- Short and concise multiple choice quiz to be included and each quiz should comprise around three questions;
- Interactive activities explaining the functionality to be included;
- Include videos of length up to three minutes for the explanation.

5.3. Research Question 3

Explore students' perception towards use of AR-LabOr for lab orientation and its impact on their motivation? In order to answer this question, the participants were asked to experience the application by completing the activities and fill in the questionnaire which contained a mix of five point Likert scale and open-ended questions as mentioned above. A total of 56 students participated in this study which was conducted towards the end of second semester of 2019. The participants of this study might or might not be the same who participated in earlier studies as it was held at a different time. The details about the participants' demography are provided in Table 5. It can be seen that no staff member and post-graduate student participated in the studies, which may be due to their busy schedule towards the end of semester. The same reason may account for the low participation of the international students. The female participation is very close to the pre-design study.

Table 5. Post-design participants' demographics.

	Male	**Female**	**Total**
Participants Gender recount % of total	44 73.7%	12 26.3%	56 100%
	Students	**Staff**	**Total**
Designation recount % of total	56 96.4%	0 3.6%	56 100%
	Undergraduate	**Post-graduate**	**Total**
Degree recount % of total	56 96.4%	0 3.6%	56 100%
	Local	**International**	**Total**
Residency recount % of total	54 84.2%	2 15.8%	56 100%

The outcomes of the survey are provided in Figure 11 indicating students' perception of the AR-LabOr. The majority of students found the application easy to use (>87% overall), more than 87% thought it was intuitive, and the same percentage liked the user interface whereas all female students agreed. About 96% of the students overall and found the application more engaging than the instructor-led orientation. More than 87% students overall found the AR application to be more engaging than the traditional orientation. Students found the application beneficial and helpful for understanding the use of equipment in the lab. More than 77% students overall agreed that contents were relevant while all of them recommended its use for orientation in future. These results fall in line with other studies proving that the application of AR has a significant effect within the field of education and orientation.

The breakdown of the response to the post-design survey is given in Table 6. It can be seen that all the female students and international students also found the application helpful and easy. Only 7% of the students were neutral about its helpfulness and 6% were neutral about the ease of use. The same is the case with the intuitiveness and only 8% were neutral; all female and international students found it intuitive. Similarly, apart from around ~7% participants found the application engaging than the manual experience. Therefore, overall participants expressed positive feelings towards the use of the application, especially the female and the international students who exhibited discontent with the instructor-led method of orientation.

Table 6. Breakdown of the post-design survey responses.

Questions	Answer	Male	Female	Local	Inter-national	Under-grad	Post-grad.
Application was easy to use.	A+SA	37 (66.1%)	12 (21.4%)	47 (83.9%)	2 (3.6%)	50 (87.5%)	0 (0.0%)
	DA+SDA	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	N	7 (12.5%)	0 (0.0%)	7 (12.5%)	0 (0.0%)	7 (12.5%)	0 (0.0%)
I liked the user interface.	A+SA	38 (67.9%)	12 (21.4%)	48 (85.7%)	2 (3.6%)	50 (89.3%)	0 (0.0%)
	DA+SDA	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	N	6 (10.7%)	0 (0.0%)	6 (10.7%)	0 (0.0%)	6 (10.7%)	0 (0.0%)
Application was intuitive.	A+SA	38 (67.9%)0 (0.0%)	10 (17.8%)	46 (82.1%)	2 (3.6%)	48 (85.7%)	0 (0.0%)
	DA+SDA	8 (14.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0%)	0 (0.0%)
	N		0 (0.0%)	8 (14.3%)	0 (0.0%)	8 (14.3%)	0 (0.0%)
The experience was more engaging than manual.	A+SA	40 (71.5%)	12 (21.4%)	50 (89.3%)	2 (3.6%)	52 (92.9%)	0 (0.0%)
	DA+SDA	4 (7.1%)	0 (0.0%)	4 (7.1%)	0 (0.0%)	4 (7.1%)	0 (0.0%)
	N	0 (0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
AR app was helpful for understanding.	A+SA	38 (67.9%)2 (3.6%)	12 (21.4%)	48 (85.7%)	2 (3.6%)	50 (89.3%)	0 (0.0%)
	DA+SDA	4 (7.14%)	0 (0%)	2 (3.6%)	0 (0%)	2 (3.6%)	0 (0.0%)
	N		0 (0%)	4 (7.14%)	0 (0%)	4 (7.14%)	0 (0.0%)
Contents included app relevant to the lab orientation.	A+SA	44 (78.6%)	12 (21.4%)	54 (96.4%)	2 (3.6%)	56 (100%)	0 (0.0%)
	DA+SDA	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	N	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Augmented contents were appealing.	A+SA	30 (53.7%)	8 (14.3%)	36 (64.3%)	2 (3.6%)	38 (67.9%)	0 (0.0%)
	DA+SDA	4 (7.1%)	0 (0.0%)	4 (7.1%)	0 (0.0%)	4 (7.1%)	0 (0.0%)
	N	10 (17.9%)	4 (7.1%)	14 (25.0%)	0 (0.0%)	14 (25.0%)	0 (0.0%)
I will recommend the application for future students.	A+SA	44 (78.6%)	12 (21.4%)	54 (96.4%)	2 (3.6%)	56 (100%)	0 (0.0%)
	DA+SDA	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	N	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

5.4. Students' Views

We analyzed the above data and responses to the open-ended questions and only the most noticeable students' opinions are highlighted here, categorized by criterion.

5.4.1. Suitability

They affirmed that the application is far better and quick to get the information about the lab with just a pop-up in front without the assistance of anyone at their own convenience. Most students suggested that the effectiveness of the application could further be improved by adding more information about the devices as well as by adding more devices as reflected from the questionnaire and following students' comments:

- Provide support for more devices in the labs and add more information about them.
- General Datasheet for beginners might help.

5.4.2. Ease of Use

This was generally recognized as a conspicuous attribute of the technology for both learners and instructors, even for those who do not have proficiency in using software tools. The orientation activities were testified to be innately easily completed and there were no concerns raised from students as manifested from the responses below:

- "I like the application because as it is easy to use and allows me to access the resources on the equipment."

This application was built dynamically in such a way that content providers are able to categorize or include any other information related to the lab and update the documents instantaneously.

5.4.3. Engagement

The students appreciated the use of multimedia features such as videos and audio information. The students could experience and play with the augmentation proved to be a highly interactive feature. Some students interpreted the requirement of completing the quiz and affirmation on answers as feedback mechanism and a way to test the retention of the knowledge.

- "I liked doing the quiz. Shows how much I don't know about the equipment."
- "I liked how there are various options in terms of the media to understand equipment e.g., video, pdf, and text."

The solution proposed in the form of mobile app ascertained to be effective and possesses the ability of transforming the students' experiences of the lab orientation from an introspective fruition to an active and engaging one.

5.4.4. Novelty

Students unanimously stated that lab orientation AR-LabOr is an innovative method and highly suitable for the purpose which is evident from students' remarks as follows:

- "I like its usage of machine learning and AR tech to help with lab orientation."
- "I really like that it is able to capture the various essential lab devices and provide information regarding them".

5.4.5. Relevance

The student found the application relevant as they could easily relate the features of the lab to solve the problem they face during the lab. This is evident from the following remarks from the student.

- "Allows me to access resources on equipment."
- "I wish I had this app in my first hardware/software project."
- "Provided easily accessible information about activity in the labs that would have been useful during second year onwards."

5.4.6. Feedback

Students were of the view that the application provided real-time and useful feedback on their understanding of the matter and indicated gaps in their learning. Example of students' remarks about the feedback are provided below:

- "I liked doing the quiz. Shows how much I don't know about the equipment."
- "I immediately find out if my answer is right and wrong."

5.4.7. Flexibility and Control

The participants were of the view that this application provided them with a lot of flexibility as they could complete the orientation at any time without the hassle of booking and attending the session. They could complete at the own pace which is evident from the following students remarks:

- Thank God, I don't need to book and attend orientation session any more. I can do it whenever I want.

5.4.8. Problems and Suggestions for Improvements

Students also faced some problems when using this application. Some of the examples of students' comments are provided below:

- "Some of the image recognition identified stuff wrong."
- "The third mode could use some fixing. The rules function is a bit unintuitive."

The students also provided some very valuable suggestions to improve the performance and efficacy of the existing prototype.

- "Perhaps it could support more devices in the labs."
- "More features, and detailed information."
- "General datasheet for beginners might help."

6. Discussion

This study demonstrated the design and experimentation of mobile augmented reality based interactive education design for lab orientation of novice students at a metropolitan university. The findings indicate that students did not favor the existing instructor-led method of orientation as it fails to engage the students, which is in line with the findings of the past research which stress the significance of the engagement in learning process [65]. The lab orientation sessions timings often conflicted with the students' schedule resulting in missing the orientation. The student has no option but to book an alternative date to attend the orientation, resulting in usage of extra resources. Since this is compulsory for students to attend as missing it can bar them from working in the office, this entices them to miss the regular lecture resulting in missed learning opportunity which can lead to poor performance [66], unnecessary stress, and anxiety.

The study results also suggested that instructor-led orientation is not inclusive as some students are reluctant to ask question in the presence of other students due to communication barriers and they are often left seeking the answers to their queries on their own. Students also found that the documents related to the orientation were not kept updated with new information. Even some of the procedures had changed which were not reflected in the documents immediately, as printing takes a lot of time. Even technicians were not aware of the change in process. Many students want to receive feedback on their understanding of the procedure and this facility was not available with the existing approach. Furthermore, this method did not include any means to assess whether a student has acquired the required information. This method is passive in nature as a lab technician has to disseminate the required information in a limited time that results in one-way communication and there is no time to answer students queries, which results in surface learning. If a student fails to attend the orientation session, it creates a lot of hassle as it requires booking a new session, which causes a lot of unnecessary stress as students are competing for a limited number of places. In addition, some students have no other option but to book a conflicting session thus skipping another important course lectures as failure to attend this lab session might bar them from completing lab-based courses.

The above problem is solved by integrating modern technology into the education design. The use of technology only in the instruction design is not enough; it is also important that the material is presented to the user in an easier and preferred way. Therefore, it is important to take into account the user input and provide them with the best possible user experience. The results indicate that the students favored the use of integration of modern AR technologies into instruction design and preferred the use of mobile phones over the other available AR technologies. The reasons for this are the affordability of mobile devices as well the integration of hardware into modern phones, enhancing graphics processing capabilities thus making its deployment feasible for AR-based learning [67]. Previous studies have revealed that mobile AR has great potential for its use for pedagogical purposes and continues to offer many benefits [68,69]. The result also shows that students wanted the information to be presented to them using different modes, which is in line with multimodal communication theory [70]. The students were hugely in favor of the short duration videos and MCQs to reduce the cognitive load and it can also be an indication of their reduced attention span. The outcomes of the evaluation revealed that learner had positive feelings towards the developed prototype and they were overwhelmed when using this application. The use of AR-LabOr has motivated them and each element of ARCS model of motivational design was also satisfied as indicated by the survey results. The students perceived the application as a novel way of learning. The novelty brings features which immediately capture students' attention, which is essential for motivating the students. This is in line with the ARCS model of motivational design, which claims that for motivating students, it is vital to grab their attention through the use of attractive and stimulating medium or learning materials [63]. The students' attention was sustained through multiple ways including the ease of use and engagement as indicated in the results above. The attention motivation factor demonstrated learner's interest towards the task performed. AR-Labor enabled the supplementation of the sensory and emotional engagement of the students, by including audio-visual feature to communicate the information and making lab orientation an enjoyable experience. It also ameliorated the cognitive facet of orientation by offering deeper information about the rules, procedures, and equipment. This is also endorsed by the previous studies revealing that the type of interaction provided by AR-LabOr between the student and the learning content enhances students' cognitive and learning abilities [71]. The learners also found the contents of the application relevant and suitable for the purpose of lab orientation. It was observed that many students were excited when using the app and even recommended to other friends as evident from the students' views, above. The virtual objects' information overlaid on real-world objects or environment proved to be effective as it drew the attention of the students. Students found it very useful not only for refreshers but also to their year of study and found it particularly helpful in first-year courses involving the projects. They were quick to point out the problems which could be solved using this application, which indicates that the students found the application relevant which is

an essential element for motivating the students. The students recommended the use of AR-LabOr for upcoming students, meaning that the application was helpful in meeting the requirements and goals of orientation. The student also indicated that they found the application very intuitive and it provided real-time feedback on their learning which encouraged perseverance [72]. The short quizzes and other activities were designed in a way to provide continuous feedback to students on their apprehension and retention of the knowledge obtained during the information. The students were of the view that this application was helpful for the understanding of the lab procedures and provided control of learning. All these contributed towards satisfying the confidence factor of the ARCS model of motivational design. Finally, students also appreciated the feedback provided after each question and each stage of the orientation process and enjoyment of learning served as reward and brought a sense of satisfaction. Completion of the lab orientation session was also a source of reward and satisfaction as they were then eligible to work in the lab.

Overall, the findings indicate that AR-LabOr boosts student motivation when undertaking learning activities [73,74]. The extent of motivation was also evident from their engagement in the learning environment as all the students were exceedingly motivated and spontaneously participated in learning tasks without anticipating any external dividends [75]. There is a consensus among researchers that learners who are motivated to learn are expected to engage more and exert to complete the task compared to those who are unmotivated [76,77]. Instructors and instructional designers endeavor to create environments for learning that are intrinsically rewarding and encourage students to take part in academic activities founded on an aspiration to experience pleasure, challenge, and distinctiveness without involving any outside pressure or the anticipation of external reward. Students can be motivated intrinsically through seven aspects, namely; challenge, curiosity, control, fantasy, competition, cooperation and recognition [78]. AR-LabOr is equipped with most of these factors which are necessary for creating motivation among students and, in particular, increases the attention, satisfaction, and confidence factors of motivation [79,80].

Results suggest that the proposed augmented reality tool presents a more engaging, enjoyable, curiosity inducing, and motivating method of lab orientation when compared to traditional method of orientation. Furthermore, the addition of multimedia contents, assessments, and feedback mechanism significantly boosted students' engagement and made it richer in content. Although students found the existing features very suitable, they also suggested some improvements in performance.

Limitations of The Study

This application is only available for Android operating systems running on Android version 8.1 and above. This application can only be used within the lab; thus, users from a distant location are unable to tour around the campus virtually. In addition, the results are based on self-report study, as it required participants to fill in questionnaires regarding their user experience of the AR-LabOr app. A Qualitative method with detailed interview and observation of the participants could have been more prolific and factual. The participants were recruited using a convenience sampling technique, as it was fast and easier, thus subjected to limitations in generalization and inference, resulting to low external validity of the research.

7. Conclusions

Augmented Reality (AR) is an evolving technology that has been receiving excessive attention from academia and redefining the way we conduct activities at university. The existing method of orientation is manual, costly and creates logistical constraints, as it requires conducting multiple sessions for hundreds of students. It also creates a hassle for students due to conflicts in schedule and does not appeal to students due to it passive nature and non-inclusiveness.

The aforementioned issues provided enough motivation to design and implement a mobile app, AR-LabOr, offering a cheaper yet convenient way for lab orientation. In this paper, a mobile AR application is described aimed at replacing the traditional method of lab orientation, which helps students quickly and easily adapt to the educational environment by familiarizing them with the lab equipment, staff, and safety rules in a fun and interactive manner. This application targets the mobile (and tablet) platform due to availability, portability and embedded cameras. It provides a great way to engage students in lab orientation process, and students perceived it in a positive way as indicated by the post-design survey results. Eventually, these students will keep on using the AR-LabOr during their academic life, making it easier than ever for them to obtain the knowledge and resources essential for a successful and productive university career.

As future lines of research, we intend to extend the functionality of the application by including more equipment as well as provide support for iOS devices. In order to get more authentic results, we will implement quantitative methods such as in-depth interviews and observations, since the findings are based on self-reported data.

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Abbreviations

Acronym	Definition
AR	Augmented Reality
AR-LabOr	Augmented Reality Lab Orientation
ARCS	Attention, Relevance, Confidence, and Satisfaction
AUM	American University of the Middle East
ECSE	Electrical, Computer, and Software Engineering
GPS	Global Positioning System
HMD	Head-Mounted Display
HUD	Heads-Up Display
IC	Integrated Circuit
MCQ	Multiple Choice Question
OS	Operating System
UoA	University of Auckland
JSON	JavaScript Object Notation

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