AN INVESTIGATION OF MOBILE AUGMENTED REALITY-BASED LEARNING FEATURES IN COGNITIVE AND AFFECTIVE ENVIRONMENTS

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This thesis is presented for the degree of Doctor of Philosophy of Murdoch University, Perth, WA, Australia
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DECLARATION

I declare that this thesis is an account of my own research and contains as its main content, work which has not previously been submitted for a degree at any tertiary education institution.

Siti Salmi Jamali

ABSTRACT

This research focuses on the effectiveness of using mobile Augmented Reality (mAR) for learning. Prior research has focused primarily on developing virtual contents for Augmented Reality (AR) and has largely ignored AR in the mobile context. Herein, this research primarily aims to examine the effectiveness of learning through two modes: mobile Augmented Reality (mAR) and the Current Learning Mode (CLM). This research is extended to the development stage of a theoretical model, to evaluate the ability of mAR in improving the learning outcomes that guide a further consideration of growth in learning.

The first phase of this thesis is to examine the impact of how mAR influences the learning outcomes in cognitive ability and affective learning outcomes. The cognitive outcome was measured by the experimental method of using pre/ post-test performance achievement, while the affective learning outcome was measured by perceived usefulness, self-efficacy and satisfaction. This research contributes to cognitive ability and affective learning by investigating the differences in the learning outcomes and performance achievements of mAR within a self-centred learning environment, a classroom. The findings show that students' performance achievement, learning outcomes, perceived learning effectiveness and self-efficacy were greater in the mAR group, as compared to the CLM group.

Second, a theoretical model was developed and analysed using Structural Equation Modelling (SEM). SEM examines significant relationships between the determinants that integrate and facilitate effective mAR-based learning environments. SEM produces a feasible alternative in measuring the causal relationship amongst the constructs. This model evaluates to implement mAR as a learning aid in student-centred learning and to evaluate the motivation among students through the features of mAR, due to the absence of an in-depth understanding of the motivation of mAR-based learning from the current literature. This model also provides an insight into the causal factors amongst the dimensions of mAR. Finally, in the model, the moderating effects of students' characteristics, which include their experience and age, are investigated to determine the factors influencing mAR.

The findings of this research will help to verify the learning effectiveness of mAR, to improve the learning experiences, learning outcomes and performance achievements of students. Based on the results, it is confirmed that mAR can be leveraged upon and used as an optimum

learning tool, exemplifying the use of technology within an educational context. In the aspects of information retention and learning outcome enhancement, mAR is significant in education as it facilitates students' understanding by supporting abstract ideas throughout the course, enabling the students to learn in a limited period. Based on the results, it can be concluded that mAR is a technology that aids students with a better understanding of the subject matter and hence, resulting in greater motivation. With regards to the model fitness via the analysis of goodness-of-fit, all the results are confirmed as appropriate and good fit. Also, the model also shows a positive causal path from the mAR features' determinant. The thesis can also assist educational administrators and educational policy makers in gauging the importance of mAR as a learning tool. This helps mainly to overcome the issue of educators being criticised for the lack of real-life experience that is being exposed to students at the university level. Furthermore, academia can use the model's findings as appropriate groundwork to initiate other related studies, and this will help to fill the gap in the mAR learning area.

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LIST OF ABBREVIATIONS

ANOVA	:	Analysis of variance
AR	:	Augmented Reality
CFA	:	Confirmatory Factor Analysis
CFI	:	Comparative Fit Index
CG	:	Computer Generated
CLM	:	Current Learning Method
CPU	:	Central Processing Unit
C.R	:	Critical Ratio
EFA	:	Exploratory Factor Analysis
FBX	:	FiLMBOX
GB	:	Gigabyte
GFI	:	Goodness-of-Fit Index
GPS	:	Global Positioning System
GUI	:	Graphic User Interface
HD	:	High Definition
HMD	:	Head Mounted Display
HumAR	:	Human Anatomy with Mobile Augmented Reality
LO	:	Learning Outcome
MANOVA	:	Multivariate of Analysis of Variance
MAR	:	Mobile Augmented Reality
MARF	:	Mobile Augmented Reality Features
MicroSD	:	Micro Secure Digital
MOTIV	:	Motivation
POI	:	Point Of Information
PRC	:	Perceived Learning Effectiveness
RAM	:	Random Access Memory
RMSEA	:	Root Mean Square Error of Approximation
SAT	:	Satisfaction
SD	:	Standard Deviation
SDK	:	Software Development Kit
SE	:	Self-Efficacy
SEM	:	Structural Equation Modelling

SPSS	:	Statistical Package for Social Sciences
TAM	:	Technology Acceptance Model
TLI	:	Tucker Lewis Index
VE	:	Virtual Environment
VLE	:	Virtual Learning Environment
VR	:	Virtual Reality
2D	:	2-Dimensional
3D	:	3-Dimensional

LIST OF PUBLICATIONS AND CONTRIBUTIONS OF THIS THESIS

Journal Papers

J1. Jamali, S. S., Shiratuddin, M. F., & Wong, K. W. (2014). An Overview of mobile Augmented Reality in Higher Education. *International Journal on Recent Trends in Engineering and Technology, 11*(1), 10.

J2. Jamali, S. S., Shiratuddin, M. F., & Wong, K. W. (2013). A Review of Augmented Reality (AR) and mobile Augmented Reality (mar) Technology: Learning in Tertiary Education. *International Journal of Learning in Higher Education*, *20*(2), 37-54.

Conference Papers

C1. Jamali, S. S., Shiratuddin, M. F., Wong, K. W., & Oskam, C. L. (2015). Utilising MobileAugmented Reality for Learning Human Anatomy. *Procedia - Social and Behavioral Sciences, 197*, 659-668. doi: http://dx.doi.org/10.1016/j.sbspro.2015.07.054 (http://www.sciencedirect.com/science/article/pii/S1877042815040483)

C2. Jamali, S. S., Shiratuddin, M. F., Wong, K. W., & Oskam, C. L. (2015). "Development and Pilot Testing of Human Anatomy in Mobile Augmented Reality (HumAR)," Proceedings SCIECONF (ScieConf), ISBN: 978-80-554-0891-0, ISSN: 1339-9071, vol. 3, issue 1, pp.129-134, (http://www.scieconf.com/archive/?vid=1&aid=2&kid=90301-3282)

C3. Jamali, S. S., Shiratuddin, M. F., & Wong, K. W. (2013). Educational Tools: A Review of Interfaces of Mobile Augmented Reality (mAR) Applications. In U. o. B. Engineering and Computer Science, Computer Science and Engineering, University of Bridgeport (Ed.), *CISSE Online E-Conference* (Vol. 313, pp. 569-573). United States of America Springer.

SUMMARY OF THE CONTRIBUTIONS OF THIS THESIS

Chapter	**Contributions**	**Paper No.**
Chapter 1: Introduction Chapter 2: Literature Review	Literature survey on previous work in applying mAR in higher education, and regarding the interaction between learning, teaching and instructional design. The findings of this study contribute to our understanding of how a suitable mAR interface/ content delivery is to be designed for the education field, based on the success rate of the mAR interface in industries - to implement mAR in solving issues in the learning process, and the articulation of current mAR implementations in higher education.	C3, J2
Chapter 3: Research model and hypotheses development Chapter 4: Methodology	The impact of the mAR theoretical model in assisting students to improve their cognitive and affective learning outcomes where a template is proposed to guide the development of the mAR-based learning environment. This proposal could aid practitioners in studying the group differences or effects on different technological interventions.	J1
Chapter 5: The development of prototype of Human Anatomy in mobile Augmented Reality (HumAR) Chapter 6: Evaluation of user experiences in HumAR application	This study provides the platform and technical capabilities on how the multimodal interface of mAR was developed. The initial findings provide an insight into the influence of mAR implementation in learning for educators.	C2
Chapter 7: Result I: The effectiveness of learning using mobile Augmented Reality and Current Learning Method	The preliminary results show the reliability of the items' internal consistency in the survey questionnaire reliability, as well as the validity of the instruments of cognitive and affective learning. The findings encourage mAR to be further explored so as to improve students' performance in a viable population (in the actual data collection). Also, this study provides	C1

	equivalent cognitive and affective benefits of the learning activities, processes and styles.	
Chapter 8: Result II: How does mAR enhance students' learning experience and improve their learning outcomes? Chapter 9: Discussion and Conclusion	A model that identifies the relevant constructs and their relationships in mAR-based learning environments. A good fit of the theoretical model has been developed. This study makes a significant contribution by bringing us closer to the potential of mAR features as antecedent and reliable factors in the model. The results verify the direct and indirect effects of mAR features on the learning outcomes. Also, mAR features support and enhance the learning materials, and thus, improve learning retention.	

The findings of this research contribute to the comprehension of cognitive and affective learning that result in a classroom, student or self-centred learning, where the latter takes place in mAR-based learning environments. The findings establish that mAR-technology enhances learning effectiveness and improves the learning environment, performance achievement and learning outcomes. mAR technology also gives the students a chance to have facilitated access to the subject matter and mobilises the learning environment, regardless of the location and scheduled time of learning. This enables learning flexibility, particularly as this is needed in higher education. Additional, mobile learning using mAR offers convenience and brings the learning environment to the students, and this is important in learning complex subject matters like the human skeletal system. A prototype called Human Anatomy in mobile Augmented Reality (HumAR) offers convenient features to assist in the retention of knowledge as the topic can frequently be revised. Students do not have to be confined to learning and reviewing the physical human skeletal system based on laboratory availability. mAR facilitates the understanding of students by supporting abstract ideas during the courses and enables students to learn in a limited period. The findings in this research also offer empirical evidence on the advantages of mAR as an appropriate learning tool that enhances student motivation. Moreover, the studies reviewed in the literature show a paucity of systematic studies concerning university students learning and training through mAR. Therefore, the present research findings contribute to the literature and are dedicated to the issue of the effectiveness of mAR application through a validated model, in the context of the learning environment.

CHAPTER 1
INTRODUCTION

1.0 Background of the Research – Modes of Learning

Cognitive and social changes are a crucial process of learning in an individual's life (Gagne, 1977). At present, there have been shifts in the approaches of how people learn. Most notably is the integration of technology, particularly at the secondary school level and at institutions of higher learning (Fuxin, 2012; Holzinger et al., 2005). Both studies by Fuxin (2012) and Holzinger et al. (2005) add that technology provides students with easily accessible information and reference material when needed. Through the use of advancing technologies, the learning environment is stimulated, and students are motivated, leading to better quality educational outcomes (Chiang et al., 2014; Holzinger et al., 2005).

Furthermore, several factors have been highlighted to control the quality of learning, which includes individual students' aptitude, the level of motivation and learning pace (Markwell, 2003). Markwell (2003) argues that the quality and diversity of learning also hinge on the:

1) existence of the student body that is involved with the syllabus;
2) syllabus being studied;
3) teaching strategies;
4) assessment process and feedback methods;
5) learning resources availability such as libraries, laboratories, ICT, etc. and;
6) learning scope in the classroom that encapsulates in-house and extra-curricular environments, as well as the extensive institutional and social scope.

Based on these factors, the quality of teaching and learning design becomes significant, and the enhancement of the learning resources for both could be the factors worthy of consideration. Therefore, any type of educational application and domain specific technology has to be scrutinised, as such enhancements could result in enhanced learning methods, improved motivation among students and quality learning outcomes (Balog & Pribeanu, 2010; Di Serio et al., 2013; Markwell, 2003).

One such technology, Augmented Reality (AR), can be embedded into a learning environment in higher education. AR is a technology that augments or superimposes a real-time real-world image, with either two-dimensional (2D) or three-dimensional (3D) computer generated (CG) objects, allowing users to interact with an image or object (Azuma et al., 2001). AR technology can be viewed using various devices, including the see-through Head Mounted Display (HMD), desktop computer and projector, laptop computer with a front camera, or mobile device with an integrated back camera.

In this research, AR technology is presented through a handheld tablet device. A handheld device is "primarily designed to provide a suite of computing, communication and informational tools in a device about the size of a standard palm." (Techopedia, 2017). A handheld device may contain cellular communication, such as smart mobile phones and can include other computing devices, for instance, Personal Digital Assistants (PDA), tablet PCs, and portable media players are all considered handheld devices (Techopedia, 2017). In this research context, smartphones and Android tablet device were used and it is known as mobile Augmented Reality (mAR). This mobile assistive learning tool is implemented to increase the interest and engagement during the learning process (Balog & Pribeanu, 2010; Ke & Hsu, 2015). mAR is a mobile learning environment that provides students with the opportunity to gain easier access to the study material, regardless of the location and time (Kamphuis et al., 2014; Kucuk et al., 2016), and therefore offers learning flexibility, particularly in higher education institutes. This flexibility supports the learning according to the student's pace and learning styles (Bujak et al., 2013). Also, mAR "improves the success rate of physical interaction learning tasks, supports memory related learning activities and enable personalised and self-directed learning" (Chien et al., 2010; Looi, 2009; Shirazi & Behzadan, 2015).

mAR supports students in learning complex subjects by synchronising virtual and real environments (Wu et al., 2013) and engaging in the meaningful learning of knowledge building (Ke & Hsu, 2015). In particular, the subject of concern in this thesis is Human Anatomy. This subject is chosen due to the challenges in retaining memory (Ganguly, 2010). It is because, traditionally, Human Anatomy is taught through a combination of didactic lectures and practical laboratory sessions. The practical sessions often include organ system dissections of the human or alternatively the animal body. However, Ganguly (2010) reveals that this method (lectures and practical sessions) is not sufficient to produce long-lasting comprehension, concluding that the main challenge faced by students is their ability to retain information, especially after the lab hours.

Recently, Bergman et al. (2013) suggested that repetition of study material should be practised in order to retain information. However, time and location environment can affect the motivation of students, while better facilitation, i.e. time management, could result in the improvement of students' learning outcomes (Di Serio et al., 2013; Markwell, 2003). Furthermore, motivation plays an important role in maintaining the students' level of interaction with the learning activities (Chiang et al., 2014; Di Serio et al., 2013). AR technology has been advocated to relieve the difficulties associated with retention and motivation (Chehimi et al., 2007; Norman et al., 2012). Liu et al. (2012) contended that mAR has the potential to improve educational learning outcomes and experiences if it is effectively integrated into the learning classroom. Based on Akcayir and Akcayir (2017) mAR is increasingly widespread because mobile devices have become simpler and more portable, moreover the use of mAR in educational settings will increase (Akcayir & Akcayir, 2017).

With all the challenges that have been discovered in the literature on learning Human Anatomy, the use of mAR as an assistive learning tool has the potential to alleviate the timing, location, limited access resource and memory retention issues. Also, learning with mAR to enhance student-centred learning and provide advantages to learning activities through improved access to information, by motivating students and facilitating an effective interaction with their learning activities. Moreover, this could lead to the long-term retention of information (Norman et al., 2012).

1.1 Problem Statement

Personal computers (PCs) are widely utilised in many sectors, including education (AR in desktops). Previous research has shown the potential of AR in the education field (Akcayir & Akcayir, 2017; Wojcik, 2016). Nevertheless, in many cases, due to operational reasons, usability problems are bound to arise due to equipment bulkiness, stationary state, scale, hand-eye coordination, front camera for image projection and reduced 3D depth perception. Despite the extensive adoption of PCs, the use of mobile devices has grown exponentially in recent years (Fuxin, 2012). AR in mobile devices has been heralded as part of the major changes to the education of the 21st Century (Dede, 2007; Herrington & Herrington, 2007). Professionals and researchers have concluded that although mobile technology has multiplied in the 21st Century, mAR implementation is still confined in academic institutions and is a novelty in practice especially in learning materials, classroom settings or in the evaluation of tools, as reported in literature (Catenazzi & Sommaruga, 2013; Dunser et al., 2012; Hamilton, 2012; Herrington & Herrington, 2007; Shelton & Hedley, 2002; Zhu et al., 2014). Therefore, this research in mAR proposes to resolve the limitations in evaluating the effectiveness of mAR in higher academic learning environments and in improving the motivation of students, which can lead to enhanced retention throughout their learning process (Di Serio et al., 2013).

In relation to the subject of Human Anatomy, learning resources and techniques in the classroom contribute to the challenges in memory retention (Di Serio et al., 2013; Ganguly, 2010; Whelan et al., 2015) and this issue requires consideration. The present techniques employed to teach Science subjects involve the use of traditional methods and computers, a typical combination applied by the majority of higher learning institutions. According to Albion and Gibson (1997) and Saenz et al. (2015), learning through computer-based technology, particularly when it comes to Science subjects, has evidenced to be effective. Nevertheless, most research has primarily focused on the ease of using multimedia, instead of focusing on the effectiveness in information retention, which is more essential for learning (Sadler et al., 2015; Timmers et al., 2015; Van der Kleij et al., 2015; Venkataraman & Sivakumar, 2015).

Given these limitations and identified requirements, the work presented in this thesis will provide pedagogical contributions, within a suitable model, for the process of developing educational mAR learning operations as an effective learning aid in tertiary education. This research bridges the gap between the Current Learning Method (CLM) and technology-aided learning in the classroom. The CLM refers to physical teaching and learning materials that have been used in the lectures nowadays, and they include textbook, human skeleton, web-site, CD-ROM and slide presentation.

1.2 Purpose of the Research

Considering that effective learning is attributed to the use of technology in learning, the main aims of this research are to 1) investigate the effectiveness of mAR in influencing the learning outcomes and the performance achievements of students, to 2) in improving the motivation of the students in the learning process, thus in improving the memory retention. This research has advanced to the development stage of a theoretical model, to evaluate the ability of mAR in improving the learning outcomes that guide a further growth in learning.

Examining the relationship and interaction effects of mAR helps to shape the learning process in cognitive ability and affective learning environments. Cognitive ability in the context of this research is the ability of a person particularly in learning performance in memory retention. It is also closely linked to a working memory and long span of memory measures. While, affective learning environments, refer to their perceptual experiences of satisfaction, the appreciation of experience and attitude in the learning environment.

Understanding these factors would optimise the benefits of mAR technology and minimise the concern of retaining information and then boost the motivation among students within the higher education environment. Hence, due to its crucial part in the mAR field, research is required regarding mAR use to relay a more robust understanding of the experience, particularly in the context of learning tools and user evaluations of motivation (Azuma et al., 2011; Di Serio et al., 2013; Lee, 2012; Margetis et al., 2012; Rogers, 2012; Tarng & Ou, 2012; Ternier & De Vries, 2011). This research explores the relevant constructs that significantly fit and their relationships that play a vital role in the theoretical model. Moreover, the causal effects will be defined to discover which determinants have established the connections between the mAR features, motivation and affective learning outcomes. Finally, moderating the effects with learning characteristics (age and experience) of the students will be explored, and this will help to illustrate the significant role of the mAR learning environment.

A prototype of the mAR application is developed and used for the mAR-based learning environment to support the result in this research. It is termed 'Human Anatomy in mobile Augmented Reality' (HumAR). HumAR covers the topic of Human Anatomy and is embedded within multimedia elements that will be installed as an application on handheld devices, specifically Android tablets and mobile smart phones. Students manipulate the realism of 3D anatomical images within the mAR learning environment to enhance their understanding of the study topic and stimulate the individual's motivation to learn. HumAR will be focusing on a specific topic which is the lower limb. Nevertheless, other examples of similar mobile applications are available for learning and education, for instance, Anatomy Cards Anatomicus, Visual Body Anatomy, Anatomy 4D and Human Anatomy RA and much more.

1.3 Research Objectives

The specific objectives of this research are:

1. To investigate the significant differences in the learning outcomes and performance achievements between mAR mode and CLM mode;
2. To investigate the effects of a student's motivations towards learning through the use of mAR technology;
3. To determine the dimensions and antecedents that fit into the model of mAR effectiveness;
4. To determine the moderating effects of students' learning characteristics on the mAR learning mode, in terms of the learning outcomes.

1.4 Research Questions

In order to achieve the objectives of this research, the following research questions are proposed:

1. Are there any significant differences in the learning outcomes, perceived learning effectiveness, satisfaction and self-efficacy between students' learning in mAR and those learning via the CLM?
2. Are there any significant memory retention differences in the performance achievements between students' learning in the mAR mode versus the CLM mode?
3. Are there any significant differences in the performance achievements of intrinsically and extrinsically motivated students in the learning modes?
4. Are there any significant differences in the learning outcomes for highly motivated and less motivated students in the mAR mode?
5. Are there any significant differences in the performance achievements of highly motivated and less motivated students in the mAR mode?

6. Are there any significant interaction effects between students' motivation and the learning modes, related to the performance achievements?
7. Are there any significant interaction effects between students' motivation and the learning modes, related to the learning outcomes?
8. Do the dimensions and antecedents fit the model of mobile Augmented Reality (mAR) effectiveness?
9. Are there any moderating effects of the learning mode on students' learning characteristics and outcomes?

1.5 Research Scope

This research examines the effectiveness of learning through the application of mAR technology, a technology that is highlighted in the tertiary education's learning environment. Accordingly, the study objectives are developed to investigate the effectiveness of learning among students in mAR-based learning and those in the CLM. This research determines the student's motivation towards mAR technology. The motivation is measured through dimensions; intrinsic and extrinsic. Moreover, the motivation level is extended with the poorly (score<19.0) and highly (score>19.0) motivation scores in the learning outcomes and performance achievements. The mAR contains information on one of the topics concerning Human Anatomy. In addition, this chosen topic is recommended and supervised by a qualified teaching professional at the School of Veterinary and Life Sciences, Murdoch University, Perth, Western Australia, Australia.

1.6 Research Design

The research model is designed to achieve the main aims and research questions (Figure 1.1). A Virtual Learning Environment (VLE) conceptual model, developed by Piccoli et al. (2001), will be adopted to guide the evaluation of the mAR-based learning environment, as compared to the CLM. VLE has offered a relatively complete view of the framework for investigating the effectiveness of technology-mediated learning in higher education. Piccoli et al. (2001), defined VLEs share many similarities with computer-aided instruction (CAI). For example learners can access the material independently. Additionally, VLE concept is broader than CIA and adds the learning environment, process and experience amongst technology, interaction and control. Hence, the technology-mediated learning VLE is adopted as a platform for this research.

The target population of this research is higher education students, aged between 18 to 28 years old. Students from the Science field, for instance Human Anatomy, Biology, Mathematics, Chemistry and Foundation unit classes, were involved. These groups of students were selected using purposive sampling to address the problem in the learning process and can account for the sources of variation in the students' responses in the Science study. The quasi-experiment is deployed in the research design to investigate the effectiveness of learning using mAR. The evaluations were conducted with the quantitative methodological approach, through surveys and questionnaires as the instruments for data collection.

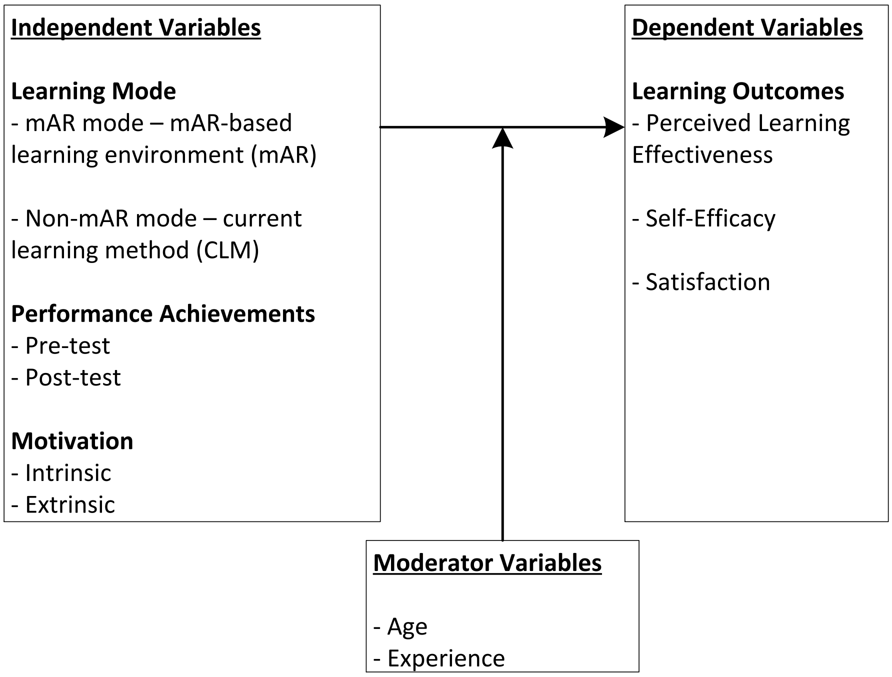


Figure 1.1: Conceptual model and their causal relationship in the mAR-based learning environment

1.7 Significance of the Research

The findings of this research will help to verify the learning effectiveness of mAR to improve the learning experience, learning outcomes and performance achievements of the students. The importance of AR in the educational environment, as it mainly facilitates students' understanding by reinforcing abstract ideas throughout the courses, enabling them to observe and gain experience in a limited period (Chang et al., 2008; Chang et al., 2016). Furthermore, AR has received increasing attention in recent years (Chang et al., 2016; Wu et al., 2013). Nevertheless, the majority of the studies dedicated to mAR concentrate on the significance of mAR technology, its effectiveness, attention, behaviour and motivation, without delving in detail into the intrinsic and extrinsic aspects of learning (Albrecht et al., 2013; Catenazzi & Sommaruga, 2013; Chang et al., 2014; Chiang et al., 2014; Juanes et al., 2014; Ke & Hsu, 2015). Empirical studies have not supported or rejected the assumptions about how motivation can boost one of the cognitive abilities, for instance, memory. The points listed below outline the perception, experience and knowledge gained from this research which will provide benefit to the educator, students, and instructional designers and mAR software developers in the future:

- This research is anticipated to endorse the positive differences in discovering mAR-based learning that can enhance students' understanding, as well as promote optimistic learning effects and performance accomplishments.
- It is expected to provide flexible learning alternatives based on the pace of the study and to facilitate learning anytime and anywhere.
- With easy access and mobility features, it leads students towards higher motivation levels by absorbing and stimulating their working memory, to retain information for longer than usual.
- A high degree of fidelity produces interesting and engaging interaction effects in the learning environment. Understanding the consequences of behavioural intention, intrinsically and extrinsically through the attributes of mAR, would be beneficial to educators and students.
- An initial theoretical model of the causal factors of learning effectiveness in the mAR-based learning environment contributes in filling the gap of deficiency of causal paths in mAR. The findings will distinguish the determinants that play an essential role in mAR learning, thus, enriching learning. With mAR notable features, students' characteristics are given careful attention in the shaping of the learning outcomes and performance achievements more effectively.

In order to better understand the characteristics and the scarcities in mediated-technology learning based, this research has considered other related research in education especially in AR (Weng et al., 2016) and VR (Ip et al., 2016; Lee, 2011). Furthermore, the findings of this research are expected to help educational instructors, administrators and policymakers in understanding the importance of mAR as an educational tool to increase learning outcomes in higher education institutions.

1.8 Contributions of the Research

The findings of this research contribute to the comprehension of cognitive and affective learning that result in a classroom, student or self-centred learning, where the latter takes place in mAR-based learning environments. The findings in this research establish that mAR-technology enhances learning effectiveness and improves the learning environment, performance achievement and learning outcomes. mAR technology also gives the students a chance to have facilitated access to the subject matter and mobilises the learning environment, by using the markers provided. It is mentioned, it increases the student's attention explicitly because it promotes interesting interactions between the markers and the content at anytime (Diegmann et al., 2015; Kamphuis et al., 2014). This enables learning flexibility, particularly as this is needed in higher education. Additional, mobile learning using mAR offers convenience and brings the learning environment to the students at any time according to their own pace (Bujak et al., 2013; Kamphuis et al., 2014), and this is important in learning complex subject matters like the human skeletal system. The HumAR's convenient features assist in the retention of knowledge as the topic can frequently be revised. Students do not have to be confined to learning and reviewing the physical human skeletal system based on laboratory availability. mAR facilitates the understanding of students by supporting abstract ideas during the courses and enables students to learn in a limited period. Therefore, the present research findings contribute to the literature and are dedicated to the issue of the effectiveness of mAR application, in the context of the learning environment.

The findings in this research also offer empirical evidence on the advantages of mAR as an appropriate learning tool that enhances student motivation. Moreover, the studies reviewed in the literature show a paucity of systematic studies concerning university students learning and training through mAR. This research shows that mAR accommodates individual differences and the interaction effects of students with high or poor motivation learning levels. The manner in which individuals interact with different learning environments are explained, and such information may assist instructors in identifying self-centred treatments that can accommodate individual learning.

Additionally, these research findings can also assist educational administrators and educational policy makers in gauging the importance of mAR as a learning tool that facilitates individualised learning and raises the importance of effectiveness and success of mAR as an educational instrument could have important implications for course preparation, computer hardware and software and other support software development. Furthermore, academia can use the model's findings as appropriate groundwork to initiate other related studies, and this will help to fill the gap in the mAR learning area.

1.9 Outline of this thesis

This thesis examines the effectiveness of mAR in learning in the context of higher education and is divided into nine chapters as outlined in Figure 1.2.

Chapter 1 presents the background, aims, objectives and research questions of the effectiveness of learning using mAR.

Chapter 2 reviews the relevant past and current studies of mAR in higher education. In this chapter, the general understanding of mAR and the hardware requirements are explained. This chapter also discusses the gaps and problems found in the learning environment.

Chapter 3 presents a theory and model that is adopted in the mAR model. This chapter further explains the adopted dimensions and variables from the relevant model, regarding the effectiveness and learning capability using technological intervention in affective learning outcomes.

Chapter 4 provides a detailed explanation of the research method developed and implemented in this thesis. The chapter consists of the research design, approach and technique, setting of the study, population, study sample and sampling method, as well as the data collection instruments and procedures.

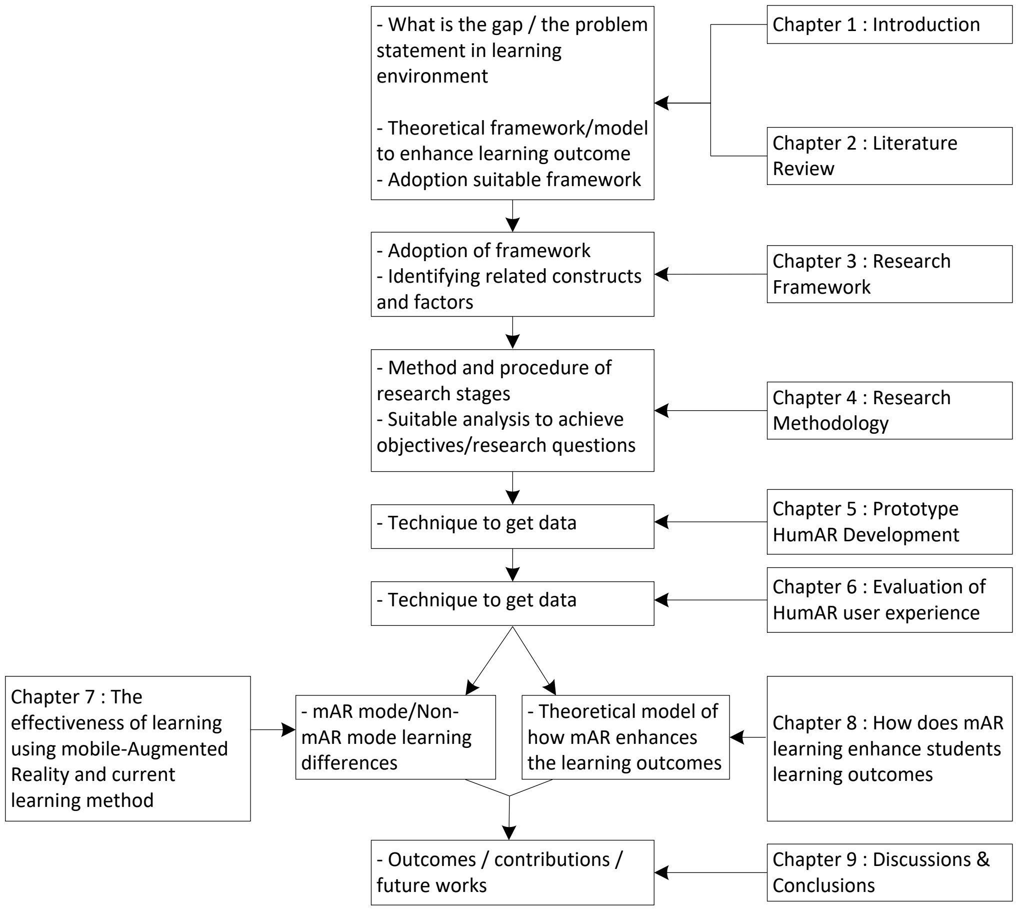


Figure 1.2: Overview of this thesis

Chapter 5 discusses the mAR prototype development and expands on the prototype's features, software specifications and hardware requirements. The prototype is used as a tool to support data collection. The development process of the prototype is described in this chapter.

Chapter 6 presents the results of the pilot study in the form of an evaluation of user experience in the prototype HumAR application. This chapter also includes the initial results of the reliability and validation of the instruments before the actual event of data collection.

Chapter 7 discusses the data analyses results. Descriptive statistics and statistical analyses are presented on the effectiveness of learning through mAR and the CLM modes. The analyses were conducted using the Statistical Package Social Science (SPSS) software.

Chapter 8 endorses that the mAR model fits in the context of higher education. The model suggests that the latent variables enhance and stimulate students' understanding. The chapter also describes the way the model is tested, with regards to modelling in the mAR environment in higher education, with the help of Structural Equation Modelling (SEM).

Chapter 9 is the final chapter. It discusses the two major outcomes of this research. Firstly, the results are discussed in relation to the effectiveness of learning through mAR and non-mAR modes and the implications of them. Secondly, the suitability of the model is evaluated. Lastly, this final chapter provides a concise conclusion of the major findings and impact of this thesis. The final sections of the chapter are dedicated to the research impacts and recommendations for future work.

CHAPTER 2
LITERATURE REVIEW

2.0 Overview

The purpose of this literature review is to set the foundation of the specific research objectives as described in Section 1.3 of Chapter 1. This chapter describes mobile Augmented Reality (mAR) and critically reviews how mAR has been implemented in an education setting. This chapter further describes the application of mAR in various fields, for example, advertising, entertainment and tourism, then adopts its benefits and successes in an educational setting; the related model of the theoretical foundation are then adopted; and finally, a model of how the mAR-based learning environment can enhance learning outcomes is presented.

2.1 What is Mobile Augmented Reality?

The idea of AR is related to and extended from Virtual Reality or VR (Ternier & De Vries, 2011) or the Virtual Environment or VE (Hollerer & Feiner, 2004). AR is positioned between the real and virtual environment, and the state within these two environments is called a 'mixed reality'. A mixed reality integrates digital information in the real environment. According to Azuma (1997), AR merges both types of objects either in 2D or 3D, leading to an interaction in real time, which reflects the term, 'mixed reality', as depicted in Milgram's Virtuality Continuum (VC) (Figure 2.1). In Figure 2.1, as the point moves towards the right that leads to the VE, users will experience an environment surrounded by objects that exist in a VE. In the VE, real objects may be added and mixed with the virtual ones. In contrast, on the left side of Milgram's VC, as it moves towards the real environment, there is a range of digital objects, such as videos, audios, images, and haptic or touch, that can be embedded and overlaid. These can be augmented on top of the real environment, which allows the users to interact with them (Azuma, 1997; Carmigniani & Burko, 2011; Carmigniani et al., 2011).

AR requires a collection of technologies to enable it to work. Some of the required technologies include global positioning and tracking, location-based computing and services, as well as wearable computing and wireless communication (Hollerer & Feiner, 2004). mAR brings AR to handheld devices, such as smartphones and tablets. This is different from the traditional VR or VE setting of being a specifically purposed environment (Hollerer & Feiner, 2004). Emerging and affordable mobile technologies, such as the ones found in smartphones, have made it possible for mAR to be applied in practical settings.

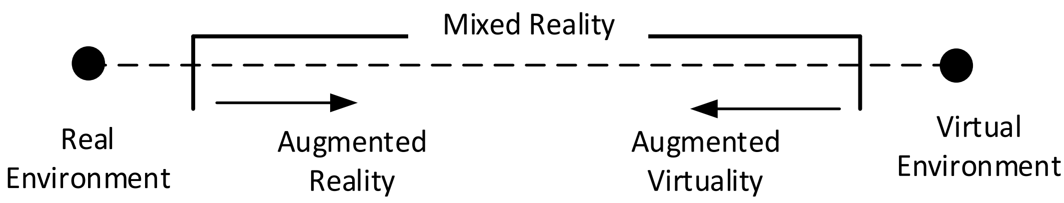


Figure 2.1: Milgram's Virtuality Continuum

mAR allows the user to move freely throughout a wireless environment and does not constrain the user to one location. As a display technology, mAR could replace the typical wired Head Mounted Display (HMD), binoculars and helmets, by projecting the visuals using the mobile or smartphone and Android tablet device's screen. "Moreover, the cost of typical head tracking systems in current HMD system is exceedingly expensive"(Hill et al., 2015). This is the rationale why mAR was selected for this research. mAR is a fast emerging field within AR (Irshad & Awang 2016), with recent research involving the use of GPS tracking, user studies, visualisation and collaborative applications. One study by Fuxin (2012) states that mobile devices, such as smartphones and tablets, are the most widely used technology, as found in the areas of advertising, construction, education, entertainment, journalism, maintenance, personal location-based information, navigational aids and tourism, and mobile would be a great platform for AR. By introducing mAR as part of daily living, it is not only shifted the form of how the information is delivered, but the user can interact with the quality and quantity of relevant information in both virtual and the real world at the same time (Adhani & Awang, 2012). When developing a mAR application, the main components, including display, tracking and interaction, should be considered.

2.1.1 mAR Display

mAR comprised of the integration of a real environment in a virtual environment. In order to use the mAR application, a display device is required to enhance users' perception and accommodate the interactions with the application (Carmigniani & Burko, 2011). Mobile devices use an inbuilt back camera to capture the real world surroundings, while the front panel display is used to view the augmentations, such as the information that have been highlighted by specific AR markers (Azuma et al., 2011).

2.1.2 Tracking

Tracking is a method of registering what is being captured by the camera and how the virtual image generated is merged by a computer. The two most common tracking methods used are position and orientation. Tracking the position initiates the graphic system to render views from the users' position. There are several other methods for mAR tracking, which includes the use of digital cameras or other optical sensors, GPS, accelerometer, solid state compass and wireless sensor. In this case, the quality and level of accuracy mainly depend on each technology. The orientation of the virtual image is subjected to the physical position of the mobile phone. Most mobile phones have built-in sensors e.g. accelerometer or GPS to "register the virtual viewing position of the tracked mobile device from its camera (i.e. viewpoint) and spatially register the viewpoint with digital images that are displayed on its screen. This enables mobile devices such as tablets and smartphones capable of supporting AR as they can accurately place the user's viewpoint in the computer-generated environment in relation to its position in the real world. This situation helps to eliminate motion sickness that is related to VR applications using HMDs since tablets and smartphones do not entirely cover the field of vision of the user" (Hill et al., 2015).

2.1.3 Interaction with the content in mAR

One common method of interaction between the user and mAR is "selection and manipulation" via a haptic interface, such as a touch screen on a mobile device (Hurst & Wezel, 2012). A successful interaction with mAR is defined as "an application that enables the user to focus on the application, interacts with the device naturally and in a socially acceptable way, and provides the user with private information" (Carmigniani & Burko, 2011). For a mobile handheld display, users utilise the touch screen to interact with the augmented object, e.g. to zoom in or out, to rotate or to click.

2.1.4 mAR User Interfaces

Hurst and Wezel (2012) propose a basic user interfaces concept for the application with small feature sizes, specifically if the buttons and icons are to be clicked or touched by large-sized fingers. This application (Figure 2.2) is presented in 3-Dimension (3D), and the concept has been widely used in most applications that have the same function as a desktop computer (e.g. mouse clicking) (Ashraf et al., 2012; Latif, 2012; LearnAR, 2012). However, in the same study, Hurst and Wezel (2012) emphasise that the small screen size issue is natural, depending on the gesture of interaction, and based on the user's finger tracking in front of a phone's camera. While this approach can be applied to gaming and entertainment, it has to be "in combination with standardised graphical interface objects such as widgets or controls, which enables users to control arbitrary applications" (Schall et al., 2011).

Figure 2.2: mAR Interaction via touch screen (Hurst & Wezel, 2012)

2.1.4.1 Types of mAR Interfaces

There are four main mAR interfaces which include: tangible interface, collaborative interface, hybrid interface and multimodal interface.

- ***Tangible Interface*** supports direct interaction by utilising real equipment and physical objects and tools (Carmigniani et al., 2011), such as mobile phones, car keys and spectacles. TaPuMa (Mistry et al., 2008) is one example of a table top screen map, which uses personal belongings to interact and access any relevant information or directions from the map.
- ***Collaborative Interface*** refers to multiple displays supporting the co-location and remote activities. Co-location enhances the display and improves physical collaboration using 3D interfaces. Remote sharing allows multiple mAR devices to be integrated with multiple locations, hence enhancing teleconferences (Carmigniani et al., 2011). The TELEPORTAL supports "a group of users fully immersed and engaged with a 3D task in a high information bandwidth environment. It allows multiple local and remote collaborators to simultaneously interact with virtual and real objects and models" (Wichert, 2002).
- ***Hybrid Interface*** allows users to focus on a specific physical object. Once the system recognises the object, relevant information will be displayed on the screen (Carmigniani et al., 2011).
- ***Multimodal Interface*** merges the real objects and the system in the form of languages and behaviours, i.e. speech, touch, natural hand gestures or gaze (Carmigniani et al.,

2011). Also, multimedia elements are present in the application to enhance user interaction. For example in learning Biology:Organs developed by (LearnAR, 2012), it shows the human organs at the correct location in the body. Using this application, students can study using the interactive mAR application, rather than having to examine an actual replica of a human skeleton or referring to textbooks. With a multimodal interface, it offers a more meaningful learning experience for students, which they are able to interact with the application by clicking the buttons just like a courseware and the augmented object will automatically be displayed (Carmigniani et al., 2011).

2.2 Review of mAR in industries

This section summarises some of the industries where mAR has been utilised.

2.2.1 Advertising

mAR is widely utilised in advertising and branding, where this technology enhances the needs of marketing strategy (Ashraf et al., 2012). According to a survey done by the web AR Survey of Web-based AR Applications, it recognises that mAR is a powerful medium for product advertising in marketing specification (Ashraf et al., 2012). The application of mAR can attract and efficiently convey product information, as well as for the purpose of sales promotion, to the extent that it involves the point of sales (POS) (Ashraf et al., 2012). With regards to the cost, mAR is cheaper compared to television advertisements (Chehimi et al., 2007). In reality, television advertising cost can be high. According to commercial television experts, “there are some factors that determine the cost of broadcasting a TV ad. Such variables include the region it will be aired (some areas are more expensive than others); time of day; day of the week; quantity of viewers; length of the commercial (15 secs, 30 secs, 60 secs or a 30 min infomercial) and how frequently the ads will run. More fundamentally, the cost of a 30-second spot varies according to the number of viewers expected to be watching it” (Alger, 2016). On the other hand, the mobility feature of mAR creates a viable business opportunity, since users can view information anytime and anywhere. Furthermore, it helps users to interact effectively with the product advertisement.

Proton is a Malaysian car manufacturer that offers the facility of mAR for potential buyers to view and become familiar with its product offerings. Proton integrates interactive buttons that allow existing or potential buyers to seek out more information, such as specific details about their car (Ashraf et al., 2012). Heinz also uses mAR as part of their marketing, where the Heinz brand uses AR technology as part of their persuasive strategy. It was built by Blippar, a mobile application developer specifically for android and iOS devices. During the buying process of a bottle of ketchup, users may discover various recipes that can be accessed from that particular product in the form of an interactive multimedia application with mAR (Blippar, 2014; Scholz & Smith, 2016).

2.2.2 Entertainment

AR allows users to overlay digital information upon the real world. In a creative atmosphere, AR enriches the information by presenting parts of a multimedia production specifically for storyboarding. In a study of mAR application, Harris (2011) implements mAR in short film segments from the movie *The Lion King,* which were attached to the markers. Contents, such as static images, texts and additional movie clips, which had repeatedly been streamed, were added to the storyboard. It offered a demonstration of every scene during the discussion process. The advantage of this implementation was its ability to make almost immediate amendments during the discussion, with visual images that granted high understanding about what would be executed in the scenes for the final production.

One of the most popular mAR games is Pokemon Go (Niantic, 2017; Pokémon, 2017). It is a geolocation game that built on Niantic’s Real World Gaming Platform. It encourages players to search far and wide in the real world to explore the surroundings and discover Pokemon. As the user moves around, user’s smartphone will vibrate and get notified that user is near a Pokemon. The user will be able to scan the area by using the Pokemon Application on the smartphone’s then aim for a Pokemon and throw a Poke Ball to catch it. This game also provides PokeStops where it directs you to the interesting places such as public art installations, historical markers and monuments which user can collect more Poke Balls and other items. The excitement user can enjoy is even more with Poke Gym. The user will be detected by the Global Positioning System (GPS) if there are gyms nearby. This mixed reality gym brings the user to another level to train his/her Pokemon collections for a power battle. Pokemon Go encourages people to mingle around especially with Pokemon fan and have fun at the same time.

Another entertaining game is called Ingress (Niantic, 2017; Pratt, 2017). It is a game that involves groups of people under The Resistance, that corporate each other to save the world from the dark energy known as The Enlightened. The corporation is across neighbourhoods, cities and countries to achieve the victory. Ingres transforms the material world into the landscape for a planetary game of mystery, intrigue and competition. The user needs to strategize the struggle of being played out globally. The game able to trail the player around the world, plan for next steps and communicate with others by using an intelligence map.

2.2.3 Tourism

In tourism, visual information is provided by the mAR application. Some of the information includes restaurants, places of interests, attractions, historical facts, Wi-Fi hot spots, car parks, ATMs, transportation routes along with local news and weather (Hu & Tsai, 2016; Scarles et al., 2016; Shabani & Hassan, 2017). For example, Magnetic London (London, 2017), by simply pointing the smart phone's camera viewfinder towards one location of interest, that specific location will automatically be shown on the screen. The display of visual information is made possible through the concept of Point of Information (POI), where relevant information is being displayed and updated at anytime and anyplace in real time. Other mAR browsers and applications that provide and support mAR in tourism are; Wikitude AR Travel Guide (WikitudeGmbH, 2017), Incredible India (Blippar, 2016), 3D Augmented Reality Tourist Guide (MetaioGmbH, 2017), Layar Webinar (Layar, 2017) and Travel Portland (Layar, 2017). Some AR-supported applications are meant for specific purposes, for instance, to obtain information while sightseeing at certain places. This travel guide application offers travel and tourism, accommodation, events, and food and beverages options in their browser. The Layar (Layar, 2017) browser provides added features by directing tourists to certain locations, i.e. an art gallery, and upon arrival further information becomes available, i.e. the architectural description of the art gallery.

2.3 Comparing the Different mAR Interfaces in Various Industries

There are important interfaces that need to be considered between the education field and other applications, summarised in Table 2.1. The summary depicts the current types of mAR interfaces in numerous applications as discussed earlier (see Section 2.1.2.1), suggesting that the current use of AR in mobile devices lacks in a few important interfaces, especially in education.

To date, only two interfaces have been applied in education: tangible and collaborative interfaces. For advertisements, it effectively implements all types of interfaces based on the high sales rate of the product through the use of product advertisement. A study by Chehimi et al. (2007) proved that an advertisement employing the multimodal technique, coupled with the interactive courseware function, delivers quality products and services without forcing customers to view the information and make quick purchasing decisions. Customers are typically driven by their curiosity when using the mAR application. They feel a “heightened degree of intrinsic motivation, intense concentration and enjoyment while engaging with mAR, and increased learning and participation” (Chehimi et al., 2007).

An interface should have intuitive and interactive characteristics between the user and the mAR system. Multimodal and hybrid interfaces are emerging as the most preferred interfaces for future mAR applications. Furthermore, the multimodal interface is highlighted to deliver factual learning activities, due to the interaction in terms of their “robustness, efficiency and expressiveness” (Ashraf et al., 2012; Carmigniani et al., 2011). With a multimodal interface, students are expected to be able to interact with the topic where they can enlarge a specific part of the subject matter and explore it in more detail. mAR with a multimodal interface is the most effective medium to convey information and increase sales (Ashraf et al., 2012). Besides being beneficial to educators, adopting and implementing the same concept of multimodal interface in any learning environment may boost students’ learning outcomes and their motivation levels.

Table 2.1: Comparing The Different mAR Interfaces in Various Industries

Current mAR	**Types of mAR interface**							
Application	**Tangible**		**Collaborative**		**Hybrid**		**Multimodal**	
Dimension	**2D**	**3D**	**2D**	**3D**	**2D**	**3D**	**2D**	**3D**
Education	√	√	√	√	x	x	x	x
Advertisement **Interactive product evaluation*	√	√	√	√	√	√	*√	*√
Entertainment	√	√	x	x	x	x	x	x
Tourism	√	√	x	x	√	x	x	x

2.4 mAR Application in Education

AR has been recognised to be an effective tool in increasing the motivation in learning (Balog & Pribeanu, 2010). Balog and Pribeanu (2010) argue that AR should be further explored to support mobile learning environment in higher education. Although there are few important issues relating to AR in terms of equipment, integrating emerging technologies with the traditional learning method, development cost, as well as maintenance and conflict, comprehensive assessment regarding the application of mAR is perceived to have the ability to resolve these drawbacks (Balog & Pribeanu, 2010). mAR is created with the potential to enhance the user's learning experience, as well as to capture students' attention and increase their respective motivations.

This research proposes a mAR model for higher education to enhance students' attention through mAR features, especially to increase motivation, as well as when dealing with complex objects, for example in learning the anatomy of the human body. In studies conducted by Ganguly (2010) and Whelan et al. (2015), biology students have difficulties retaining the information they learn. This research proposes a mAR model as a response to the findings discovered by Ganguly (2010) and Whelan et al. (2015), to help students retain information for a longer period. In this study, the current learning methods being utilised in learning Human Anatomy in higher education are Conventional Learning and Computer-Supported Learning. These are explained below:

2.4.1 Conventional Learning of the Human Anatomy

The conventional way of learning Human Anatomy is grounded on the dissection of a plastinated cadaveric specimens (or routine cadaveric dissection/prosection) (Ganguly, 2010). This type of learning method enables a detailed study of the structure of skeletal elements. However, challenges arise in learning about the anatomy of the human body. Some of the challenges are resource and learning based, such as storage of the cadavers, moral issues, quality and a limited quantity of cadavers, limited lab opening hours and low retention of information (Chien et al., 2010; Ganguly, 2010; Whelan et al., 2015). This research focuses on these gaps in learning about Human Anatomy by proposing a learning style that mobilises the learning environment using mAR.

2.4.2 Computer-Supported Learning of the Human Anatomy

Learning the human anatomy using the computer is common nowadays (Attardi & Rogers, 2015; Canty et al., 2015). With the CD-ROM or web-based courseware, this learning method includes using multimedia like audio, video, image and text, and is further supported by valuable and additional links. Adopting visual images, in particular, is part of the spatial learning style, and it has attracted researchers to implement it more as part of their teaching methods (Chariker et al., 2011; Juan et al., 2014; Latif, 2012; LearnAR, 2012). Multimedia elements have made a great impact in establishing a more interactive learning environment. Due to all the issues that have been raised, during the study of Human Anatomy, technology intervention assists to enhance the learning style. By using anatomic visual resources, complex structures can be better understood (Paalman, 2000; Trelease et al., 2000). Below are some examples of how mAR technology is being utilised in higher education.

A. Creating Augmented Reality in Education Project

The Creating Augmented Reality in Education project presents two cases of mAR (Latif, 2012). The first case uses mAR in clinical skills for lab treatment is from the Centre for Excellence in Teaching and Learning (CETL) in London, United Kingdom, where students are exposed to a clinical lab environment to learn the skills needed in the operating theatre, as well as in accident and emergency circumstances (Latif, 2012). mAR helps to overlay those environments into a normal practice, increasing students' knowledge and enriching their clinical skills. At the same time, this will help to reduce their anxiety towards practical clinical skills. mAR also supports the self-centred learning concept and does not require additional hours to run a lab or an academic staff or lab technician to monitor the students.

As part of the locality project for the nursing students' orientation, the second case is related to tracking the location of the points of interest around the East London route (Latif, 2012). Students are required to use the Layar browser on their mobile devices to find certain places and complete the tasks given. By using mAR, students can access information associated with the surrounding areas. Students work in groups to apply collaborative and self-directed learning.

The next example is the Augmented Collaborative Campus (ACCampus)(De Lucia et al., 2012). The ACCampus refers to the physical environment equipped with the Quick Response (QR) codes. In order to obtain information, students must be able to interact with areas which have QR codes. The areas include wall class boards, windows and doors. These areas allow students to interact freely with the QR codes provided by the university to acquire relevant information and activities. Furthermore, by using mobile devices, the augmented information can be projected onto a 2D or 3D interface. The ACCampus uses QR codes instead of GPS because the mAR walls are indoors where the GPS signal is unavailable. The mAR environment can also be viewed by aligning the mobile phone camera with the QR code.

B. Cultural Science Field Trip

The Cultural Science Field Trip is another study conducted by Ternier and De Vries (2011), whereby mAR is utilised in different types of game design, delivery channel and pedagogical approach of case studies. This application is designed for navigation and exploration using the gaming concept.

Case study 1: *Florence* had the concept of a scavenger game and situated learning. Students must explore the street view vision using GPS and utilise the full function of the application. After obtaining the street view vision, they are required to complete the given tasks.

Case study 2: *Hostage* requires decision-making skills in completing given assignments by navigating using a mAR application.

These two location-based case studies applied team-based efforts amongst students to encourage collaboration with one another, particularly to aim for high scores, which increased learning performance. In this study, Ternier and De Vries (2011), discovered that the quality of the essays from the mAR group is higher than that of the non-AR group. Therefore, mAR has the potential to enhance the learning outcomes and educational experience, if it is integrated effectively into the learning environment.

2.5 Overview of Learning in Higher Education

2.5.1 Learning Activity and mAR

In this research, the learning activity refers to 'students' actions or movements of gestures during teaching. In this context, digital technology has contributed a new aspect into teaching anatomy, and it possesses a significant value to the students in terms of memorising and visualising effectively (Ganguly, 2010). Because the learning activity takes place in the learning environment, it is deemed to be a part of it; in the sense of place, time and space (Piccoli et al., 2001). According to Piccoli et al. (2001), the learning environment appears to be the factor that remains the same, as opposed to behaviour and efficiency, the subject has to match the learning environment with the help of technology. Therefore, in this research, mAR is the aided technology that assists in students' learning Human Anatomy.

Learning is often related to two conditions: location and time (Holzinger et al., 2005). There are several related challenges under these two conditions, including accessing important laboratory references because of the confined working hours of the lab, as well as the limited physical resources such as human skeleton for revision (Chien et al., 2010; Whelan et al., 2015). The above challenges may prevent the long-lasting understanding of the subject, but these can be tackled through the introduction of alternative teaching tools like mAR (Holzinger et al., 2005). The information is always accessible via a mobile device (Norman et al., 2012) and repetition of the knowledge can be learned when required. In contrast, CLM such as textbooks and slide presentations are insufficient in providing visual comprehension of the topic under study (Cahyaningrum et al., 2016). Moreover, the physical skeleton as a learning aid in the lab has limited access due to the stringent lab opening hours. Thus, it can be concluded that the mobile learning tool offers the advantage of mobility and helps to improve the learning environment. In this respect, mobile learning is referred to as ubiquitous learning (Anders & Mark, 2004; Lee et al., 2012; Norman et al., 2012), as it provides students with information through handheld devices, also known as learning tools, for example, mobile phones and tablets.

2.5.2 Learning Process and mAR

In this research, mAR is asserted to have positive effects on the learning process and the learning experiences by two aspects: cognitive learning and affective learning outcomes.

2.5.2.1 Cognitive Learning

The learning process based on the cognitive perspective has been extensively addressed in a current study by Laks (2015). According to Laks (2015), learning is a process consisting of three phases, as presented in Figure 2.3, starting with information reception and experience acquisition. The next phase entails information storage as knowledge and the transformation of such knowledge in a specific subject matter. In this phase, the retrieval and indexing of stored information are facilitated in the brain and memories are produced as a result. The experience and memory process are interconnected with each other. The memory will be registered during the learning process in the context of the experience. Moreover, when new things are learned, they get connected through interactions and inter-linkages with previously experienced interactions. Consequently, performance and behaviour are interrelated with both prior processes (Laks, 2015).

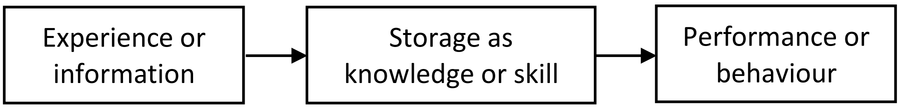


Figure 2.3: The learning process

The premise behind the principles of behaviourism, cognitivism and constructivism, is frequently built on learning. Cognitive learning is deemed to be mental constructs in the mind of the student, as well as the learning process that culminates in the memory (Siemens, 2014).

There are various methods of enriching learning using computer intelligence, which could include multimedia elements (Park et al., 2015), simulation using virtual reality (Kockro et al., 2015; Moloney & Amor, 2003), robotics demonstrations (Chiou et al., 2011) and augmented reality (Chien et al., 2010; Chow et al., 2013; Dunleavy & Dede, 2014; Martin-Gutierrez et al., 2015). Previous studies have shown learning that is assisted with technology relies upon the cognitive interaction between learning and technology before learning outcomes are successfully produced. This environment allows students to access and interact with the content in a manner that assists in goal achievement through technology use (O'Shea & Elliott, 2015). O'Shea and Elliott (2015) present on the growth and technological progress, whereby the basic aims behind technology learning do not go over the content display, despite their flexible capabilities. O'Shea and Elliott (2015) further stress on the requirement to differentiate between technologies that assist teachers in grade management, classroom management, and those content technologies that contribute towards enhancing interaction and engagement or learning results. Also, O'Shea and Elliott (2015) add that it is pertinent to accept that technology has the potential to maximise interaction, engagement or achievement and sans pedagogical design. The possibility to do so is debatable. Hence its value is minimised. In order to improve cognitive learning, the mAR features should be differentiated in the learning process (O'Shea & Elliott, 2015).

With regards to the mAR features, Chiang et al. (2014) point out some of its specific characteristics that can enhance cognitive learning. These include the interaction of real and virtual objects in real-time. There are three types of interactions that mAR supports. The first type is student-learning content interaction. A prior study showed that this interaction type contributes to students' cognitive and learning abilities, including comprehension, memory and imagination (Dalgarno, 2004). These abilities, particularly memory, have involved the capacity of the cognitive load. Specifically, the memory in cognitive learning has to do with the cognitive ability in maintaining information, and it is termed cognitive load. According to Young et al. (2014), the cognitive load includes the subsystem of sensory, working memory, as well as long-term memory. The sensory subsystem is considered as the perception and processing of visual information. Moreover, most of the sensory information stems from sounds and images in the form of printed words and pictures. On the other hand, pictures are perceived by the eyes and are contained momentarily in the visual sensory memory system. Both the visual and auditory systems are exposed to a considerable amount of information, but it can only contain a specific information piece for a very short time. The second type is an interaction between the student and the learning aid, while the third type is the interaction between students. These three types of interaction enable students to identify the solutions (through cooperation and teamwork) to the problems that arise in situations.

In order to retain information following a class or lab session (Ganguly, 2010; Whelan et al., 2015), mAR-based learning has been proposed in the literature. In this regard, mAR is considered to be a ubiquitous learning that offers expedient access to materials and is easy to use as a learning tool (Looi et al., 2010). Through the employment of mAR, it is possible to minimise or even bridge the gap between formal and informal types of learning (Looi et al., 2010). While the former type of learning has a fixed curriculum that is based in the classroom, the latter is one where the students unintentionally participate in the institutional time. In the classroom where learning is coupled with mAR-based learning, information is expected to be retained longer (Section 7.2.4.2).

2.5.2.2 Affective Learning and mAR

mAR technology draws the students' attention into visualising a layer of information on real objects through handheld devices like tablets and smartphones (Majid et al., 2015). Affective learning outcomes in relation to this include the perceptions of students with regards to their satisfaction, attitude, respect and appreciation for their experiences during the learning process (Sharda et al., 2004). Similarly, Majid et al. (2015) reveal positive students' experience in learning through the use of mAR, in terms of their enjoyment and perception. mAR's features and flexibility urge students to interact and achieve their tasks actively. In addition, learning with the help of mAR motivates students and maintains their interest in learning (Chiang et al., 2014; Majid et al., 2015; Siemens, 2014).

2.5.3 Learning Styles and mAR

The initial phase in understanding the student is to profile their preferred learning style(s) (Laks, 2015). Students have their own preferred learning style and distinctive capabilities to absorb important information that is useful for them. Laks (2015) categorises the learning styles into four categories:

- *Auditory Learning* – individuals learn best through hearing the information and the spoken word during the classroom session.
- *Visual-textual learning* – students learn and process information through writing down texts. This type of student often gets motivated to learn through textbooks and notes.
- *Visual-graphical learning* – students leverage on graphical images or pictures, diagrams, visual aids, mind maps and images while learning.
- *Kinaesthetic learning* – students mostly learn through movement, touch, body language, physical gestures, or activity while processing information. They can learn through the manipulation of physical objects, in this case, the physical human skeleton.

Learning using mAR incorporates all four styles of learning and students are benefitted by the use of the 3D feature learning style (Lee, 2011). This comprehensive combination of learning styles also encourages independent learning among students as depicted in Figure 2.4, indicating that students do benefit from visually graphical and self-directed activities during and after the classroom activities (Laks, 2015). The Analysis, Design, Development, Implementation and Evaluation (ADDIE) model (Hannum, 2005; Laks, 2015; Muruganantham, 2015) integrates eight principals of transformed learning styles, consisting of instruction, learning towards a student-centred interactive and collaborative learning process. The instruction is observed to be more organised, cohesive and student-centred. Thus, cognitive problems and information can be comprehended and retained better respectively.

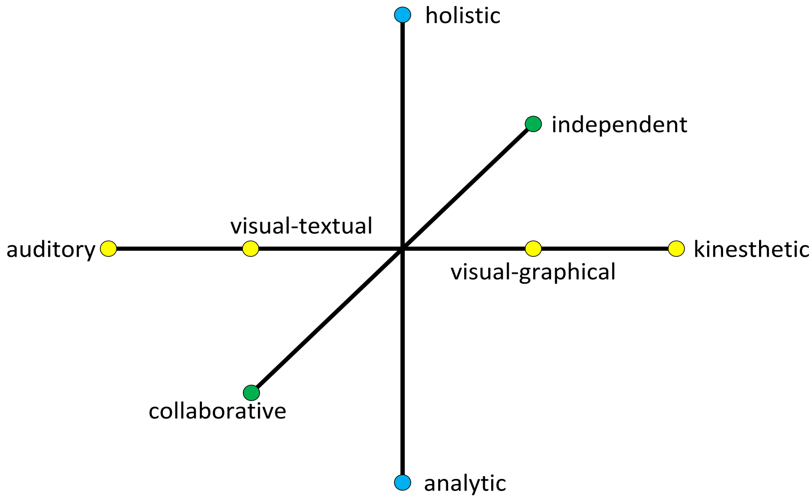


Figure 2.4: A 3D learning style space adapted from Laks, 2015

Aside from the above, students are allowed to learn the subject through digital means that can be realistically improved through multimedia elements. A combination of the current learning methods (using textbooks, slide presentations and the physical human skeleton) and virtual learning materials engage students more effectively in the learning process (Dunleavy & Dede, 2014; Klopfer & Sheldon, 2010). Furthermore, Dunleavy and Dede (2014) show that learning experiences through mAR in the physical environment forms an environment that is digitally immersed. In addition, Dede (2007) states that immersive learning refers to the interactive media comprising different levels of digital forms in subjective impressions within a realistic and extensive experience. Along with a study conducted by Tomi and Rambli (2013), where interactive learning can change passive students to active learners. Hence, the inclusion of mAR features in immersive digital learning improves the learning environment, particularly in the higher learning institutions (Dunleavy & Dede, 2014).

2.6 Summary

This chapter provided a comprehensive outline of mAR and its evaluation in various applications in the context of education and different industries. The capability of mAR technology in supporting the processes and different styles of learning has also been discussed. In addition, the learning issue is addressed with proposed methods to overcome the drawbacks of mAR learning environments.

CHAPTER 3
RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

3.0 Overview

This chapter discusses the suitable theoretical foundations for the development of the theoretical model of how mAR enhances the learning outcomes. The hypotheses for this research are also developed in this chapter. In the previous chapter, based on the overview of learning in higher education and, by analysing the factors associated with the theoretical model and related to the mAR technology used in learning, the drawbacks are then described. However, literature related to the theoretical model still remains limited, especially in terms of systematic and empirical tests relating to how mAR supports and enhances learning. Therefore, one of the research objectives is to fill in the knowledge gap. This research also investigates the relevant constructs and measurements that play substantial roles in the affective learning outcomes.

3.1 Model for Determining the Effects of the mAR-based Learning Environment

In any learning environment, the learning outcomes are vital. FitzGerald et al. (2012) propose a theoretical model which categorises the learning outcomes into three components which are:

(i) the cognitive learning outcomes which include knowledge, comprehension, application, analysis, synthesis and evaluation;

(ii) the affective learning outcomes which include students' perceptions of satisfaction, motivation, respect and appreciation for the learning experience and

(iii) the psychomotor learning outcomes which refer to efficiency, accuracy and response magnitude.

A model adapted from Piccoli et al. (2001) (Figure 3.1), draws the attention in the learning outcome using a Virtual Learning Environment (VLE) method. The term 'VLE' is defined as "computer-based environments that relatively open systems, allowing interactions and encounters with other participants". The VLE is where students are individually involved in the self-centred learning and classroom environment, together with diverse technologies, as an effective tool to support learning. Throughout this VLE model, the learning outcome is measured through the effectiveness of three dimensions: performance, satisfaction and self-efficacy.

In the VLE, one of the dimensions is human, and it comprises of the interaction between teachers and their students. It is then broken down further into maturity, motivation, technology comfort, technology attitudes, previous experience, computer anxiety and epistemic beliefs. However, for teachers, the breakdown of the same dimension includes technology controls, technology attitudes, teaching style, self-efficacy and availability. In most cases that involve the development within a VLE, design is the salient issue that must be put into consideration because it gives great impact to the users.

In the model suggested by Piccoli et al. (2001), the design dimension consists of the learning model (objectivist and constructivist), technology (quality, reliability and availability), student control (pace, sequence and content), content (factual, procedural and conceptual knowledge) and interaction (timing, frequency and quantity). In this VLE model, effectiveness is the dependent variable consisting of three antecedents, for instance, performance (achievement, recall and time on task), self-efficacy and satisfaction. Effectiveness is measured through performance and is much needed to achieve the learning goals, to recall what has been learned from the subject, as well as to complete given tasks on time. Self-efficacy symbolises people's opinion on how a student is capable and competent in organising and executing the required actions, while satisfaction represents the evaluation of the effectiveness of the learning environment in an academic setting. In the field of teaching and learning, it is important to assess students' satisfaction because it relates to students' engagement in their learning activities, when and where they favour those activities. This determines the ability to learn at their own pace and to mark the significant material to engender a positive interest.

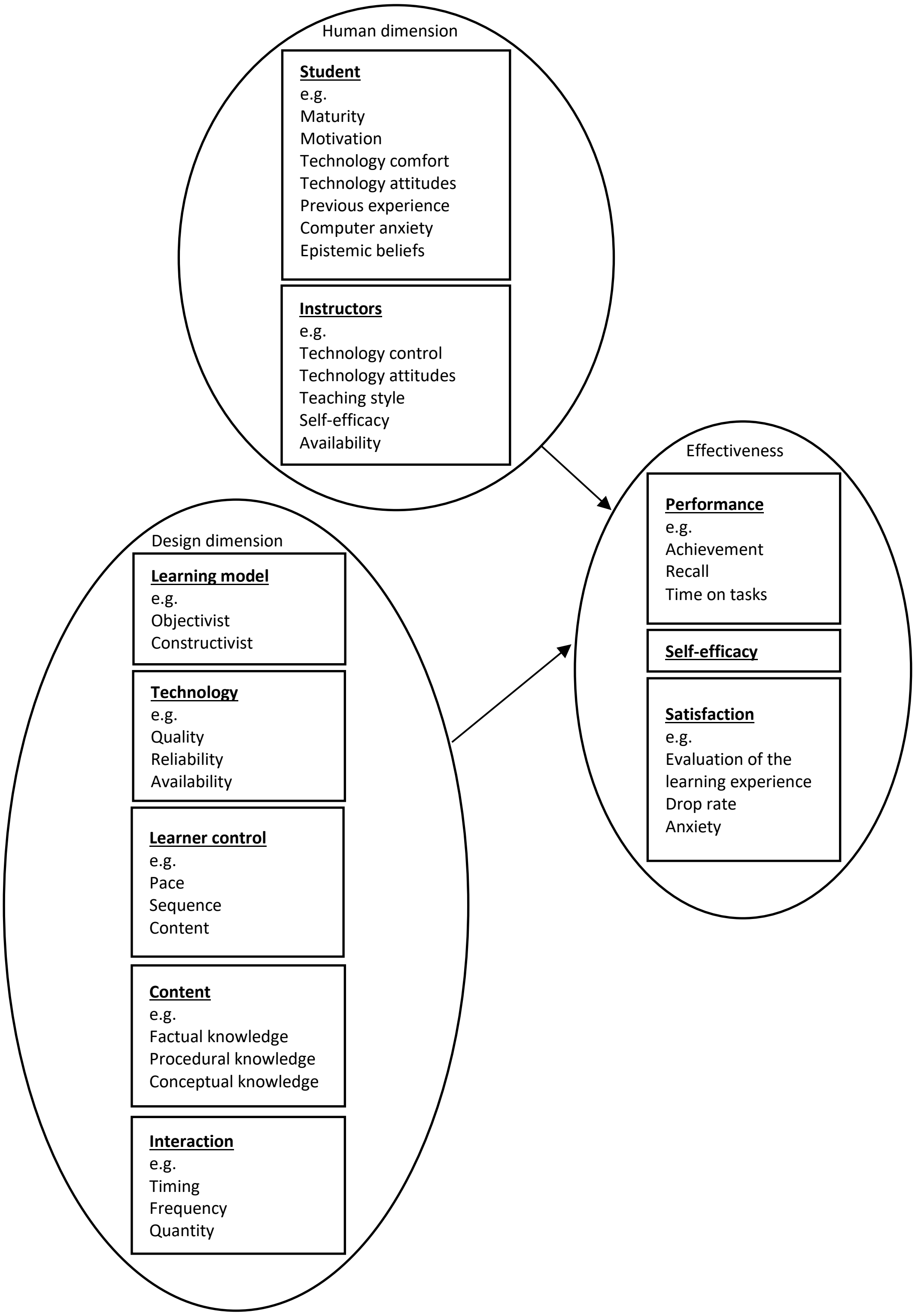


Figure 3.1: Dimensions and antecedents of the Virtual Learning Environment (Piccoli et al., 2001)

3.2 Hypotheses for Determining the Effects of the mAR-Based Learning Environment

To address the objectives and research questions 1 to 7 as described in Chapter 1 - Section 1.4, the following null hypotheses are developed.

H_{01}: There is no significant difference in the learning outcomes between students in the mAR mode and students in CLM mode.

H_{02}: There is no significant difference in perceived learning effectiveness between students in the mAR mode and students in the CLM mode.

H_{03}: There is no significant difference in the satisfaction among students in the mAR mode and students in the CLM mode.

H_{04}: There is no significant difference in the self-efficacy between students in the mAR mode and students in the CLM mode.

H_{05}: There is no significant difference in terms of memory retention in the performance achievement between students in the mAR mode and students in the CLM mode.

H_{06}: There is no significant difference between students' intrinsic and extrinsic motivation in the performance achievement of students in the mAR mode.

H_{07}: There is no significant difference in the performance achievement between highly and poorly motivated students in the mAR mode.

H_{08}: There is no significant difference in the perceived learning effectiveness between highly and poorly motivated students in the mAR mode.

H_{09}: There is no significant difference in the satisfaction between highly and poorly motivated students in the mAR mode.

H_{10}: There is no significant difference in the self-efficacy between highly and poorly motivated students in the mAR mode.

H_{11}: There is no significant difference in the learning outcomes between highly and poorly motivated students in the mAR mode.

H_{12}: There is no significant interaction effect between student's motivation and learning modes, which is related to performance achievement.

H_{13}: There is no significant interaction effect between the student's motivation and learning modes, which is related to the learning outcome.

H_{14}: There is no significant interaction effect between the student's motivation and learning modes, which is related to perceived learning effectiveness.

H_{15}: There is no significant interaction effect between the student's motivation and learning modes, which is related to satisfaction.

H_{16}: There is no significant interaction effect between the student's motivation and learning modes, which is related to self-efficacy.

3.3 Model for Evaluating How mAR Enhances Learning Outcomes

This research will cover the mobile applications of AR, as described earlier in accordance with the learning objectives. The research investigates the learning activities within environments that improve learning outcomes for the students using mAR. Several variables such as motivation, learning modes, perceived learning effectiveness, self-efficacy and satisfaction of the learning outcomes will be measured. The specific focus will be the potential use of mAR in university settings. Education has been selected as the domain due to the lack of the AR medium and the use of mAR for the learning activities. The use of mAR and its impact on students' learning outcomes will be measured.

This section presents a model that can regulate the tools and measure the motivation of student-centred learning using mAR, as illustrated in Figure 3.2. Previous studies focused on the development of virtual contents for AR, but were deficient in mAR, particularly in regards to the measure of students' motivation. Although mAR is common, there is still a need for more research on its use to convey a compelling mAR experience, specifically in a user evaluation of motivation (Azuma et al., 2011). In particular, motivation studies that utilise mAR as a learning tool in education are lacking (Lee, 2012; Margetis et al., 2012; Rogers, 2012; Tarng & Ou, 2012; Ternier & De Vries, 2011). The theory of the dimensions and antecedents of the VLE by Piccoli et al. (2001) are adopted when investigating the effectiveness of the learning outcomes in tertiary education. The VLE is specifically selected due to its similarity in the antecedents required to assess the mAR model presented in this research. Referring to Figure 3.2 and the model from the VLE (Piccoli et al., 2001), one attribute, namely motivation, is selected from the Human Dimension, as the platform of the model. Based on this conceptual model, a new model is developed to evaluate how mAR enhances the learning outcomes, as shown in Figure 3.3. The fits of the hypothesised model are assessed using Structural Equation Modelling (SEM). The model expands to learning modes/groups and student motivation. The conceptual model comprises two independent variables which are: (i) learning modes (mAR-based and CLM-based) and (ii) motivation (the effectiveness of mAR in the learning environment is to be investigated). Meanwhile, the learning outcome as a dependent variable holds three attributes, which are namely perceived learning effectiveness, satisfaction and self-efficacy.

This research focuses on a greater profundity of the group and individual effects, as well as using mAR as an intervention in the learning environment. As a result, this model helps to identify the constructs to be considered as independent and produces implications and insights. The relevant constructs and variables are described in the following subsections.

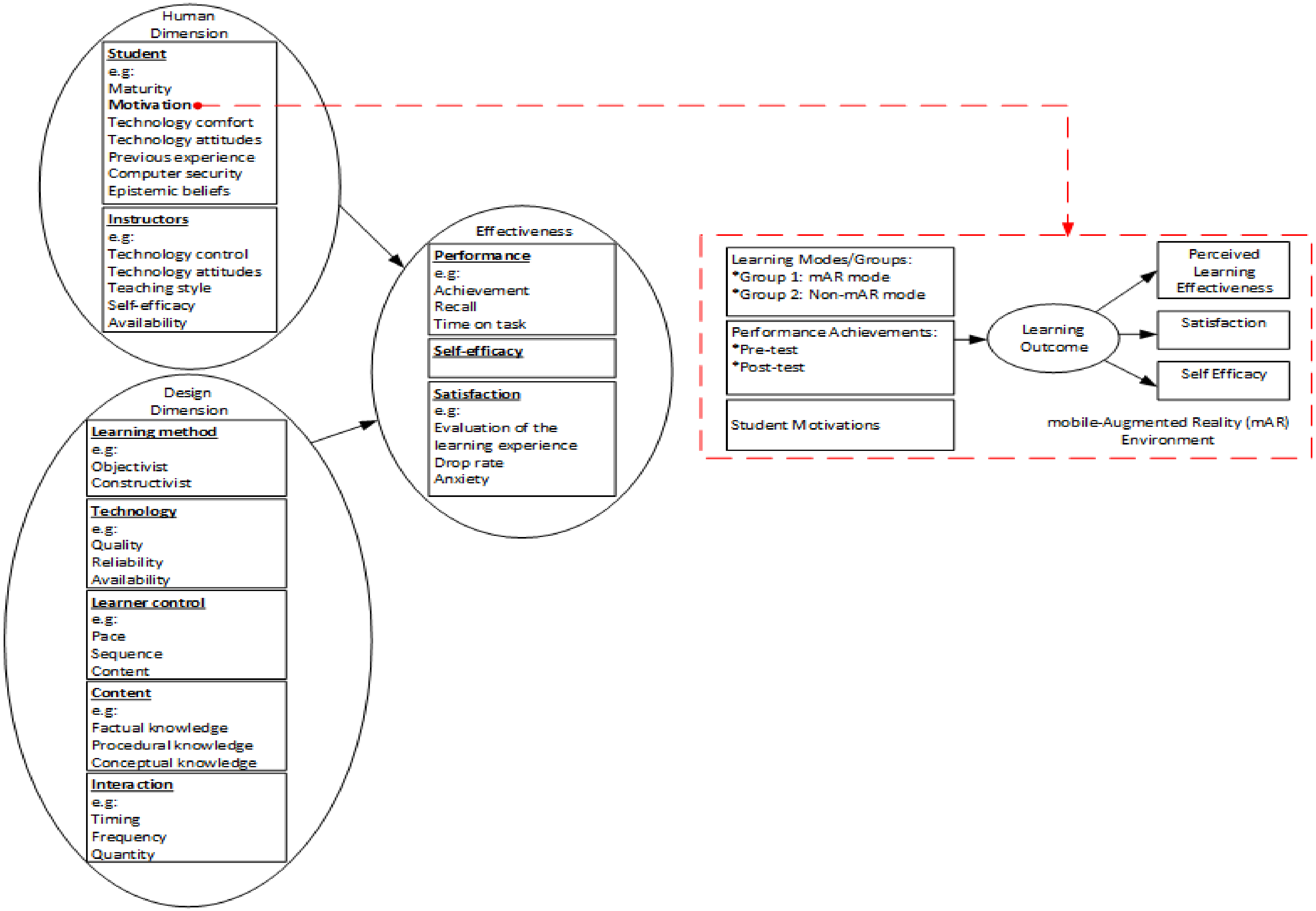


Figure 3.2: Calibration of the Research Model

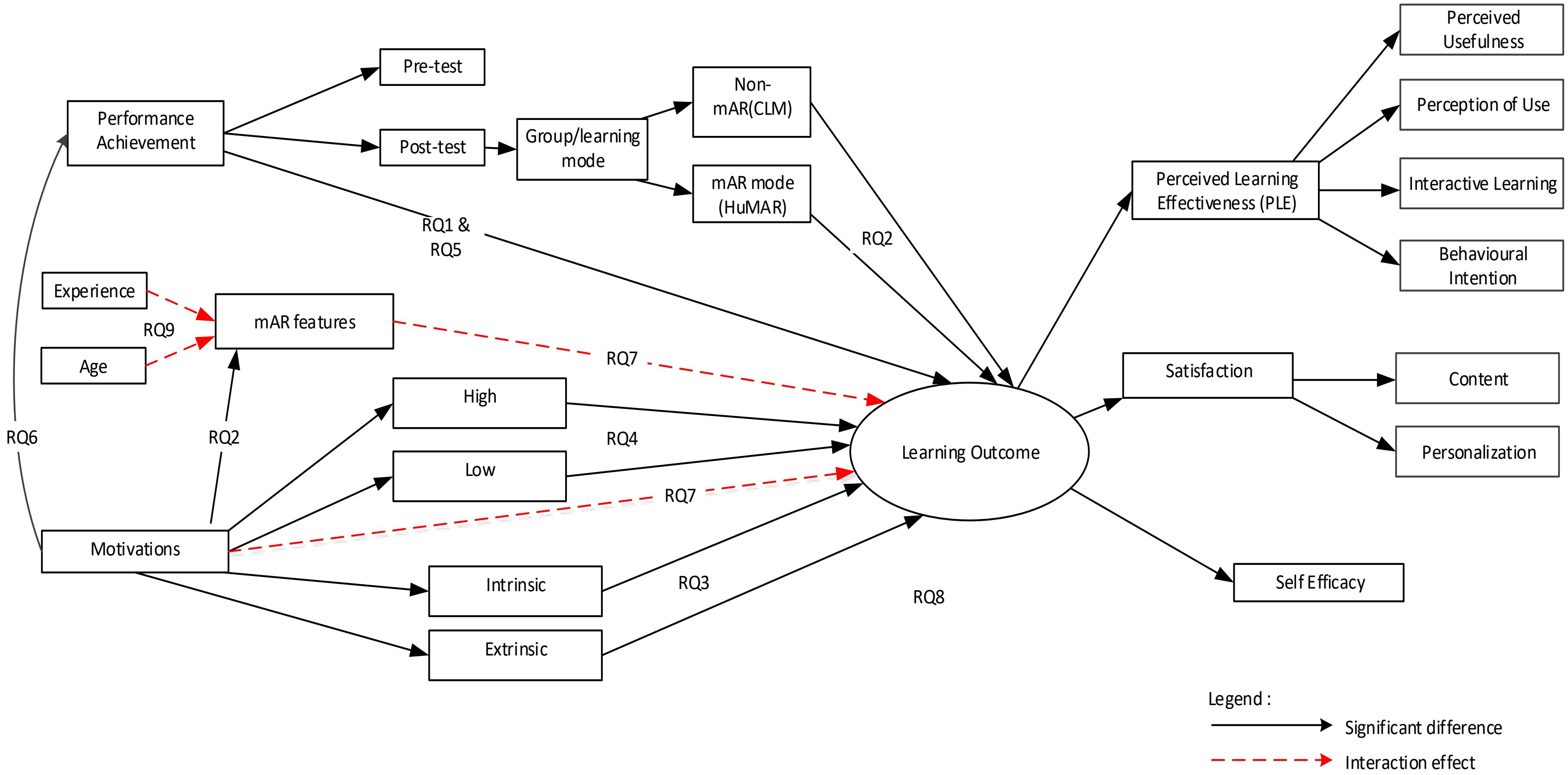


Figure 3.3: Model to evaluate how mAR enhances learning outcomes

3.3.1 Learning Modes/ Groups

Many researchers believe that more research and development is needed in the area of mAR for education (Catenazzi & Sommaruga, 2013; Chu et al., 2010; Hwang et al., 2008; Kaufmann et al., 2005; Tsai et al., 2012; Zhang et al., 2006). The research and development include the maturity of tools for content creation, learning strategies, publishing, improving the efficacy and hosting virtual content that can be used by educators. Therefore, in addition to studying the successful application of the mAR method as well as students' attitudes, this research also needs to be carried out due to the lack of AR adoption in academic settings, particularly in identifying its enhancement of learning outcomes. Consequently, institutions have inadequate funding, thus resulting in a lack of implementation of mAR, as cost and device are the central issues (Lee, 2012). Nevertheless, after ten years, the cost is not the main reason anymore, as the majority of mobile devices are equipped with all AR requirements (Carmigniani et al., 2011).

In achieving the main aim of the research, there are a few sub-motives linking to the prior objective, such as making comparisons in terms of the learning effectiveness between mobile-AR-based learning (AR mode) and the current method of classroom learning (non-AR mode), as well as recognising the differences between student's attitude towards the AR technology. The groups are divided into two, which are mAR and non-mAR mode. The learning modes/ groups consist of the learning backgrounds, styles and preferences. Age and experience, in particular, are the specific components to better understand the important factors that determine the way that the students acquire knowledge.

3.3.2 Motivation

By adopting the VLE context in the proposed conceptual model for mAR, the learning outcome can be measured through the experimental method to obtain the result. In this research, the characteristics of motivation are intrinsic and extrinsic. These characteristics are the antecedents in the proposed model to obtain the effect of students' motivation and to improve students' learning outcomes. It also includes the context and the process of learning using mAR as a medium.

Context delivery is a critical factor for effective use of e-learning tools and content, which includes the precise learning context consisting of access to the tools. Context can become a facilitating factor in students' support, or it can produce significant obstacles to the delivery of information. It is also the process of learning in formal curricula-based learning time and during informal learning. In most part, it reflects upon methods, theories and models used to support learning practices. It needs to hold up deeper thought when developing lesson plans and learning activities. An argument from Fuxin (2012) states that salient attention needs to be addressed from the students' learning perspective.

Next, motivation refers to "what people choose to do and what they commit to doing" (Keller, 2010). The study of human motivation includes the concept of perceptions of control, what needs to be achieved, curiosity, anxiety and attributions for success or failure. A trait will be based on these conditions – with respect to the motivational characteristics, for instance, intrinsic and extrinsic (Keller, 2010). With motivation as one of the crucial components in determining a student's achievement (Abd Wahab, 2007), this research intends to seek the same value applied in mAR learning.

Being intrinsically motivated refers to individuals who are moved by their reasons, none of which is expected to be rewarded despite the job being done (Keller, 2010). A study by Tripathi and Chaturvedi (2014) highlight the importance of encouraging students to be intrinsically motivated in the classroom. Intrinsic motivation is the fundamental element of knowledge where the students can take control and have ownership over their learning. This reflects the fact that students who are driven by their interests are slightly more motivated to get involved and complete any given tasks. Furthermore, Tripathi and Chaturvedi (2014) remark that over time, student engagement and content delivery needs to be reconsidered. If these aspects are not being well-delivered during the learning session, it can cause disruptions to the learning environment.

In contrast, being extrinsically motivated means that individuals engage in tasks for rewards that fallout from a failure to complete them, not for the pleasure that comes along the journey of completing the tasks (Keller, 2010). The relationship between motivation and task satisfaction has been reported to be effective in improving workers' task satisfaction (Alam & Shahi, 2015). Alam and Shahi (2015) further argue that there are chances to incite them through management style, business design and company events. Additionally, other motivational factors include money, conditions of service, communication and data accessibility. From the results obtained in their study, this research will be embarking on the similar psychological needs, together with mAR features, in the learning environment. Data accessibility is highlighted in Alam and Shahi (2015) research, with ubiquitous learning concepts, information will be easily accessible and can regularly be viewed. Furthermore, the appropriate learning style, syllabus design and learning activity play an essential role to obtain promising results which help to increase students' level of self-esteem in a motivated-based learning environment (Alam & Shahi, 2015; Van der Kleij et al., 2015).

Moreover, this research also explores the motivation levels; high and poor, that are influenced by intrinsic and extrinsic motivation, to gauge someone who is energised or activated towards an end with the technology.

3.3.3 Learning Outcomes

Based on the literature search, VLE model was used as a platform to guide the development of the conceptual model for evaluating how mAR enhances learning outcomes. VLE was adopted in the conceptual model, due to its similarities that compare a traditional teaching with technology-mediated learning methods, which include the affective outcomes. Whilst, for this research is current learning methods versus mAR learning mode.

Learning Outcomes in this research focuses on the affective learning outcomes which consist of perceived learning effectiveness, satisfaction and self-efficacy. Additional, the Learning Outcomes in this research that includes how their perceptions of satisfaction are, the appreciation of experience and attitude in learning (Eom & Ashill, 2016; Honebein & Honebein, 2015; Sharda et al., 2004). It is important to assess the learner's propensity to really utilise what they grew in their ability (Piccoli et al., 2001), especially in mAR context. The detail of each construct is explained in the next subsections.

3.3.3.1 Perceived Learning Effectiveness

Perceived Learning Effectiveness is defined as prospective users' computer acceptance behaviour. It also provides the probability that using a specific computer application will increase their performance (Davis et al., 1989). To measure this subjective probability, there are four metrics, i.e. perceived usefulness, the perception of use, interactive learning and behavioural intention. These metrics understand the extent, importance and implications for formal and informal learning, with respect to reinforcement and learning speed, support for higher-order cognitive progress and fortification of beliefs, as well as the perceived learning environment (de Freitas & Levene, 2004; Delanghe, 2001; Green & Bavelier, 2003).

3.3.3.2 Self-Efficacy

Self-efficacy symbolises people's opinion on how a student is capable and competent in organising and executing the required actions (Piccoli et al., 2001). It is described as the individual's ability and self-esteem in problem-solving or task completion (Abd Wahab, 2007; Piccoli et al., 2001). In this research, self-efficacy refers to the learning activities using mAR technology and how students will be able to cooperate and control the self-centred learning environment. Self-efficacy consists of perceived self-efficacy, learning strategies, conceptualization and control. It refers to the mAR learning activities and the ability of students to interact with and control the self-centred learning environment. It also investigates the confidence level of the students when learning with mAR. Furthermore, self-efficacy is one way to determine whether self-esteem will be built and nurtured through mAR learning. Additionally, the use of mAR has the potential to boost the learning activities in a motivated learning environment (Kucuk et al., 2016; Shirazi & Behzadan, 2015).

3.3.3.3 Satisfaction

Finally, Satisfaction, on the other hand, measures system and information quality, as well as user satisfaction with regards to an individual or organisational impacts (Delone & McLean, 2003). The satisfaction construct has two dimensions, which are student interface and content personalisation (intention to use). To analyse an accurate measurement for this conceptual model, the quality of delivery will be taken into consideration on the satisfaction scale. Based on Ocker and Yaverbaum (1999), satisfaction is broken into several dimensions such as "learning, solution quality, solution content and student perceptions regarding satisfaction with the learning experience". The achievement of these dimensions may increase the quality of the learning outcomes.

3.3.4 Characteristics of Students

Students' characteristics might affect the learning outcomes, including demographics like age and experience, cognitive skills, affective skills and learning styles (Lee, 2011; Piccoli et al., 2001). There is a significant difference in students' abilities to interact with the virtual environment, as reported in ScienceSpace project (Lee, 2011).

3.4 Hypotheses to Evaluate How mAR Enhances Learning Outcomes

In order to determine the answers to research questions 8 and 9, this research has developed the following null hypotheses:

H_{17}: The dimensions do not fit the model of mobile Augmented Reality (mAR) effectiveness.

H_{18}: mAR features are not significant antecedents for the learning outcomes in the model of mobile Augmented Reality (mAR) effectiveness.

H_{19}: Motivation is not a significant antecedent to the learning outcomes in the model of mobile Augmented Reality (mAR) effectiveness.

H_{20}: Experience has no moderating effect between students' learning characteristics of the learning mode, with regards to the learning outcomes.

H_{21}: Age has no moderating effect between students' learning characteristics of the learning mode, with regards to the learning outcomes.

3.5 Summary

The chapter provides an elaboration of the theoretical foundation and model that includes the constructs and interrelations among them, as well as their contributions to improving learning with mAR. The research model emphasises the motivation and characteristics of mAR as independent variables. This research is aimed at providing a deeper insight into the information system, particularly the way in which mAR technology can help to improve learning outcomes.

CHAPTER 4
METHODOLOGY

4.0 Overview

This chapter describes the methodology used in this thesis. The chapter begins with a description of the research design, followed by an outline of the research approach and details of the population and sampling. Next, different research stages are elaborated upon, including the preliminary study, recruitment participants, prototype development, construction of instruments, procedures in the data collection, and finally the data analysis techniques. Lastly, an explanation of the Structural Equation Modelling (SEM) approach for the measurement development model and structural model estimation is provided.

4.1 Research Design

A quasi-experimental research method related to controlled experiments for quantitative analysis was used. The function of a research design is to ensure that the evidence obtained enables the research to respond to the initial questions as unambiguously as possible (Blaxter, 2010). There are good reasons for selecting the quasi-experimental method, as it relates to human behaviour and perspectives (Blaxter et al., 1996) that are relevant to this research. A mixed-design of pre/ post-test control group was employed (Serin, 2011). Serin (2011) states that a mixed-design is a factorial design widely used in Social Sciences, especially in Education and Psychology. It reduces the threats to internal validity through the manipulation of one or more independent variables and the measurement of dependent variables that can influence the researcher's ability to pinpoint any differences between the groups (Creswell, 2003).

Based on Figure 4.1, there are two groups for the pre/ post-tests. One group was the treatment group who were exposed to the Human Anatomy with Mobile Augmented Reality (HumAR) software application. The other group was the control group who used the Current Learning Method (CLM). The CLM group is the group where the non-mAR mode was used. With the CLM, the media commonly used in the learning environment were the physical plastinated specimens or prosections (human skeleton), books and slide presentations. Participants of both groups were randomly selected, consisting of students enrolled in Biological Science at three Malaysian public and private universities.

To maintain the accuracy of the hypothesis, the content of the unit section under research for each group was the same. Nevertheless, there were minor differences in terms of the general learning material for both groups. The specific topic covered in this experimental session, for both pre-test and post-test, was “The Introduction to the Human Skeletal System”.

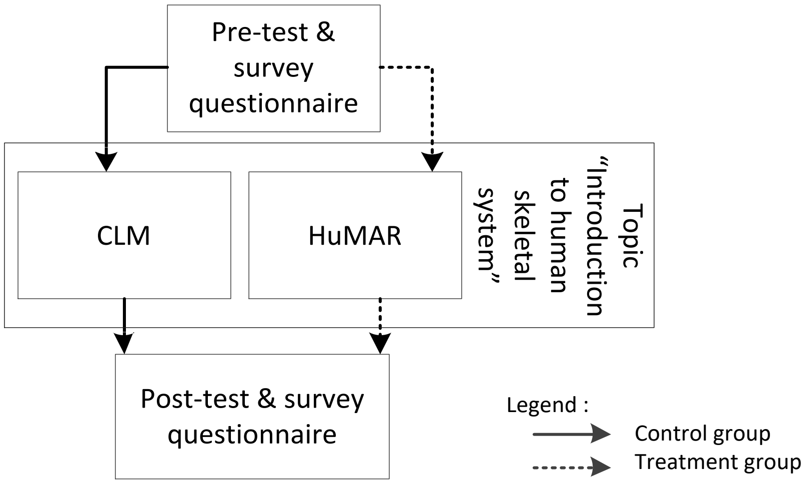


Figure 4.1: Experimental for pre/ post-test flow

4.2 Population and Sample

The sample population for this research consists of higher level Biological Science students, aged between 17 to 28 years old. There are 260 participants that consist of a foundation, semester 1 and semester 2 students were involved. They were selected based on the current enrollment at public and private universities in the Central Region part of Malaysia. This sampling decision was made based on the aforementioned problem statement. Three universities were selected from the list using the simple random method. Random sampling was used because each individual has an equal probability of being chosen as an inconvenience or voluntary response in the surveys and will be representative of the population (Keppel, 1991). The selected universities are Universiti Putra Malaysia (UPM) in Serdang, Malaysia, Universiti Teknologi MARA (UiTM) in Shah Alam, Malaysia and Cyber University College Medical Sciences (CUCMS) in Cyberjaya, Malaysia. The students are in the Science field, studying Biology-related courses or units. For each selected university, two or four classes were determined as suitable for the experimental criteria in terms of their learning materials. For instance, the practical dissection sessions used multimedia computer technology and were equipped with museum laboratories.

4.3 Distribution of Students

The participants were randomly divided into two learning modes. One group was based on the mAR mode (HumAR), and the other group was the non-mAR mode (CLM). The classes were randomly chosen, and all participation in this research was on a voluntary basis. In addition, the pilot study and actual study involved a different set of students.

Each cohort in each university had the same experimental HumAR and CLM groupings. Having multiple respondents from three different universities enhances the validity of the study and minimises common source bias. The procedures of the data collection and experimental session were carefully kept the same, so as to avoid any misconception or gap between the universities. There was insufficient research on the placebo effect in some of the research theses, especially when dealing with technology interventions in educational settings. Nonetheless, the placebo effect, an issue that was raised in the experimental method in Social Science, had been taken into consideration during the design of the experiment. The following steps were taken into consideration to avoid this issue:

1. Consultation with academic, technology and course (Human Biology) experts.
2. Advice from the experts through discussions regarding the research design.
3. Random separation of subjects into treatment and control groups. Bengston and Moga (2007) have a similar opinion that supports the random assignment of subjects, to ensure that the two groups are equivalent to avoid placebo effects.
4. In terms of a lack of awareness among all participants with the technology intervention objective, the questionnaires used are the same for all participants in the class or lab. At this introductory stage, no groups were split, and no participant had prior exposure to HumAR. A relevant body of research is concerned with the occurrence of condition learning in the absence of awareness (Williams & Podd, 2004).
5. The anonymity of participants with regards to the use of HumAR.

4.4 Development of the Measurement Instruments

For the construction of instruments, data matching for both independent and dependent variables were executed. A suitable structure of questions from the literature reviews was adopted and constructed to match the aim and objectives of the research. The quantitative method was applied using the survey technique as a research approach.

There were three sets of questions that the participants had to answer; this encompassed the pre-test, post-test and survey questionnaires. The objective of the pre/ post-test is to measure the initial knowledge of the subject matter before and after the learning session. It is also used to compare the diversity of students' performance and experience, relative to the two learning methods offered - CLM and HumAR. The survey questionnaires were prepared to obtain the statements concerning a particular level of agreement of perception and motivation towards learning using the CLM or HumAR method in the learning environment. The pre/ post-test questions and the items in the survey questionnaire were validated by academic experts and anatomists from Murdoch University for errors in spelling, question structure and appropriate use of technical terminology.

4.4.1 Pre-test and Post-test

The contents of HumAR support the use of the laboratory session to study the pelvic limb. Bones of the pelvic limb include the pelvis, femur, tibia, fibula, tarsus, metatarsals and phalanges. Both pre/ post-tests had similar content, but the order of the questions was rearranged to avoid conflicts in responses. The pre/ post-tests comprises of two parts, Part A and Part B. There are 21 questions related to labelling of the lower limb bones in Part A, whilst a set of 11 multiple choice questions is used in Part B. Both of these parts were used to gauge the pre-existing knowledge, as well as compare the performance based on the specific learning method. The pre/ post-test questions are listed in Appendix A. Also; the pre/ post-test results were not used in the students' grading of the unit. Moreover, withdrawal from participation in the survey did not disadvantage the participants towards achieving the learning objectives of the unit.

The data collection began with the presentation of the research aim and objectives in the information letter (Appendix E). In the first week, the participants and lecturers consented and voluntarily agreed to be part of the research via the consent form (Appendices F and G). Next, the students were given the pre-test questions to answer within twenty minutes and without access to any information or reference books. Then, the students continued with their class activity for 30 minutes. Next, they were handed the survey questionnaire relating to the perception of their current learning method. The students were required to answer the questionnaire in ten minutes.

The post-test was conducted in the following week. A one-week gap between the pre and post-tests was instituted to minimise the chance of sensitivity of the pre-test threat (Christensson, 2010). During the post-test, the participants were split into two groups and each group were located at different class, as well as it was organised in a parallel session. The first group was a control group (non-technology). This group had access to the human skeleton as a resource for their learning activity. In this learning activity, the students were taught for 30 minutes and were required to complete the post-test questions in twenty minutes and ten minutes to complete the survey questionnaire at the end of the session (Appendix B).

The second group was exposed to mAR-technology in their learning activity. The students were given a five-minute training in the use of the prototype HumAR application before the commencement of the learning activity. Similar procedures of learning activity were used with the control group. The learning activity lasted 30 minutes, after which, twenty minutes for the post-test questions and ten minutes final survey questionnaires were distributed to the students for completion (Appendix C). The prototype HumAR was developed by the researcher as a mechanism to support the data collection process, particularly in mAR learning environment. HumAR was built for smartphones and Android tablet device for minimum specification in 2.3 operating system (See Chapter 5). In this research, Android tablet device, brand Pendo with 7 inches High Definition (HD) Touchscreen, memory 1Gigabyte (GB) Random Access Memory (RAM) + 8 GB Internal Micro Secure Digital (SD) and 1.3GHz Quad Core Processor was used (See Chapter 5). There are ten Pendo Android tablets were provided by the researcher to the participants during the data collection process (post-test) for mAR group. Also, participants were able to use their smartphones and any Android tablet devices to install HumAR application.

4.4.1.1 Scoring

The total score for the pre/ post-test was 32 marks. In Part A, one mark was given for the correct label for each bone part and zero for any incorrect answer or blank space. Similarly, with Part B, one mark was given for the correct answer and none for the incorrect or unchecked response. The total score was then converted into a percentage.

4.4.2 Survey Questionnaire

Based on the literature review and previous studies, most of the items in this research were adopted from established models and theories. The items in the questionnaire were replicated from the DeLone and McLean IS Success Model (MIS) (Delone & McLean, 2003), Technology Acceptance Model (TAM) (Davis et al., 1989), Three-tier Technology Use Model (3-TUM) (Liaw, 2007), Attention, Relevance, Confidence, Satisfaction Model (ARCS) (Keller, 2010) and Self-Efficacy Theory (Hair, 2006). The items were then modified based on the suitability of the research objectives.

The survey questionnaire was used as a data collection instrument based on the five-point Likert Scale. The scale measures 1-Strongly Disagree, 2-Disagree, 3-Neither, 4-Agree and 5-Strongly Agree. The questionnaire is composed of two parts, including demographic information and items related to the following constructs: "A-Demography", "B-Perceived Learning Effectiveness", "C-Satisfaction", "D-Self Efficacy", "E-Motivation" and "F-Learning Environment (CLM/HumAR)". The questionnaire was designed to cover all these six constructs. The students were also asked to provide any additional written feedback about the learning method at the end of the survey questionnaire. The metrics and references cited for each construct are shown in Table 4.1.

For all the constructs, each individual score was quantified by means of all the items in the scale. The mean was set as more than 0.5 as an indicator for the Standard Deviation (SD) to guarantee that the overall score was an engaged response from the respondents. The mean score of each construct was calculated and formed into one distinct compound. The instruments developed are attached in Appendices B and C.

Table 4.1: Summary of the instruments implemented in the preliminary study

Sections	Constructs	Metrics	Tools	Reference
A	Demography	Age, the level of education, university, gender, the device used to get information, duration/ frequency of attendance in class and the experience of Human Anatomy.	Crafted own questionnaire (Chen et al., 2010)	(Chen et al., 2010)

B	Perceived Learning Effectiveness	Perceived usefulness, perception of use, interactive learning and behavioural intention.	Technology Acceptance Model (Davis et al., 1989), Three-tier Technology Use Model (Liaw, 2007)	(Subramanian, 2007) (Liaw, 2008)
C	Satisfaction	Learner interface, content and personalisation (intention to use).	Model of Information Systems Success (Delone & McLean, 2003) Three-tier Technology Use Model (Liaw, 2007)	(Chen et al., 2010) (Liaw, 2008)
D	Self-efficacy	Perceived self-efficacy, learning strategies, conceptualisation and control.	ARCS Model (Keller, 2010) Self-Efficacy Theory (Hair, 2006)	(Liaw, 2008) (Abd Wahab, 2007) (Butler, 2011)
E	Motivation	Intrinsic and extrinsic	ARCS Model (Keller, 2010)	(Abd Wahab, 2007) (Pintrich & De Groot, 1990)
F	Features of HumAR		Crafted own questionnaire (Lee, 2011) (Azuma et al., 2011)	(Lee, 2011) (Azuma et al., 2011)

4.4.2.1 Perceived Learning Effectiveness

There were eighteen items used to measure perceived learning effectiveness. Two of the variables were adopted from the TAM (Davis et al., 1989), for example, perceived usefulness and perceived ease of use. The following ten items were replicated from the TAM in a study conducted by Subramanian (2007). These items were developed to measure the ability of intention on using the learning substance regarding acceptance and attitude (Davis et al., 1989). The remaining eight items cover variable interactive learning and behavioural intention taken from the Theory of Three-tier Technology Use Model (3-TUM), produced by Liaw (2007) in a study presented by Liaw (2008). This theory is considered suitable to explore students’ perception and apprehend their actions when learning using technology or non-technology methods (Liaw, 2008).

4.4.2.2 Satisfaction

Satisfaction was measured by items adopted from Chen et al. (2010) and Liaw (2008), which were mainly constructed from MIS (Delone & McLean, 2003) and 3-TUM. Related items were selected from the initial instruments, according to the suitability of Biology students' learning features. The measurements were made via three factors: learner interface, content and personalisation (intention to use). An aggregate of seven items represented each variable of learner interface and content. Meanwhile, there were six encompassed variable intentions. A high score of 5-Strongly Agree clearly indicates the immense enjoyment of the participants during the learning session in this research.

4.4.2.3 Self-Efficacy

There are numerous studies in the investigation of the impact of self-efficacy and motivation (Abd Wahab, 2007; Butler, 2011; Liaw, 2008) on learning with assistance from technology. Nine items were designed based on theories from ARCS (Keller, 2010) and Self-Efficacy (Bandura, 1997). In particular, the ARCS model had established variable perceived self-efficacy in the motivational belief and confidence level (Bandura, 1997).

4.4.2.4 Motivation

The motivation section has 13 items covering the motivational belief dimension. For instance, there are intrinsic and extrinsic motivations which have their roots in motivation theory (Keller, 2010). Five items were adapted from Abd Wahab (2007), and eight items were taken from Pintrich and De Groot (1990). The items were then rephrased and adapted, according to the suitability of the research. The adequacy of items was discovered using Keiser-Meyer-Olkin (KMO) analysis to value 0.883 and for factoring correlations, the overall item's value was more than 0.41 in the original instruments. A pilot study was conducted for the replicated items to determine the internal consistency and reliability of items. A further analysis was performed for the unidimensionality and reliability tests that were conducted on the actual data.

4.4.2.5 Features of Learning Mode Environment

This section is divided into two parts - CLM and mAR learning groups. Both parts use the same survey questions relative to the different learning methods. The Likert Scale 1 (Strongly Disagree) to 5 (Strongly Agree) for the quantitative responses of the features of the learning method was used to measure the features of the environment of the learning mode. These items were tested and validated by academic and technology experts. The features for the technology learning mode was gauged using nine features which are:

1) realism of the 3D objects;
2) smooth change of images;
3) precision of 3D objects;
4) learning improvement;
5) view angle for stimulating interest and motivating learning;
6) object manipulation;
7) enhancement of understanding;
8) labelling assist memorisation and
9) learning comprehension.

4.4.3 Validity Test

The content validity of the pre-test, post-test and survey questionnaires have been endorsed by academic experts in Biology, specifically three academics with teaching experience of more than four years in their respective fields. These three experts who voluntarily agreed to be the reviewers are from Murdoch University (MU), Perth, Western Australia, Management & Science University (MSU), Selangor, Malaysia, and Universiti Teknologi MARA (UiTM), Selangor, Malaysia. The questions were reviewed and vetted in terms of item correlation and consistency in the subject matter. All comments and suggestions were taken into consideration before the commencement of the pilot study.

4.4.4 Reliability Test

A pilot study was carried out after the questions were validated. The 30 participants involved were from three universities in the Central Region of Malaysia. This session was conducted to gauge the complexity of the items such as appropriate wording, percentage response of items and time frame recording. Pallant (2010) highlights four ways to identify item reliability, for instance by looking at the Reliability Statistics (Cronbach's Alpha) and negative value in the Inter-Item Correlation Matrix or in the Item-Total Statistics table with value less than 0.3 in the Corrected Item-Total Correlation and higher value in the Cronbach's Alpha 'if Item Deleted' column. These are all in comparison to the total score of Cronbach's Alpha values in the Reliability Statistics. The reliability and linearity for all items in each respective construct were analysed through Cronbach's Alpha testing where any value greater than 0.7 was considered reliable. This testing measured the internal consistency and correlation of items within each construct (Pallant, 2010). An Exploratory Factor Analysis (EFA) was run to extract the items underlying the constructs or dimensions.

4.5 Data Collection Procedure

The following subsection describes the procedure of the data collection for both the actual and pilot studies. Even though the data sessions were collected in different study settings from three different universities, the procedures, settings, target audiences, as well as the set of questionnaires were all the same. A detailed diagram of the data collection procedures for both groups was provided to the lecturers who assisted in the experiment (Appendix D).

4.5.1 Actual and Pilot Study

This session used the survey questionnaire technique as the quantitative method to collect data. The entire data collection session lasted for two weeks. The pre-test was held in the first week, while the post-test took place in the second week. Both the CLM and HumAR groups went through a one-hour session each (Section 4.4.1). Data collections were conducted at a parallel sessions at these three different universities. The researcher was assisted by two research assistance at each university, to fulfil the procedure accordingly. The same procedures in terms of time allocation, content of human skeletal structure, survey form, pre/post-test quiz were organised (Appendix D).

4.5.2 Data Analysis Technique

This subsection describes the various techniques used to analyse the actual and pilot test data. The Statistical Package for Social Sciences (SPSS) Version 21 was used to analyse the descriptive statistics, for instance, frequency and percentage. Furthermore, SPSS was used to run the statistical analyses, such as Independent t-test, Analysis of Variance (ANOVA), Multivariate of Analysis of Variance (MANOVA), reliability, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Finally, the Analysis of Moment Structures (AMOS) Version 21 was applied to develop a fit measurement model.

4.5.2.1 Statistical Analysis in the Statistical Package for Social Sciences (SPSS)

Within SPSS, the gathered data from the evaluation of the mAR learning environment was keyed-in and screened to filter out any missing values. This was followed by normality, reliability and validity tests. Next, the descriptive statistics and t-test were done. The reliability of each construct was then analysed using the Cronbach's Alpha. The cutoff value of 0.70 of the alpha readings was considered to be a good and reliable factor (Hair et al., 2010). In order to analyse the hypothesised model for each variable, the MANOVA was used.

4.5.2.1.1 Descriptive Analysis

Before conducting statistical analyses, it is pertinent to guarantee that any assumptions made for the tests were not subject to a violation and the testing of such assumptions often entails the variables' descriptive statistics including mean, standard deviation, scores range, skewness and kurtosis (Pallant, 2010).

4.5.2.1.2 Independent Sample t-test

Sekaran (2003) proposes using the independent sample t-test to examine the differences between two groups of samples such as male and female. As such, this research used the participants' gender to compare the mean scores of the variables.

4.5.2.1.3 Analysis of Variance (ANOVA)

One-way ANOVA is used in the analysis of variance when an independent variable with different levels is tested against a dependent variable. This test determines whether significant differences exist in the dependent variables' mean scores between the factor levels (Sawyer, 2009). Besides that, ANOVA has been evidenced to be invaluable and applicable to experimental design studies to test the robustness of outcomes (Hill & Lewicki, 2007; Littell et al., 2002).

4.5.2.1.4 Multivariate Analysis of Variance (MANOVA)

When a combination of factors is used to explain variations in several response variables at the same time, a multivariate analysis of variance (MANOVA) is employed as recommended by Zetterberg (2013). He adds that the benefit behind MANOVA lies in its ability to test joint hypotheses based on their differences for the purpose of factor level means. Littell et al. (2002) state that MANOVA considers the correlation between response variables and as such, it makes optimal use of the data.

4.5.2.2 Measurement Model Development in SEM-AMOS

The AMOS software was applied in the next step to establish the relationship between latent variables or constructs (Schumacker & Lomax, 2004). AMOS is a technique that combines both structures of multiple regression - path analysis and factor analysis. This allows for not only an evaluation of the complex interrelated dependency relationship but also the inclusion of the outcome of the measurement error on the structural variables in the model. AMOS was implemented to produce a fit model, or also known as the model. It was utilised for model validation and relationship between the dimensions using the measurement model, Exploratory Factor Analysis (EFA) and the structural model, Confirmatory Factor Analysis (CFA) respectively.

4.5.2.2.1 Exploratory Factor Analysis

The process began with a model from the constructed and well-integrated literature reviews. The measurement model was checked through the Exploratory Factor Analysis (EFA). EFA was employed to identify variable structures through the definition of factors based on the variables set (Hair Jr et al., 2006). In the EFA stage, the relationship between a particular variable and its respective construct was not declared. Instead, the variables were freely loaded to their respective constructs according to the variables set. Therefore, the output from the EFA allows for the provision of an improved description of the nature of the set of variable interrelationship. The values of the factor loading for each item must be greater than 0.50 to confirm if the variables are suitable for the proposed model and to confirm the covariance among the items for this research.

4.5.2.2.2 Confirmatory Factor Analysis

The Confirmatory Factor Analysis (CFA) was used to confirm if the number of factors and indicators on them (loading of factors) adhere to the expectations based on pre-established theory (Garson, 1998). Hence, in this research, validity tests were conducted to determine the level to which the measurement tool measures what is expected to be measured. In order to determine the level to which an instrument measures what is being expected, as recommended by Pijpers and Van Montfort (2006), this research statistically tested the convergent validity and discriminant validity – two dimensions of construct validity. Therefore, the CFA was performed to test the overall measures' acceptability through Root Mean Square Error of Approximation (RMSEA) that should be equal to 0.08 as this indicates a reasonable model fit (refer Table 4.2), while lower than 0.06 indicates a very close fit (Hair et al., 1998). In summary, the ratio should not be more than 5, the Tucker-Lewis Index (TLI) should be higher than 0.80 and the Comparative Fit Index (CFI) should also be higher than 0.80 (Hair et al., 1998; Hwang, 2007; Kelloway, 1998). The factor loading significant should be greater than 0.30. These values were followed to guide the factor structure determination (Hair et al., 1998; Hwang, 2007; Kelloway, 1998; Kline, 1998). During this step, if the model still does not fit well, it must be modified through the TLI and CFI. It is considered good when the indices fall within the ample range stated above.

Table 4.2: Overall Measurement Model Fit for each construct

Fit Index	Recommended Value
The Root Mean Square Error of Approximation (RMSEA)	<0.08
Comparative Fit Index (CFI)	>0.80
Tucker Lewis Index (TLI)	>0.80
Ratio or Normed (χ^2 = chi)	≤0.5

4.5.2.2.3 Reliability and Validity of Measurements

A pilot study was conducted to test and refine the instrument's validity. The analysed results were utilised to test, change and determine if the items were perceived unsuitable for the questionnaire. The instrument was strengthened based on the experience, opinions and perspectives of the experts in the relevant field. The instrument validation involved the confirmation of the construct validity and on this basis, the modification of specific tools was carried out. The test was conducted to make sure that the measurement was efficient in measuring the construct through a certain standard (Hair et al., 2010). Clarified operational definitions and measurable indicators require the acquisition of a theoretical basis in terms of the construct.

A unified type of validity (construct validity, reliability, and exploratory factor analysis) was used to assess the multivariate instruments. Reliability was tested through Cronbach's Alpha; a measure that gauges the internal consistency of the questionnaire items, with the criterion that a value greater than 0.70 indicates adequate reliability, while 0.80 and over indicates preferable reliability, as recommended by Nunnally (1978).

On the other hand, validity was tested through the psychometric evaluation of the instrument with the help of EFA. The reliability of the constructs was assessed through Cronbach's Alpha, with a cut-off point of 0.70. In this regard, reliabilities of less than 0.60 were referred to as poor, 0.70 were considered acceptable, and over 0.80 were considered good (Sekaran, 2003). Internal consistency through Cronbach's Alpha is a perfectly sufficient indication of internal consistency (Sekaran, 2003) and as such, it is extensively used as an indicator. The rule-of-thumb states that the Cronbach's Alpha value should be 0.70, but it may decrease to 0.60 in the case of exploratory research (Hair et al., 2010). Moreover, reliability, as mentioned, is the measurement's consistency; where construct reliability measures internal consistency as opposed to the reliability of one variable. In the present study, three tests were employed for the evaluation of construct reliability, i.e. squared multiple correlations (SMC), where values greater than 0.30 are deemed to be acceptable (Kripanont, 2007), along with Cronbach's Alpha of greater than 0.60.

In addition, the moderating effects of interactions in the students' characteristics (experience and age of learning with mAR technology) and learning outcomes were examined. Such moderating effects were examined with the help of multi-group analysis. After obtaining the survey data from 260 respondents, a research model with three latent variables, i.e. motivation, mAR features and learning outcomes was developed and analysed.

4.6 Summary

This chapter provides an elaboration of the methodology that was employed for gauging the effectiveness of learning using mobile Augmented Reality in the education environment. Two groups of pre-tests and post-tests in a quasi-experimental method were set to investigate the significant differences in the learning outcomes between mobile-AR-based learning (mAR mode) and the current learning method (CLM mode). Other factors were also investigated, including the effects of students' motivation using mobile-AR-based technology in the learning environment, in terms of the learning process and interaction. The data were analysed through the use of SPSS software.

AMOS was employed for the evaluation of the moderating effects of students' learning characteristics and the learning mode, with regards to the learning outcomes. Furthermore, to evaluate the fitness of dimensions and antecedents in the model of mobile Augmented Reality (mAR), the model was tested through the model indices method. This was followed by the validity and analysis structure model. The results of the actual study are reported in Chapter 7.

CHAPTER 5
PROTOTYPE DEVELOPMENT OF THE HUMAN ANATOMY WITH MOBILE AUGMENTED REALITY (HumAR) APPLICATION

5.0 Overview

This chapter discusses the development process of a mobile prototype learning environment that utilises mobile Augmented Reality (mAR) technology. The prototype is called Human Anatomy with Mobile Augmented Reality (HumAR), and the selected topic is the anatomy of the human skeletal structure. The main objective of HumAR is to aid students and see how mAR could potentially enhance their learning process. Ganguly's report states that there is a decline in the retention and generation of long-lasting information when learning the topic mentioned above (Ganguly, 2010). Therefore, HumAR was developed to support the statistical results in the data collection to verify the results of this research. This chapter describes the theory, concept and HumAR prototype development.

5.1 Concept and System

The prototype HumAR application runs on an Android tablet with a multimodal interface that functions as the Graphic User Interface (GUI). The GUI facilitates a better interaction and understanding of the learning topic using 3D objects. In the mAR interface comparative study (Section 2.3), the multimodal interface is a success from the point of sales and point of information. Therefore, HumAR adopted this multimodal interface as the GUI to deliver the learning topic efficiently. The selected learning topic for the implementation of HumAR was the bones of the lower appendicular skeleton; the pelvis, femur, patella, tibia, fibula, tarsals (which has 7 individual bones), metatarsals (a group of 5 long bones in the foot) and phalanges (14 bones that make up the digits).

HumAR runs similarly to a courseware-based application. In the field of education, courseware means an educational software that is designed for teaching and learning (Rouse & Wigmore, 2017). Normally, a courseware application has a few features, e.g. the navigation buttons, information about the learning topic and hyperlinks (Albion & Gibson, 1998; Riley, 1995). These features were added into HumAR to create interactivity with the system and to enhance the learning of the selected bones.

In order to view the augmented or superimposed object, HumAR uses the Android tablet's screen. The flow of interaction starts with a marker (which can be specified as an image on any surface), where the tablet's camera will act as an image scanner. In HumAR, the image on the surface is detected as a marker and is measured by the width of the desired dimensions. Subsequently, the tablet's camera detects and recognises the assigned marker. Once a marker has been recognised, HumAR will display and superimpose the respective 3D computer generated object on the screen. Each bone image, which was used as part of the learning topic, together with its respective laboratory manual, was assigned a specific marker in HumAR. The dimensions of the marker in terms of its height and width were set during the development. The marker size is very important, as the pose information will be detected within the same scale set. For example, if the target marker is twenty units wide and if the camera moves from the left to the right border of the target marker, the image will remain in the position of twenty units along the x and the y-axis (Siltanen, 2012).

Figure 5.1 shows an overview of how HumAR works. The top view layout depicts the processes involved in running HumAR, and it includes (i) the user; (ii) the mobile device or tablet and (iii) the marker used to project the augmented object. To enable HumAR, the user has to click on the application from the tablet through the perspective view. The application begins in the actual view environment using the tablet's camera aimed at a printed marker in the unit laboratory manual. Once the marker has been recognised, the respective augmented 3D computer generated model is displayed and superimposed onto the tablet's screen, so that the user can see the augmented computer-generated 3D object. Users can view the augmented computer-generated 3D object of different parts of a bone when they move the tablet's camera into the marker's area (as shown along the dotted line in Figure 5.1).

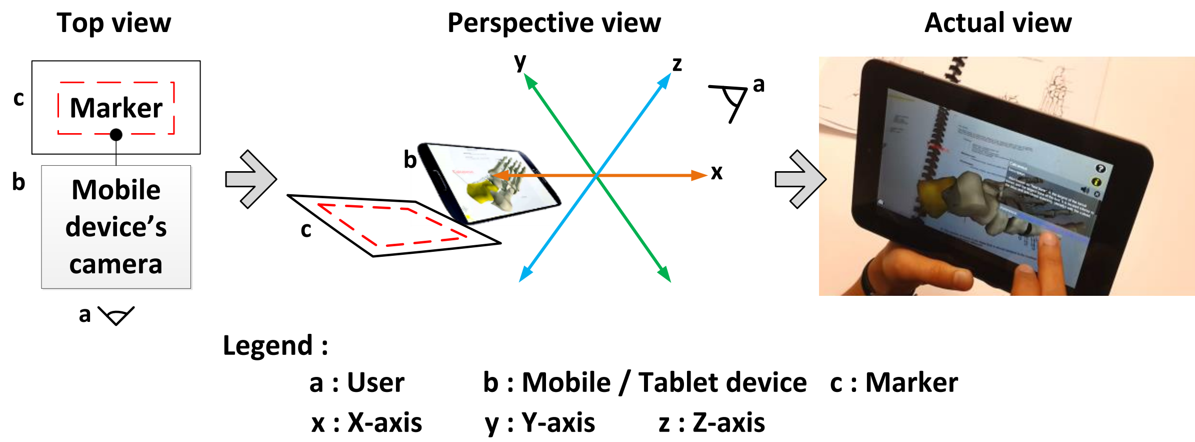


Figure 5.1: Overview of how HumAR works

5.2 The Development Phase of HumAR

Figure 5.2 illustrates the flow diagram of the development of HumAR, which consists of five phases:

1) identifying the functional requirements;
2) identifying the technical requirements;
3) prototype development;
4) pilot testing and,
5) final prototype application.

The development process begins with general requirements such as functional and technical specifications, followed by duration of development and costs, which are then carefully considered.

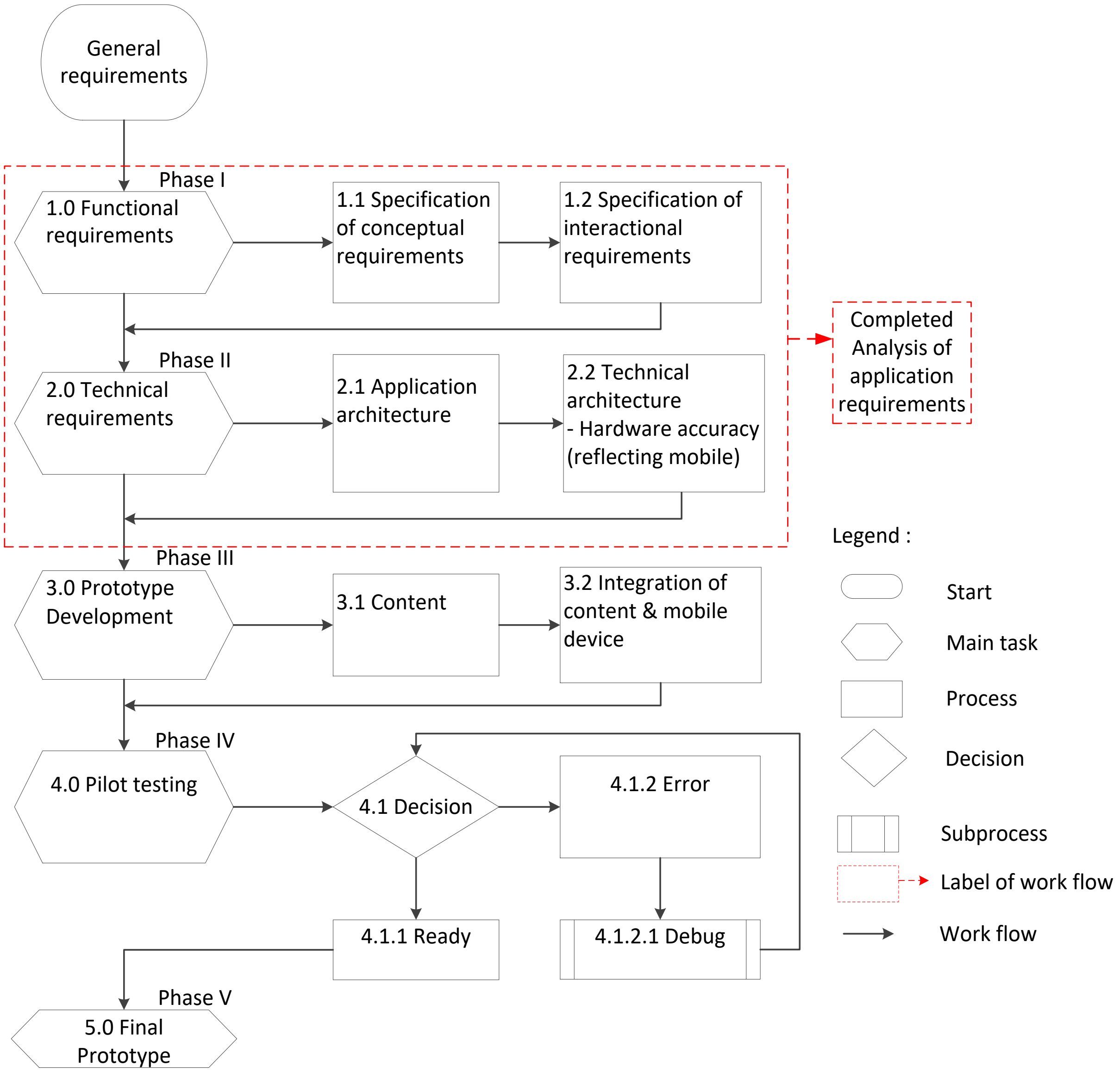


Figure 5.2: Flow diagram of the development of HumAR

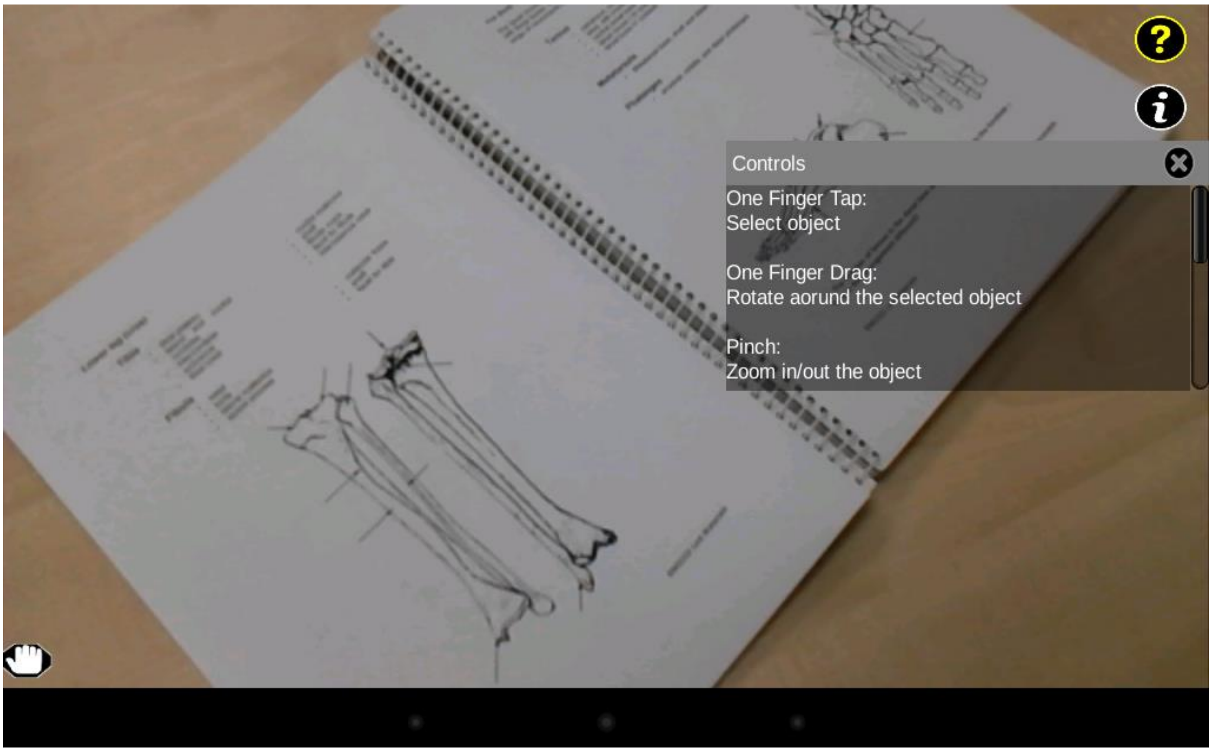
5.2.1 Functional Requirements of HumAR

The functional requirements are a series of interactive applications that allow the user to view input actions and program response actions, in terms of application capabilities. During Phase I, the conceptual features of HumAR were identified to enhance the efficiency of learning, hence offering a longer retention of information. A comparative analysis (Section 2.1.4) has been used through a few interfaces from other mAR technology applied in various industries, for instance, education, advertising, entertainment and tourism. The mAR application in advertising receives a very positive response from the users and helps companies generate high sales volume due to the mobility and easy access to the product information (Augmented Reality Trends, 2015; Chehimi et al., 2007). By implementing this concept in HumAR application, the student's desire to learn increases as they engage with the mAR technology. They are, at the same time, motivated to understand and memorise without being forced to obtain the information from other limited resources.

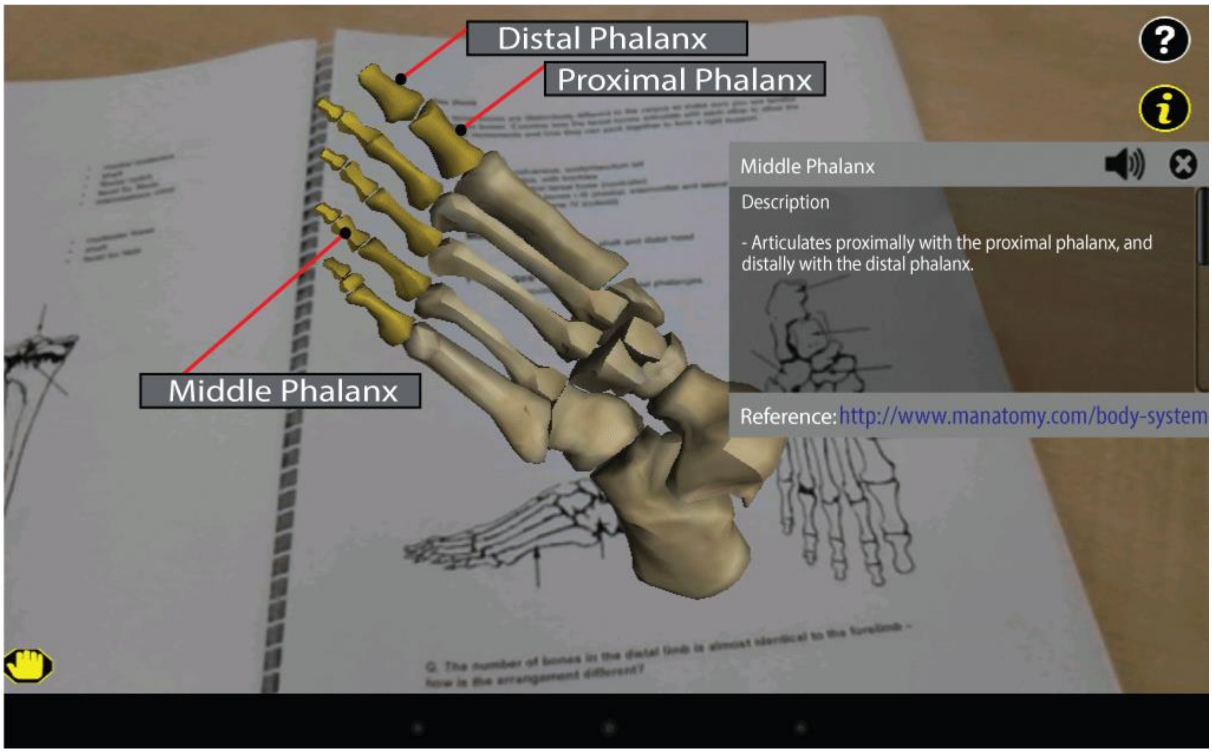
5.2.1.1 HumAR Activation on Mobile/Android Tablet Device

At this beginning of prototype stage, to successfully start using HumAR, the user will be distributed the HumAR's Android Application Package (.apk) file. APK file was used by the Android operating system for distribution and installation of the mobile application. Users are required to save the .apk file onto their mobile devices and install it by clicking on the .apk file. Once it is installed, HumAR application will be directly activated, fully functioned on the mobile and ready to be used. HumAR offers 3D bone images with 360° angles that project the subject matter more efficiently onto the visual plane to facilitate understanding. In HumAR, hand movements like finger interactions (Table 5.1) are required. Moreover, user interactions, which encompass body or hand gestures with the mobile device are a common characteristic of the kinaesthetic style of learning. This learning style provides a more exciting learning environment and serves to motivate students (Siltanen, 2012).

Furthermore, the interactions in HumAR are based on a non-linear navigation concept (Ragunath et al., 2010). Non-linear navigation allows the user to navigate freely through the application content without the requirement to follow predetermined paths (Ragunath et al., 2010). HumAR was used to provide the mixed reality of virtual and real learning environment to students. In HumAR, students can click on any part of the bone. HumAR is equipped with a control panel, which consists of two buttons for each bone. These are the *Help* and *Info* buttons. The control panel is located at the upper right corner of the screen, as shown in Figure 5.3.



a) Control page



b) Information page

Figure 5.3: The prototype of HumAR (interface)

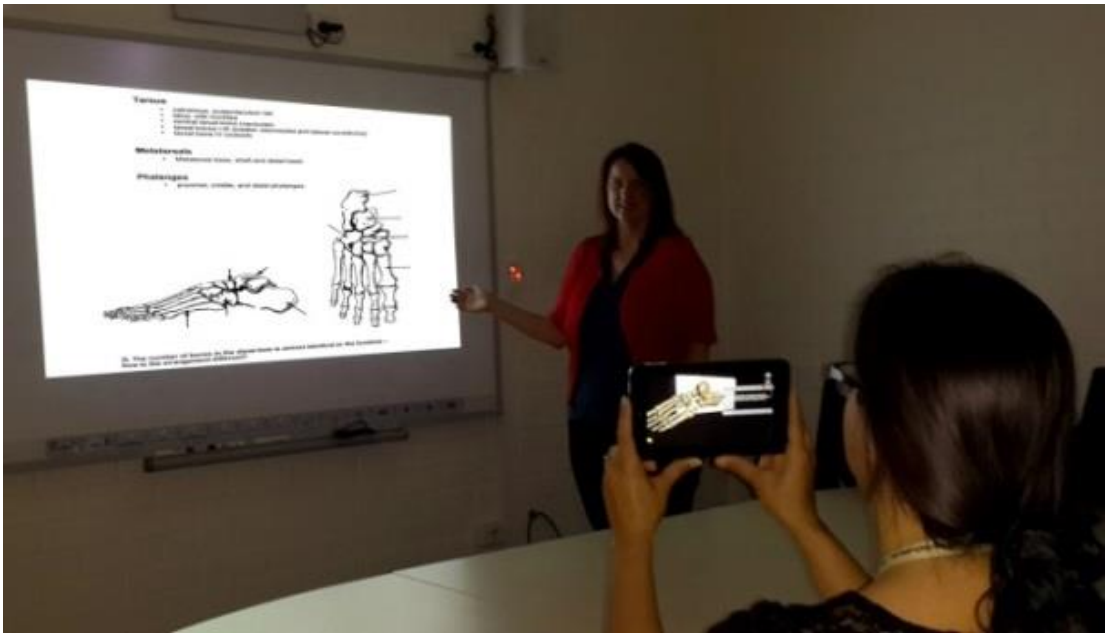
Textual information is to guide on how HumAR is functioned, with the *Help* button within the control panel on the right side of the screen will describe how users can interact with HumAR as demonstrated in Figure 5.3a. There are viewpoint manipulation tools for students in the built-in *Help* that describe how a user can use the control panel for object selection, movement, rotation, scaling and zoom the bone. Detailed manipulation of the haptic touch and finger gestures of HumAR are listed in Table 5.1. The students can simply manoeuvre the screen out of the marker to reset the position of the bone. With HumAR students can have a hands-on learning experience.

Table 5.1: Haptic touch / finger gesture in HumAR

Gesture	Interaction
Double tap	Select object
One finger drags right/left	Horizontally rotate around the selected object
One finger drags up/down	Vertically rotate around the selected object
Pinch	Zoom in/out
Three fingers drag	Move object

Moreover, in the Figure 5.3b, the *Info* button provides details of the skeletal system description. Each bone is explained and displayed in the description box on the right panel on HumAR's screen, whenever a student clicks on the label. A medical dictionary link is available to provide students with additional information relating to the bone features in question. HumAR provides additional assistance for students in the form of creating a virtual experience of the human anatomy. Additional, users can freeze the screen by clicking on the yellow *Hand* icon at the bottom of the screen. It allows the users to move the mobile device without losing the AR view of the embedded bones on the screen. More screenshots for other lower limbs bones (pelvis, femur, tibia, and fibula) are shown in Appendix J.

a) Textbook marker



b) Teaching using presentation slides

Figure 5.4: The prototype of HumAR application is applied in various learning materials

Figure 5.4a shows how HumAR can be used with an accompanying textbook. It illustrates the student pointing the mobile device onto the book as a marker for the mAR environment, while Figure 5.4b shows how HumAR can be used on presentation slides. Students can see and visualise complex learning topics that are taught in the classroom or during presentations whenever the student manoeuvres her mobile phone to the slide presentation for augmented reality projection on the mobile screen. 2D images (printed on paper or presented on slides) are often used as part of current learning materials, and these 2D images present some issues in comprehension. However, with the assistance of HumAR, there is a potential to enrich students' learning experience in their respective disciplines. In this sense, the students' learning revision time can be expanded according to their necessities. Students are able to initiate their own learning anytime and anywhere without relying on fixed located university labs and opening hours. This is important as each time they need to study and get extra resources, they can have them using HumAR.

5.2.2 Technical Requirements

Technical requirements are a set of specifications that must be met to allow a hardware product to be fully operable. These specifications are required to optimise the performance of HumAR. At the very least, compatible technical requirements must be met to ensure the efficiency and effectiveness of HumAR.

In displaying the augmented 3D computer generated object, this research uses a handheld mobile device, i.e. a tablet. HumAR will work on at least an Android version 2.3 operating system (OS). The Android platform includes a set of managed application programming interfaces (API). For smooth and seamless operation, HumAR must run with a Central Processor Unit (CPU) with at least 1.6 GHz frequency and a display screen resolution of 1024 x 600 pixels. For this research, Android tablet device, brand Pendo with 7 inches High Definition (HD) Touchscreen, memory 1Gigabyte (GB) Random Access Memory (RAM) + 8 GB Internal Micro Secure Digital (SD) was used.

Next, to use HumAR, the Android device must also have a back camera to track the specific AR markers. Tracking is a method of registering what is being captured by the camera and linking it with a specified 3D computer generated image. Two most common tracking methods used are position and orientation. Tracking the position initiates the graphic system to render views from the user's position. The back camera is used to capture the real world surroundings and the front panel display screen is used to view the augmentations, such as the information set earlier by a particular marker.

5.2.2.1 System Architecture of HumAR

Figure 5.5 illustrates the data flow of the system architecture of HumAR. The application begins with mAR running on the Android device. The first interaction is to point the tablet's camera onto the target or marker position. The architecture of the prototype HumAR application starts with a new database, created from the Vuforia AR toolkit online database (Qualcomm, 2014), to set the target marker for each bone. A single target-based image is selected with a customised width and dimension, according to the individual's preference. The image has to be uploaded to add a target to the database. This allows the activation of the authoring part in the Unity 3D (Unity, 2014) software (to be explained in detail later in the Prototype Development, Phase III, Integration of Content and Mobile Device). The augmented object is displayed on the tablet screen for user interaction with the mAR application.

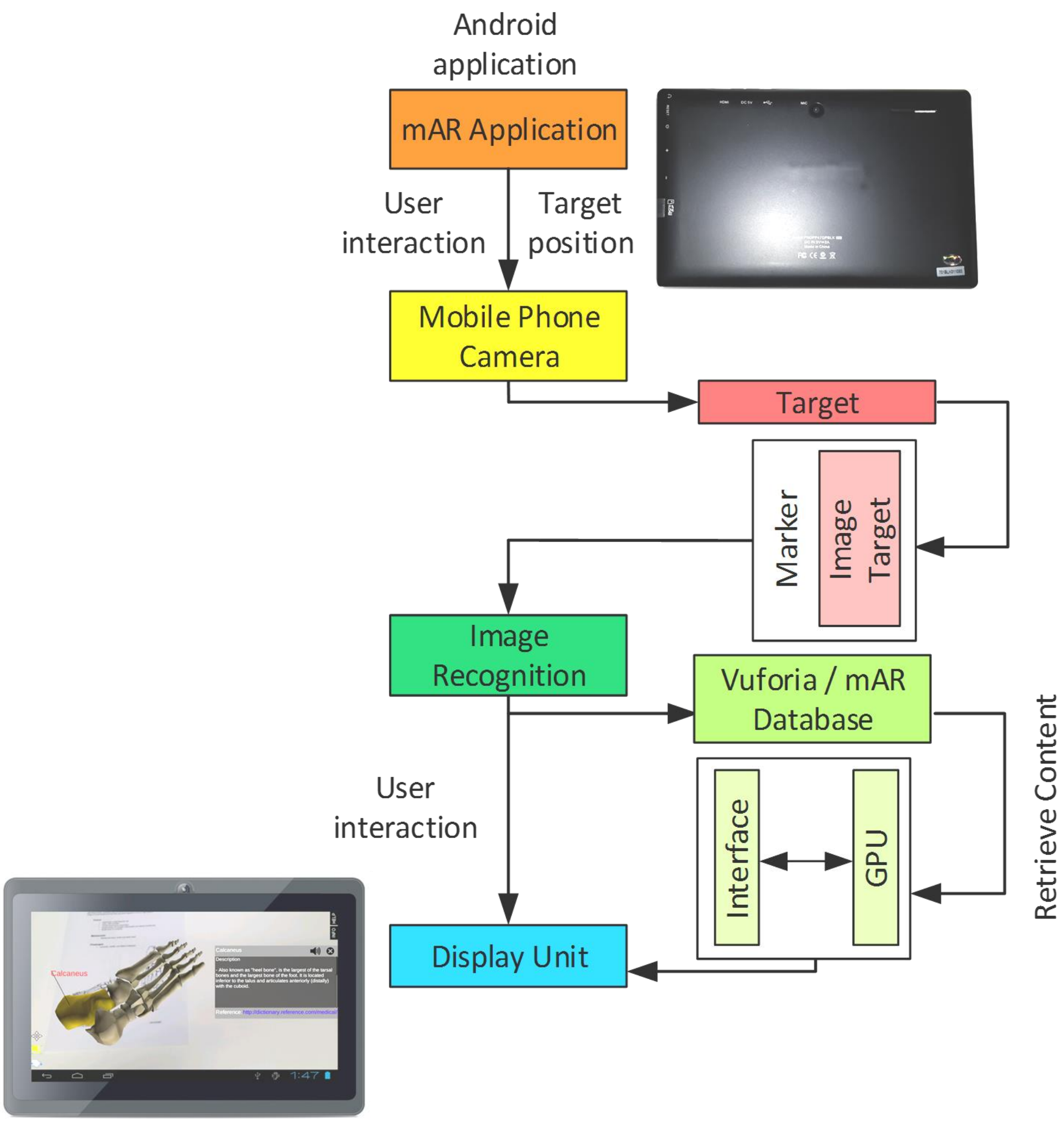


Figure 5.5: Overview of the system architecture of HumAR

5.3 Prototype Development

In HumAR's development, there are two stages involved, i.e. the creation of the content and its integration with the tablet. In this section, the development workflow is described. The development tools include the use of the software: 3D Studio Max 2013, the Augmented Reality Software Development Kit (SDK)-Vuforia and a 2D/3D Software Development tool-Unity 3D 4.3.4f1. 3D Studio Max 2013 was used for 3D modelling, while Unity 3D was used for the development of HumAR, to compile and deploy HumAR onto the Android tablet.

5.3.1 Contents

Referring to a study from Wunsche et al. (2010), the cost involved in developing content in virtual environments is high. However, it can be reduced by simplifying the content creation process to be more efficient, well-planned and integrated. The contents of HumAR starts with the bone descriptions, bone joint locations, bone part labels and reference links which were gathered following the advice and discussions with the anatomists. All of these built-in features were for students studying Forensic Anatomy and Anthropology Unit at Murdoch University in Perth, Australia to help them improve their learning environment through the use of HumAR as an effective learning tool. The main purpose was to identify the astrological features of the lower appendicular skeleton. The content of HumAR covered a laboratory topic to learn about the pelvic limb. This includes the pelvis, femur, tibia, fibula, tarsus, metatarsals and phalanges. In this research, the 3D models of the lower limb of the human skeletal structure were developed with the assistance a lecturer in anatomy, and laboratory technicians. In order to acquire images of the lower limb skeletal elements, articulated and disarticulated bones were provided for photography.

The photography session (Figure 5.6) was undertaken in the Anatomy Museum within the School of Veterinary & Life Sciences, Murdoch University. This session was organised to assist in the development of the computer generated 3D bone models.

With the anatomical assistance (Figure 5.7), each bone part was isolated from its joint, using the 3D Studio Max software, into several components according to the skeletal system. This facilitated a more detailed understanding for the students. Every bone was mapped with textures to produce a more realistic view. During the bones identification session, all bones were positioned based on human skeletal anatomy and rendered in 3D Studio Max.

Figure 5.6: Photograph of articulated and disarticulated bones

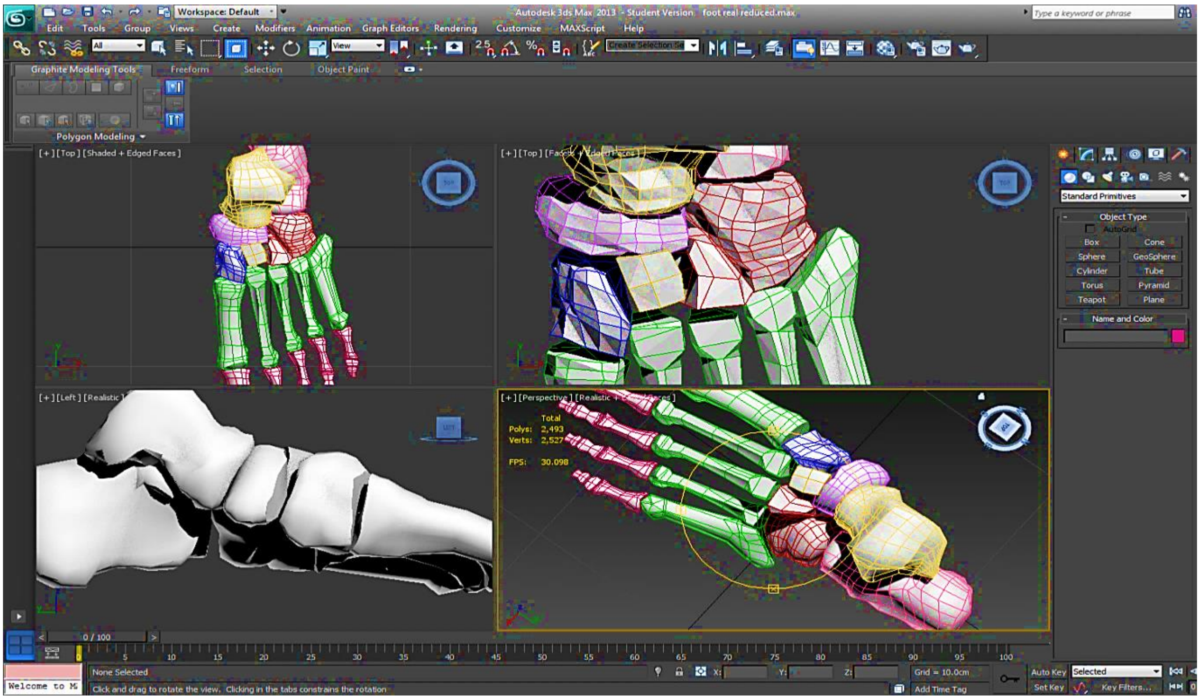


Figure 5.7: Development of the human skeletal in 3D Studio Max

5.3.1.1 Integration of Content and Deployment onto a Mobile Device

Using Unity 3D, the integration of the contents for HumAR involved two phases: i) 3D modelling and ii) using the Augmented Reality Software Development Kit.

5.3.1.2 3D Modelling Tool

For the final part of developing the 3D bone models, the lower limb skeletal features were saved to the .fbx (filmbox) file format in 3D Studio 2013. The reason it was saved in the .fbx file format is that during the HumAR development, difficulties became apparent when the Vuforia (Qualcomm, 2014) extension was integrated into the 3D Studio Max file. This resulted in limitations in supporting this extension for rendering and tracking AR. Due to this, Unity 3D 4.3.4f1 was used instead, and it worked very well with the Vuforia (Qualcomm, 2014) AR extension.

5.3.2 Augmented Reality Software Development Kit – (SDK) Tool

In producing an augmented reality environment, an AR extension was required. For HumAR, an extension called Vuforia, developed by Qualcomm (Qualcomm, 2014), was used. Vuforia is an online software platform, designed for high quantity operation of AR on mobile devices. It provides tools to create all categories of the AR experience. Several features were determined for HumAR and set in Vuforia. These features comprise of the image target, size parameter for the marker and SDK project file for Android development. A mobile educational courseware application approach was employed in the HumAR development. In particular, the educational courseware consists of educational material loaded with information about the learning topic in digital form, for teaching, training and learning purposes (Schitai, 1998).

The current implementation of the AR SDK is widely used for various types of product delivery in commercials, education, sports and in other fields (Qualcomm, 2014). In HumAR, there was a juxtaposition of the Vuforia and Unity 3D software. Unity 3D was used for the overall development of HumAR - the compilation and deployment of HumAR onto the tablet, the look and feel, the interactions, as well as the presentation of the content.

5.3.2.1 Marker Workflow using Vuforia

The Qualcomm Vuforia AR SDK was used for two purposes: i) Target manager and ii) The SDK project for Android development.

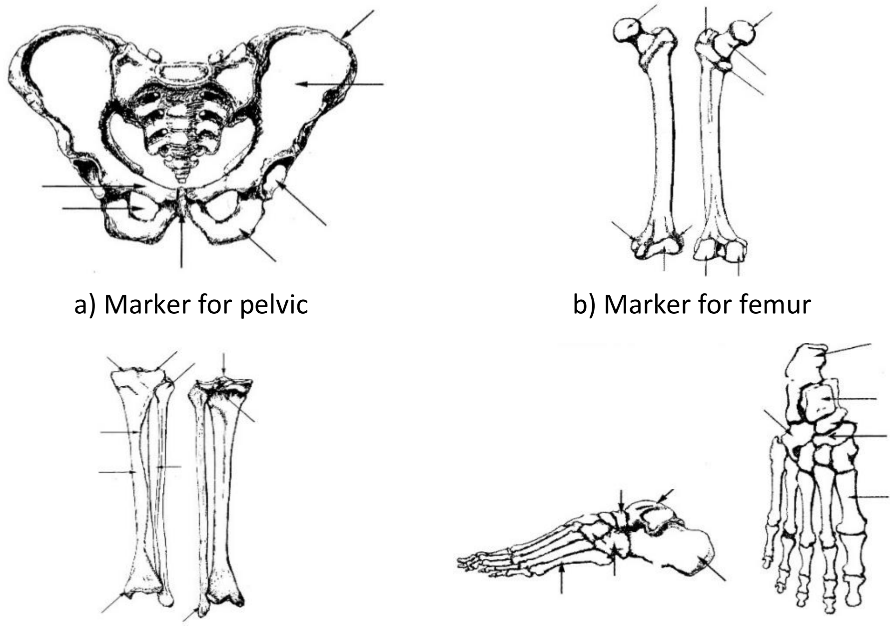
i) Target Manager – marker creation

In HumAR, the four lower limb parts of the bones- pelvis, femur, tibia/ fibula and foot were used. Markers were required for the use of AR. A marker is used to detect and allow any assigned image to be recognised and then displayed on the tablet's screen. A marker can be an image on any surface, and the tablet's camera will work as an image scanner. In HumAR, each image of the bone was taken from the unit laboratory manual and assigned with a specific marker (Figure 5.8). In HumAR, the image is detected as a marker and is measured by its width and specific dimensions. Once a marker has been recognised, HumAR will display and superimpose the respective 3D computer generated object on the tablet's screen. The markers were created using the Qualcomm Vuforia software marker manager (Qualcomm, 2014). With Vuforia, the marker can be saved into either a JPEG or PNG image file formats. In HumAR, the images of the bones were saved as JPEGs. A few steps are needed to create a marker:

- Step 1: The bone images need to be saved as a JPEG image file format.
- Step 2: A device database for the marker is created using the Vuforia online database, as shown in Figure 5.9 (Qualcomm, 2014). A new target is identified and given a

name. A single image marker is selected as the target type, which will be displayed on top of a piece of paper.

- Step 3: The target dimensions or size are set. The sizes of the parameters are important as the projected image during tracking must be of the same scale. Nevertheless, this setting can be re-scaled at runtime in Unity 3D. The target size is determined by the horizontal (x) and vertical (y) axes. As long as the tablet's camera moves to the left, right, top and bottom border of the x-y axes of the marker, the image can be tracked (Figure 5.10) (Chow et al., 2013).
- Step 4: The target image file is uploaded to the Vuforia online database.



a) Marker for pelvic
b) Marker for femur
c) Marker for fibula
d) Marker for foot

Figure 5.8: Image-based marker on HumAR application

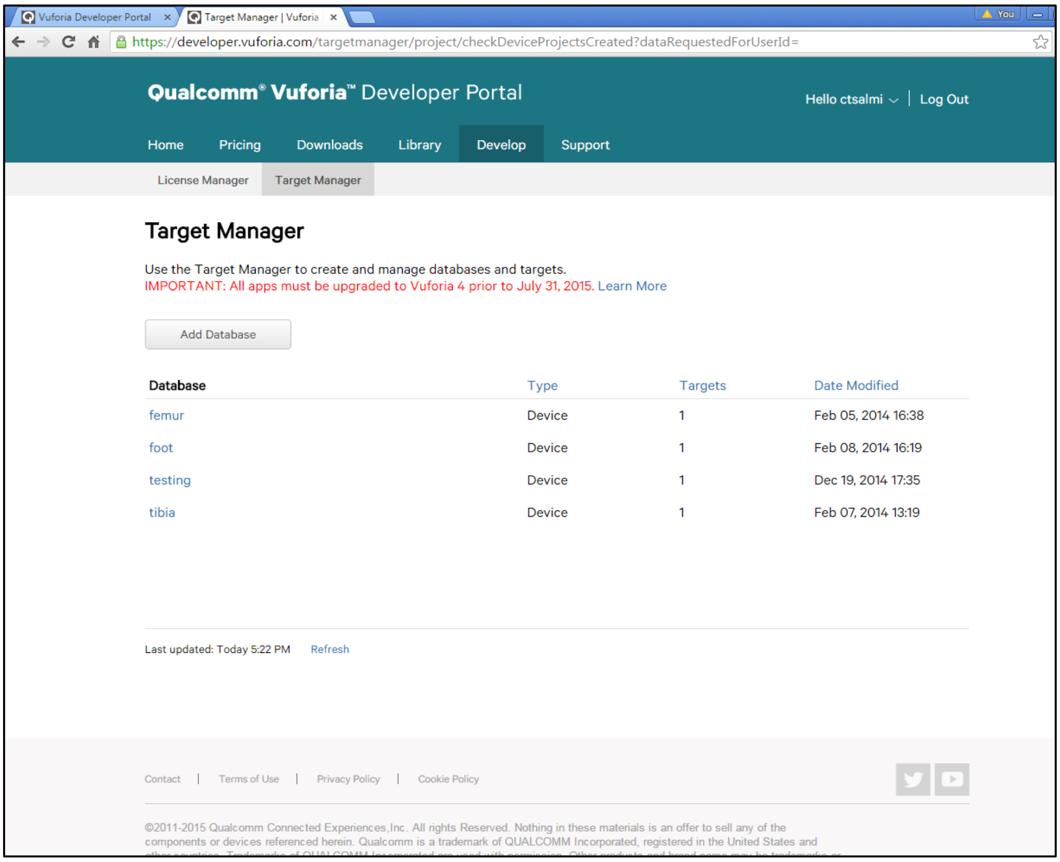


Figure 5.9: Vuforia online database for marker manager

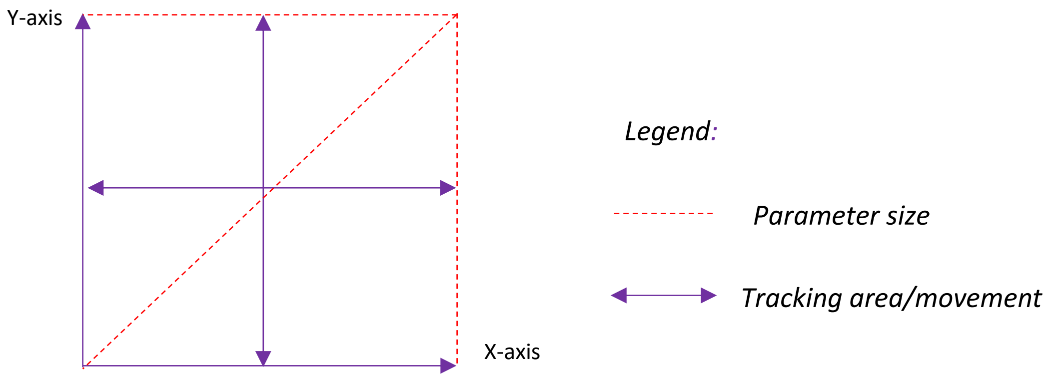


Figure 5.10: Target size parameter

ii) The SDK project for Android development

After the images had been uploaded as target markers, the marker project files were downloaded from the Vuforia database. In this research, since Unity 3D was used as the authoring software for the development of HumAR, a *Unity Editor* file format was selected to match the authoring development in the Unity 3D software where a *unitypackage* file format was created. Then the augmented reality unity project was set up with the Vuforia SDK, saved and downloaded for further development in the Unity 3D software.

5.3.2.2 Unity 3D Software Development tool

This section describes how HumAR was further developed using Unity 3D where the 3D objects and target markers were combined. In Unity 3D, all bones were labelled with the relevant information for learning the human anatomy, specifically in human osteology and with reference to the bones of the lower limbs. Then all functions such as control panel, bone placements onto the marker and finger interactions with HumAR were designed and developed using Unity 3D.

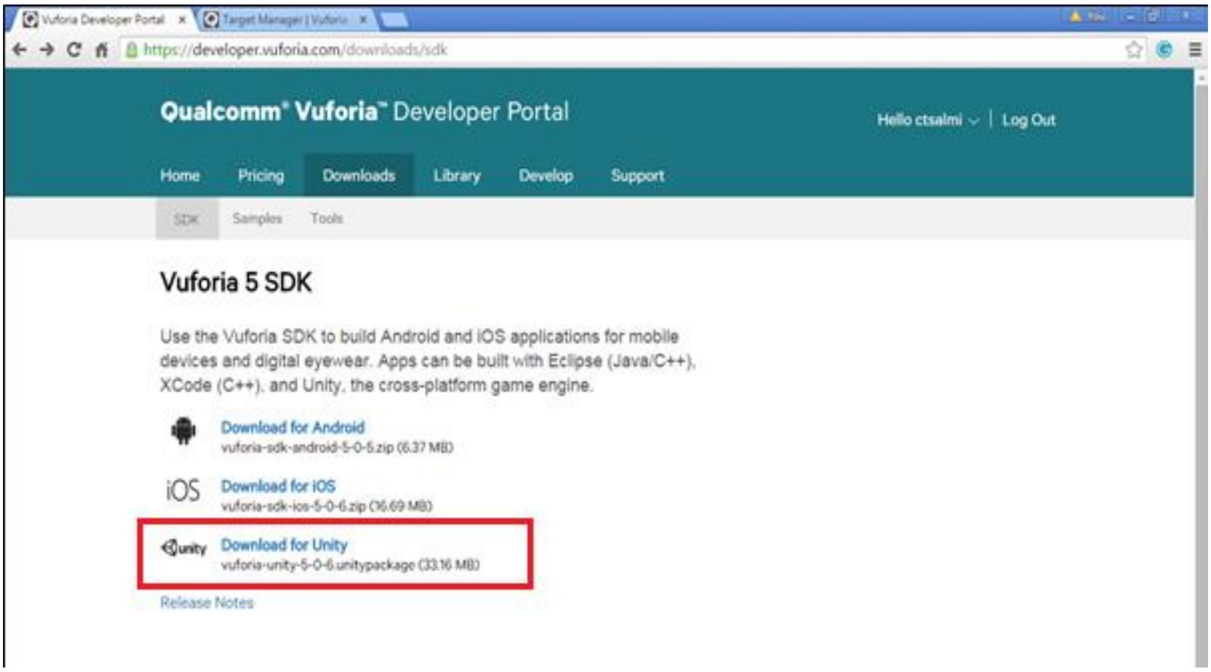
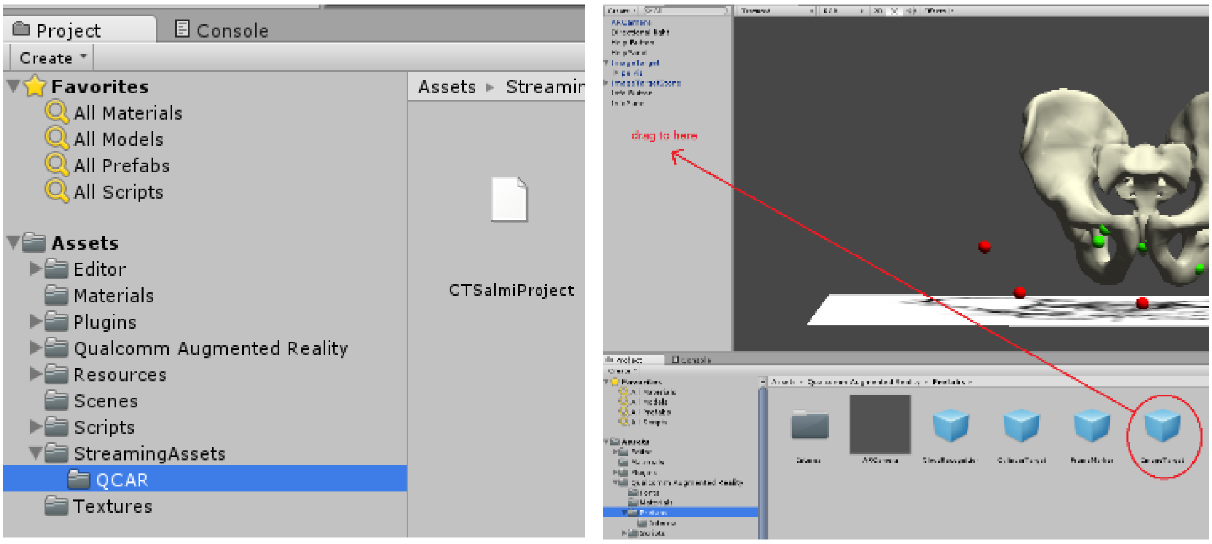


Figure 5.11: Vuforia SDK-Unitypackage

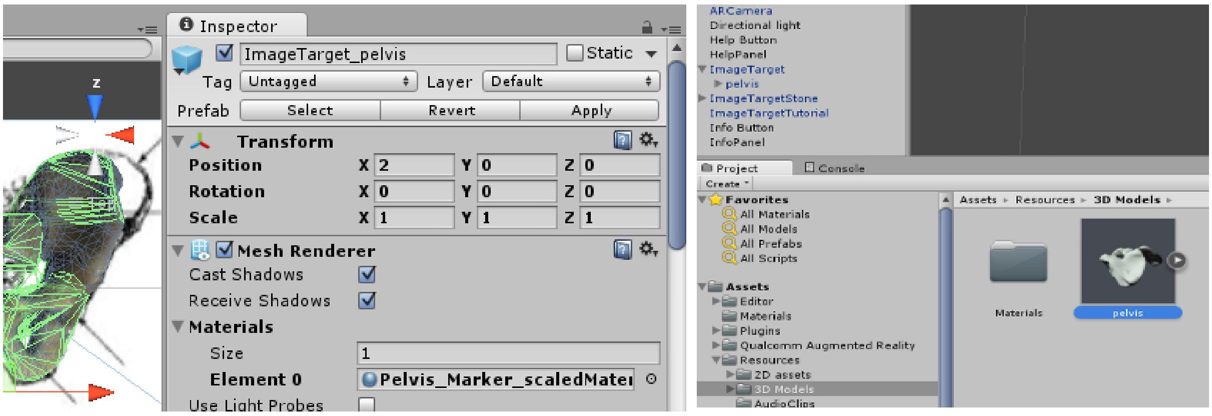
In Unity 3D, the downloaded **.unitypackage* file was imported from the Vuforia's online database (Figure 5.11) and automatically placed in Unity's asset folder *>StreamingAssets >QCAR* (Figure 5.12a). The Unity package file was then synced with the *ARCamera* by activating the dataset package project and marker dataset. A new *ImageTarget Prefab* (Figure 5.12b) was then dragged into the game object hierarchy to create a new target game object. The *Prefabs* folder is used as a labelling mechanism. A game object called *Labels* was created for use in conjunction with the 3D computer generated models. As mentioned earlier, the image target parameters can be reset in this setting, if required.

The desired marker can be seen in the *Scene Panel* with a texture corresponding to the selected marker. This image target marker game object can also be resized by changing the *scale* in the *Inspector* panel (Figure 5.13a). Next, a 3D computer generated model of part of a bone was imported into Unity 3D into the *Resources > 3D Models* folder. The 3D computer generated bone model was saved in the FBX (*.fbx)* file format. It was then exported to Unity 3D and incorporated with Vuforia (Qualcomm, 2014) for AR related tasks (Figure 5.13b). FBX is an acronym for the "FiLMBOX", and it is used to provide interoperability between digital content creation applications. The FBX file format preserves the entire functionality of the original file and can be manipulated by many 3D modelling software. An AR camera is needed for the object view, and students can manipulate the augmented object. Low polygon count of the 3D computer generated models of the bones were used to reduce the real-time processing requirements of the mobile device hence producing a better interactive experience for the students when using HumAR. These low polygon 3D computer generated models help improve the overall frame rate, smoother and faster views and are more suitable for scaling purposes.



a) Package file was imported b) Image target was dragged

Figure 5.12: Setting up a marker and 3D computer generated object in Unity 3D



a) Setting for marker

b) 3D computer generated model was imported

Figure 5.13: Inspector panel for setting up a marker in Unity 3D

5.4 Summary

This chapter describes the concept, system and development process of HumAR. HumAR was developed to support this research in investigating the learning effectiveness in an mAR-based learning environment. Furthermore, it was utilised as a medium to assist in the data collection process, in response to the research objectives and questions. HumAR has been validated through pilot testing. The evaluation of user experience in HumAR is presented in the next chapter, Chapter 6.

CHAPTER 6
RESULTS & DATA ANALYSIS - EVALUATION OF USER EXPERIENCE IN HUMAN ANATOMY MOBILE AUGMENTED REALITY (HumAR)

6.0 Overview

HumAR has been validated through pilot testings by three different categories of expert reviewers that comprise of academics, technology experts and end users. The objectives of the pilot test were to consolidate users' experience from a didactic and technical point of view. The processes and results of the pilot testing, which include content, usability and measurement items are presented. Based on the results of the pilot test, it can be concluded that the students were satisfied with HumAR in terms of its usability and features. This could have a positive impact on their learning process. There are two objectives why this preliminary testing was conducted. Firstly, it is to identify any significant differences in the learning improvement between the non-technology Current Learning Method group (CLM) and the mAR-technology group (HumAR). Secondly, it is to analyse the reliability of item measurement in the survey questionnaire before being organised in the actual study.

6.1 Pilot Testing

6.1.1 Methodology

A pilot testing of HumAR's features was conducted to measure the reliability of the prototype. Thereafter, pre/post-test sessions were arranged to obtain the preliminary results of the learning effectiveness using HumAR. In this section, the study setting, as well as the measurement of items and procedures involved in the pilot testing will be described.

6.1.2 Procedures

The perceptions of various experts in multiple fields were included in determining the suitability and usability of the prototype prior to its use in a learning session. HumAR has been through three review stages: i) academic; ii) technology expert and iii) participants. All stages are displayed in Figure 6.1. Similar procedures were applied to the three reviewers in terms of the prototype usability testing.

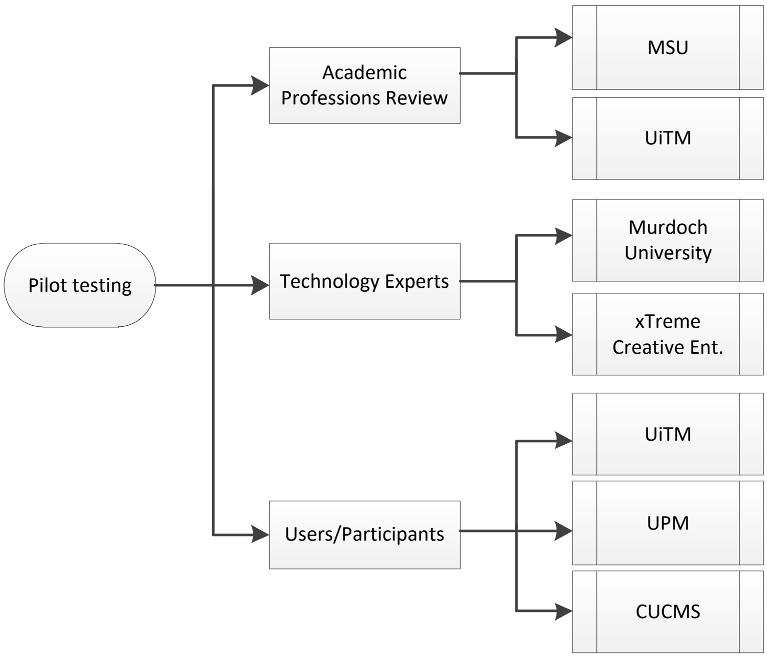


Figure 6.1: The expert reviews of HumAR

6.1.2.1 Procedure Pilot Testing – Academic Review

With reference to Figure 6.1, HumAR was reviewed by two academic experts in the field of the Science of Human Anatomy at each university, Expert 1, was a Deputy Dean of Student Affairs, International Medical School, Management & Science University (MSU), Shah Alam, Selangor, Malaysia and Expert 2, was a Senior Lecturer, School of Biological Sciences Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia. The first session started with a briefing of objectives and information on the research. Participants consented and voluntarily agreed to be reviewers and to be a part of the research. The experts were briefed on the use of HumAR prior to the commencement of the review session. They were given an hour to review HumAR. A set of questions on the characteristics of usability was distributed. In the usability set, both open-ended and close-ended (Likert Scale) question methods were applied. The open-ended questions were used to measure different opinions (Liaw et al., 2006), based on their academic experience and expertise about the subject. As shown in Table 6.1, the set of questions covered four sections – Section I: General Background Information; Section II: Content Suitability; Section III: Features of HumAR in a Learning Environment and Section IV: Comments or Suggestions (Appendix K).

Table 6.1: Set Question Type

	Open ended question	Close-ended question (Likert Scale)
Question / Section	*Section I: General Background Information* *Section II: Content Suitability* *Section IV: Comments/Suggestions*	*Section III: Features of HumAR in a learning environment*

The responses of the reviewers for each section were as follows:

6.1.2.1.1 Section I: General Background Information

This section includes collecting information such as teaching field, experience and university. A summary of the reviewers' general background information is shown in Table 6.2.

Table 6.2: Summary of Reviewers' General Background

Question No.	Info	Expert 1	Expert 2
1	Teaching field / unit	Anatomy & Physiology	Human System Biology
2	University	Management and Science University (MSU)	Universiti Teknologi MARA (UiTM)
3	Teaching experience	10 years	> 4 years

6.1.2.1.2 Section II: Suitability of Content

Next, Section II investigated the suitability of the HumAR's content and the understanding of the Human Anatomy structure for learning purposes. The respondents were required to describe their opinion based on their expertise in each of the following areas:

1) The appropriateness of content in understanding the subject presented in HumAR
2) The adequacy of information for the topic
3) The object enhancement and effectiveness of the prototype
4) Learning interaction
5) Learning assistance

The feedback received on "the understanding of the subject presented in HumAR" (from a four and ten-year experience perspective) were examined. It clearly shows that the concept of understanding the material presented in the prototype was pleasant and easy to use.

The results showed that there were ample amounts of information on the topic. The descriptions provided in HumAR were sufficient for students. Moreover, HumAR offered a direct hyperlink to a more detailed explanation about the subject.

With regards to the effectiveness and the object enhancement in understanding the subject by using HumAR, both reviewers commented that it was easy to use. The simplicity of the prototype concept made the information or content, easily digestible. Based on the interactions, the experts believed that the prototype could assist in students' interaction when learning about Human Anatomy. The concept of the "exploration in the learning – interaction with the prototype" was supported.

Considering the opinions of these experts, it can be affirmed that they support the concept that HumAR can assist in learning the human skeletal system. They reported that HumAR could be used as a learning tool.

6.1.2.1.3 Section III: HumAR Application Prototype Features in Learning Environment

For the quantitative responses of the features of the prototype, the Likert Scale 1, depicting 'Strongly Disagree' to 5, depicting 'Strongly Agree' was used to measure the features of prototype usability. As confirmed in the general overall approval rating, the experts found this prototype to be pleasant and exciting. Overall, the features received levels 4 to 5 responses. The features and functional testing were gauged using eight features: 1) the realism of the 3-Dimensional images; 2) image smoothness; 3) the precision of 3-Dimensional images; 4) learning improvement; 5) view angle for stimulating interest and motivating learning; 6) object manipulation; 7) enhancement of understanding and 8) labelling assist memorisation. Table 6.3 consists of the definitions of each feature in the user reliability testing results.

Table 6.3: Definition of prototype features

Feature	Definition
The realism of the 3-Dimensional images	The realism of the 3-Dimensional (3D) images in this application are useful in learning. The 3D characteristics provide a realistic environment, which can increase an individual's motivation to learn. This is due to the ability of an object in 3D to hold interest and attention in the learning process.
Image smoothness	The smooth changes of the images in this application are of great value. It assists in the performance of object transition - during scaling, rotating and moving of objects. The transition performance refers to the efficiency and velocity of object responsiveness.
Precision of 3-Dimensional images	The precision of the 3D images in this application helps to enhance the student's understanding. The accuracy of the object helps the student remember the real object in terms of object placements, indentations and textures.
Learning improvement	The ability to vary the perspective position of the 3D objects in this application permits the student to discover better. The 360° angles (x, y

	and z-axes) enable the student to learn about an object with more precision, especially in identifying the exact position of the subject matter.
View angle for stimulating interest and motivating learning	The ability to change the view position of the 3D objects in this application makes for more motivated and interesting learning. The level of motivation and enhanced learning experience influences the ability of individuals to achieve the learning objectives in their subject areas. This can lead to a stronger self-centred learning concept.
Object manipulation	The power to control the objects (e.g. rotate, scale and move) within the augmented reality environment encourages learning and makes it more exciting. It provides the ability to manipulate the object and to see the subject in detail. This manipulation signifies the capability of interaction, which is a main feature of the prototype.
Enhancement of understanding	The ability to manipulate the objects in real time, along with the use of the description panel provided, enhances the student's understanding and will facilitate the student in acquiring more information about the subject. This prototype has the potential to offer a greater understanding of the subject being studied.
Labelling assist memorization	The ability to learn through the labelling of each object can improve the student's memory. This label feature was built into the application to help the student retain for a longer period what he/ she has learned. Providing this feature for each bone helps the student to work out the character and position of the bone accurately.

6.1.2.1.4 Section IV: Comments or Suggestions

For improvements, all comments and suggestions were welcomed. The feedback received were as follows:

"New way of learning Human Anatomy." (Expert 1)

"We need new technology to gain interest among students in learning Human Anatomy, as a conventional textbook way will be quite tough." (Expert 2)

"Students in this era, prefer portable device, IT-based learning." (Expert 2)

Despite all the positive comments and suggestions, one of the objectives of the pilot testing is to discover and debug any errors or expose unfriendly functionality. Expert 1 suggested the font size of the prototype needed to be larger. As a result, the font size was modified and increased by 30% of the device's display resolution.

In general, HumAR can be used by non-science students as well. Both reviewers agreed that for a simple introduction to Human Anatomy, the content in the prototype could easily be learned because the diagram and explanation are clear enough to understand. Similarly, students can grasp the information without difficulty due to the interactive approach and 3D computer generated images used to enhance their understanding.

The overall consensus of the academic reviewers was that the prototype is beneficial and handy. The experts also claim that HumAR may not only be limited to Science students but may be extended for use with students in various other fields of study.

6.1.2.2 Procedure - Pilot Testing with the Technology Expert

The system evaluation steps of testing are shown in a Data Flow Diagram (DFD) as illustrated in Figure 6.2. Data-flow is a technique of requiring computations in a two-dimensional graphical method (Gurd et al., 1985). In adopting the concept from (Gurd et al., 1985), the three objectives to evaluate the prototype in a technology expert's view are: i) to identify the relative malfunction system; ii) to determine the nature of the interaction and iii) to evaluate the prototype hardware for optimum performance. A company called x-Treme Enterprise, based in Cheras, Selangor, Malaysia, was recruited to validate the prototype according to the objectives mentioned earlier. Similar procedures were used in the evaluation of the HumAR application prototype.

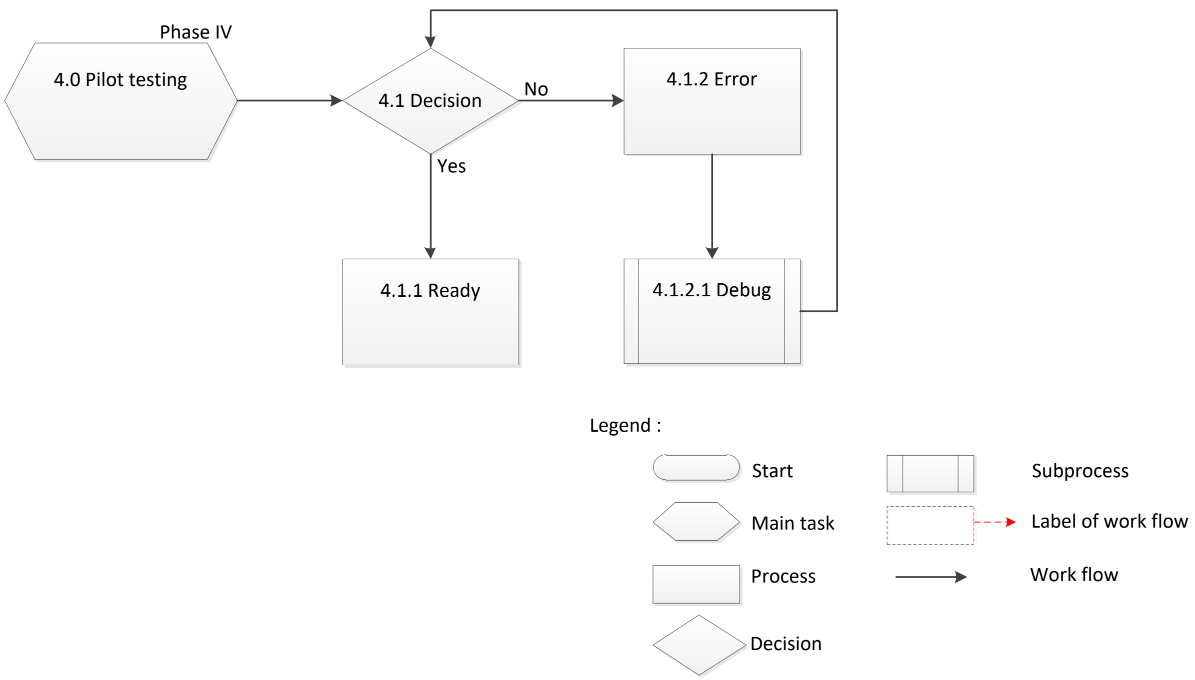


Figure 6.2: Steps of Technology Expert Testing

Firstly, the validation was for the malfunction of the system. All buttons provided in HumAR were checked. According to the DFD flow in Figure 6.2, flow number 4.1 – Decision has two parts; No and Yes. During the debugging testing session, one error was uncovered. The hyperlink provided was not linked to the specifically assigned website. In addition, the testing process will continue looping if any errors are found until the system is ready for the user. Secondly, the interaction of the system was evaluated. All interactive functions, such as finger sensing, were tested. Table 6.4 illustrates in detail the evaluation of the finger interactions involved.

Table 6.4: Finger gestures Interaction

Gesture	Interaction	Item Check
Double tap	Select object	√
One finger drags right/left	Horizontally rotate around the selected object	√
One finger drags up/down	Vertically rotate around the selected object	√
Pinch	Zoom in/out	√
Three fingers drag	Move object	√

Finally, to guarantee optimum hardware performance, the component for instant camera device compatibility by the handheld device was checked to ensure that the prototype operates smoothly. Camera detection reliability was tested to verify an accurate recognition of all lower limb parts. Based on the experts' technology experience, a question about the labelling system was raised. Consequently, the labelling and populating of the information were modified. In the initial system, the labelling was only visible when the user clicked once on a particular bone. Furthermore, when the user rotated around the 3D computer generated object, the previous label selected will still be displayed. The labels were only deselected when the user tapped on the background screen once. This effect caused some confusion due to a mass of visible labels. A modification of the labelling system was carried out to overcome this issue. A better technique was developed, whereby the labels were rendered invisible when the user rotated the object. In this way, the labels for the hidden objects or objects behind will be automatically invisible.

6.1.2.3 Procedure - Pilot Testing with the User

This phase of testing comprised of three steps which are: i) recruitment of participants; ii) cross tabulation and iii) usability testing.

6.1.2.3.1 Process of Recruitment of Participants

Based on Figure 6.3, the pilot user testing was conducted at three different universities; Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Universiti Putra Malaysia (UPM), Serdang, Selangor and Cyberjaya University College of Medical Sciences (CUCMS), Cyberjaya, Selangor, in the Central Region of Malaysia. These three universities were selected from the list using the simple random method. Even though data were collected at three different universities in three different locations, the procedures and settings were standardised. For example, data collection in these three locations was conducted concurrently. Two research assistants were available at each university during data collection. Likewise, the same set of questionnaires, as well as similar target audiences was recruited for pre/post-test at each university. The same procedure was implemented in the process of recruitment of participants for actual data.

To get access to the selected universities, letters of permission were sent to the Dean/ Head/ Director of the Health Sciences Faculty of each university. The letters were seeking permission to recruit participants, distribute the questionnaires and conduct experiments. After consent had been received, emails were sent out to the respective Science lecturers to introduce and familiarise the experimentation of HumAR to each respective faculty of the university. Telephone calls and face-to-face meetings were also carried out for further discussion.

The recruitment started with the introductory HumAR Meeting 1: Introduction of HumAR concept. HumAR was introduced, and a demonstration of HumAR was made to the Science unit lecturers for better understanding, followed by an explanation of the research objectives and HumAR experiment.

This was followed by Meeting 2: Consent Process I: Lecturers. At this meeting, consent to conduct a pilot testing and a preliminary study was obtained and participation of lecturers and students were discussed. Furthermore, this process was to obtain consent from each lecturer to enable a promotion of this research during class time to guarantee that the data collection flow will run smoothly. All procedures for the evaluation of HumAR were also explained. In addition, the date and time for the pilot testing of the features of HumAR in the learning environment were specified.

Finally, once an agreement was reached, the participants were recruited approached as shown in Meeting 3: Consent Process II: Participants. In the same way, a briefing about the main aim and objectives of the research, as well as the procedures of the experiment were delivered. Participation in this pilot testing and preliminary study were all on a voluntary basis.

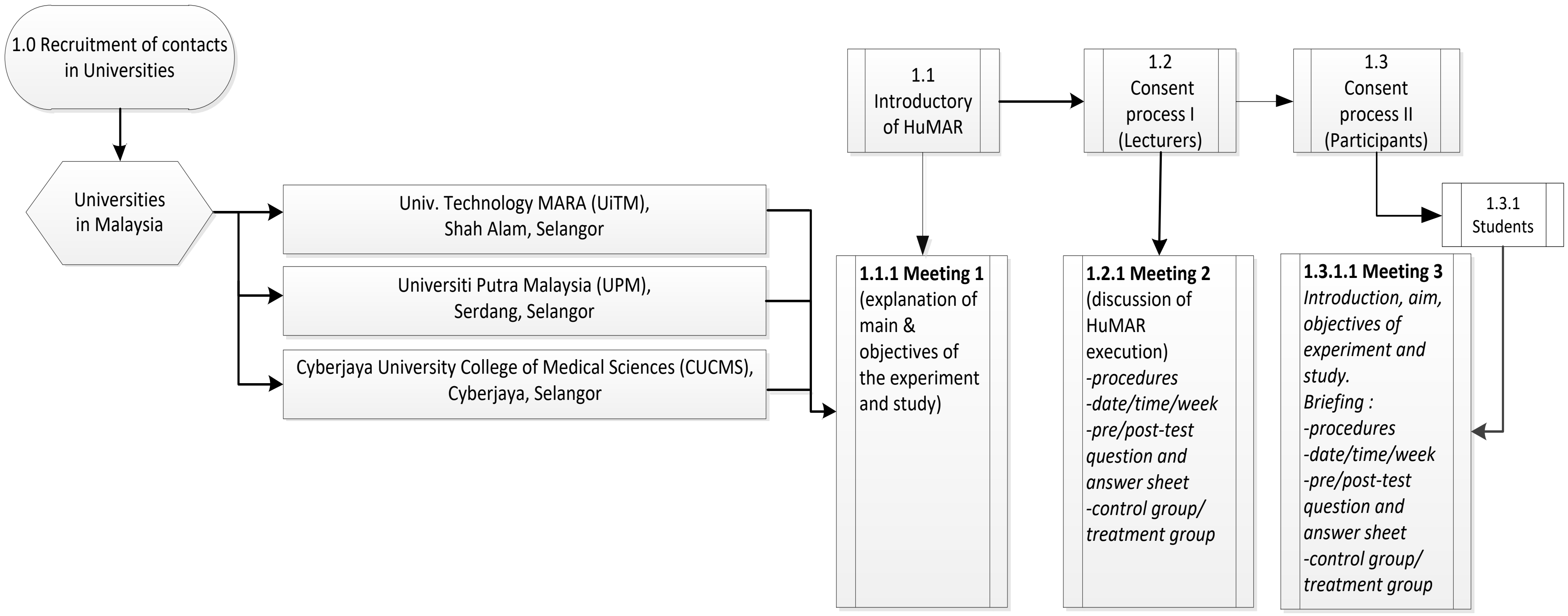


Figure 6.3: Process of recruitment of the participants

6.1.2.3.2 Participants Cross Tabulation

In reference to Table 6.5, there were 30 enrolled students (as a sample size) in the Science unit who were willing to participate. The students ranged in age from 18 to 23 years old (mean age = 20.03), of which 26.6% were male, and 73.3% were female. These students were from the first and second year of Bachelor Degrees enrolment. This usability testing involved a different set of participants from the actual study (Section 7.2). Each session was conducted at three different venues within the area of each respective university.

Table 6.5: Evaluation of cross tabulation study setting

Study setting	**Prototype testing**		
	University		
	UiTM, Shah Alam, Malaysia	UPM, Serdang, Malaysia	CUCMS, Cyberjaya, Malaysia
Sample size	9	13	8
Range of ages	21-23	19-21	18-20
Male / Female	1/8	5/8	2/6
Venue	Lecture Hall	Museum Anatomy	Classroom

6.1.2.3.3 Usability Testing

User pilot testing was conducted for measuring the reliability of HumAR. This involved 30 students, equipped with HumAR on the tablets. This testing session was prepared according to the procedure of the HumAR data collection. First, a brief training was conducted for the students to learn about the HumAR functions. The students were exposed to HumAR and familiarised themselves with the program for about one hour, having learned about the bones for their learning activity during the one-hour pre-lab session. After that, a questionnaire (Appendix C) survey was distributed to the students to rate HumAR's interaction and functionality. The results of the functionality testing were graded using a Likert scale from 1, depicting 'Strongly Disagree' to 5, depicting 'Strongly Agree'. The values that returned for each feature of HumAR (Table 6.6) are as follows.

Table 6.6: Evaluation of usability

HumAR Features	N	Minimum	Maximum	Mean	Std. Deviation
The realism of the 3-Dimensional images	30	4	5	4.27	0.450
Image smoothness	30	4	5	4.27	0.450
Precision of 3-Dimensional images	30	4	5	4.43	0.504
Learning improvement	30	4	5	4.43	0.504
View angle for stimulating interest and motivating learning	30	4	5	4.47	0.507
Object manipulation	30	4	5	4.40	0.498
Enhancement of understanding	30	4	5	4.27	0.450
Labelling assist memorisation	30	4	5	4.47	0.507
Valid N (listwise)	30				

Table 6.6 depicts the usability testing results from the HumAR features. The features consist of the ability of:

(i) the realism of the 3-Dimensional (3D);
(ii) image smoothness;
(iii) the precision of 3D images;
(iv) learning improvement;
(v) view angle for stimulating interest and motivating learning;
(vi) object manipulation;
(vii) enhancement of understanding and,
(viii) labelling assist memorisation.

Descriptive analysis was carried out on the results. Regarding task performance, it can be generalised that the students were satisfied with the HumAR usability test. Some students selected the highest and the slightly lower scores for satisfaction in the maximum column of each feature from the scale 1 to 5.

These higher mean values indicate the gratification of the users to these provided functions. These features provided satisfactory outcomes to the users of this prototype. It could be observed that the highest mean values were displayed in the features of view angle for stimulating interest and motivating learning, as well as labelling assist memorisation. These results suggest that:

i) most of the students agree that these two functions are needed to assist their learning environment;

ii) by using HumAR, the ability to change the angle view of the subject matter is inviting and possibly spurs their interest and desire to learn and;

iii) the labels provided showed that it would improve their memory to retain the information longer and have a better understanding of the subject learnt.

With the same value of mean (4.43), in the features of "the precision of the 3-Dimensional images" and "learning improvement", it could be inferred that all students experienced an enhancement in their learning ability. Most of the students had the chance to improve their study by controlling their interest in getting the precise information about the bone parts through 360° angles. With reference to the responses on a scale from 4 (Agree) to 5 (Strongly Agree), most of the students selected scale 5 on the Object Manipulation, which indicated HumAR has a substantial capacity to convey information and make learning highly interactive. This situation was considered one of the important factors in their learning environment. Furthermore, the consensus continued within the realism of the 3-Dimensional (3D), image smoothness and enhancement of understanding features. The results clearly indicate gratification on these respective features. In the last section of comments or suggestions, the following user feedback and comments were received:

- *"I think HumAR did improve our learning skills, and it should be integrated into our student life."* (Respondent 4)
- *"It's a very useful application. I hope it will be used in the learning process in the future."* (Respondent 6)
- *"Improve more on the labelling."* (Respondent 7)
- *"I think it is even better if the application is not limited to the bone only, and it is good to have an element of animation implemented in the program."* (Respondent 16)
- *"This can be done for all types of subjects and make it more fun with colourful labels."* (Respondent 25)

In summary, most of the students showed an interest and found HumAR to be a lively and intriguing experience. With the 30 cooperative students who participated in this pilot testing, it can be concluded from the outcomes that the dependability of HumAR has been achieved.

6.2 Summary

This chapter describes the theory, concept and prototype development of HumAR. HumAR has been evaluated by the academics, technology experts and students in three different sets of pilot testing. The methods of evaluation and data collection procedures were also described. In addition, the assessment includes the validation of the content and usability of HumAR. In summary, there are only a few changes attained following the pilot testing due to; 1) Font size, reviewed by the academic experts; and 2) Labelling system on HumAR, reviewed by the technology expert. These flaws have been thoroughly improved and upgraded, as follows; 1) The font size was modified and increased by 30% of the device's display resolution; and 2) Labelling and populating of the information was modified. The labels were rendered invisible when the user rotated the object. Overall, the results obtained from these pilot testing indicate that HumAR is ready to be used for data collection in the actual study.

In addition, the pilot study results were presented to obtain a preliminary result. There are two main reasons why the pilot testing was conducted. First, this pilot study was conducted to get an initial result that learning with HumAR could potentially increase interest and engagement in the students' learning process. The pilot study used the experimental method with the Science students from three different universities through pre/ post-testing. Based on the results, it is concluded that there was a higher significant increment in the experimental group. This thus leads to a promising result that learning with HumAR produces better learning outcomes. As such, they may have a potential role in determining the scores posted by the students. Second, an item analysis was also performed, measuring the reliability of items' internal consistency in the survey questionnaire (Pallant, 2010). The results of the pilot study are discussed in Chapter 7.

CHAPTER 7
RESULTS & DATA ANALYSIS - THE EFFECTIVENESS OF LEARNING USING MOBILE AUGMENTED REALITY AND CURRENT LEARNING METHOD

7.0 Overview

This research primarily aims to examine the effectiveness of learning through the mAR mode and non-mAR mode respectively, as well as the significant differences between groups of students in terms of their performance achievement, motivation and learning outcome. The learning outcome is the dependent variable, which is measured by perceived usefulness, self-efficacy and satisfaction. On the other hand, the independent variables consist of performance achievement, mAR features and the motivation of learning modes. This chapter also sheds light on the data results based on the data analysis, research questions and testing of the proposed hypotheses.

This chapter begins with the results of the pilot study. With this as the preliminary results, it was discovered that five variables are satisfactory in terms of item reliability in the questionnaire. Fundamentally, in this preliminary result, it can be said that these factors contribute to students' achievement and learning outcomes. Furthermore, the pilot study assisted in the practice with regards to the data collection procedure before the actual study was performed.

Next, the second part of this chapter discusses the results obtained from the sample's descriptive statistics of actual data. Furthermore, the statistical analysis results are enumerated based on the research questions. The analyses were taken out through several statistical techniques, for example, the descriptive statistical analysis, the independent sample t-test, the paired-samples t-test, Analysis of Variance (ANOVA), as well as Multivariate Analysis of Variance (MANOVA). Lastly, a summary of the findings of the research questions is presented.

7.1 Results of Pilot Study

7.1.1 Pre/ Post-Test

Pre-test and post-test evaluations were conducted for preliminary results. These were carried out to measure changes in knowledge, behaviours and attitudes of the participants in the learning environment, which can address and reduce the issue of low retention of information using HumAR. Thirty students were recruited and volunteered themselves for this session. This pilot study involved a different set of student group from the actual study, to avoid any placebo effects (Section 4.3).

The one-hour focus group sessions were one week apart, so the total duration hours of the focus group sessions were a maximum of two hours. These sessions were conducted in every appointed class. The pilot testing used the survey technique as the quantitative method to collect data. The instrument questionnaires were distributed to the Science students during the experimental session. The diagram of the pre/ post-test is illustrated in Appendix D.

In a twenty-minute pre-test organised during the first week, students were given a question to answer, without access to any information material or reference books. After that, the students continued with their class activity for 30 minutes. Next, they were given the questionnaire related to the current learning method and were required to complete in 10 minutes.

The post-test was conducted in the following week. During this post-test, the participants were split into two groups. The first group was exposed to mAR-technology in their learning activity. The students were given a five-minute training on the use of HumAR prior to the commencement of the learning activity. Similar procedures were used with the control group. The learning activity lasted for 30 minutes, after which, the post-test questions were distributed to the students for completion in 20 minutes time, then fill in the final questionnaire in 10 minutes.

The second group was a control group (non-technology). This group also had training on the physical skeletal bone for a five-minute training. This group had the permission to use the human skeleton as a resource for their learning activity. In this learning activity, the students were taught in 30 minutes and were required to complete the post-test questions in 20 minutes and afterwards, complete the questionnaire in 10 minutes at the end of the session.

7.1.1.1 Significant difference of the learning modes

According to the results (Table 7.1), the average score for the pre-test CLM group (m = 10.47 score) is lower than the HumAR group (m = 14.93). As supported by the pre/ post-tests scores, the results demonstrated that both learning techniques increased from the pre to post-test sessions. There are significant differences in terms of the variation in growth in the post-test sessions between the control (CLM) and treatment group (HumAR) methods.

The results explained that there is a mean growth rate of -8.20 in the current learning method. Meanwhile, the performance scores using HumAR showed nearly a double increment of mean -14.14. With a 95% confidence interval of difference, it shows that there is a positive variance between Pair 1_score_pre-CLM and Pair 2_score_pre– HumAR. Therefore, the null hypothesis is rejected and states that both groups indicate significant differences between pre and post-testing. However, the mean value reflected in HumAR has a greater value than for CLM. It can be proven that, between the control and treatment group, the effects clearly demonstrate a significant increment in HumAR. It can be concluded that the assistance of technology HumAR can enhance the understanding of the subject, increase their motivation in the learning process and improve the student's learning performance to a larger extent than common learning.

Table 7.1: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	score_pre	10.47	15	7.772	2.007
	CLM	18.67	15	5.164	1.333
Pair 2	score_pre	14.93	15	9.138	2.359
	HumAR	29.07	15	3.390	0.875

Table 7.2: Paired Samples t-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	score_pre - CLM	-8.200	10.725	2.769	-14.139	-2.261	-2.961	14	0.010
Pair 2	score_pre - HumAR	-14.133	11.432	2.952	-20.464	-7.802	-4.788	14	0.000

7.1.1.2 Homogeneity of Variance

A one-way ANOVA was performed to compare the impact, effect size and efficacy of the score of the group. Based on Table 7.3, the assumption of homogeneity of variance of pre/ post-test was verified using Levene's Test. The variables were found to be normally distributed and of equal variances. The result shows both groups with a *p* value of greater than 0.05. This result assumes that the data do not violate the assumptions of the homogeneity variance. The values discovered in pre-test score (F2= 1.471, 28= 0.235) and value for post-test score (F2= 2.470, 28= 0.127).

Table 7.3: Test of Homogeneity of Pre/ Post-Test Variances

	Levene Statistic	df1	df2	Sig.
Pre-Test_Score	1.471	1	28	0.235
Post-Test_Score	2.470	1	28	0.127

Based on Table 7.4, the assumption of homogeneity of variance was confirmed with Levene's Test. The variables were found to be normally distributed and of equal variances. The significant (*p*) values were discovered greater than 0.05.

Table 7.4: Test of Homogeneity of Variables Variances

	Levene Statistic	df1	df2	Sig.(p)
mean_bPLE	2.408	1	28	0.132
mean_cS	0.068	1	28	0.796
mean_dSE	0.007	1	28	0.934
mean_eM	0.629	1	28	0.434
mean_fLE	0.877	1	28	0.357

Note: bPLE = Section B/ Perceived Learning Effectiveness; cS = Section C/Satisfaction; dSE = Section D/Self-Efficacy; eM = Section E/Motivation; fLE = Features of HumAR

To show the correlation between each variable with the group of students, the results revealed that the five variables with p values less than 0.05 were the predictors of Perceived Learning Effectiveness (bPLE) (F (2, 28) = 38.024, *p* = 0.000), Satisfaction (cS) (F(2, 28) = 59.291, *p* = 0.000), Self-Efficacy (dSE) (F(28.817) = *p* = 0.000), Motivation (eM) (F(2, 28) = 47.904, *p* = 0.000) and Learning Environment (fLE) (F(2,28) = 31.696, *p* = 0.000). It can be seen that the results show significant differences from one group to another.

7.1.1.3 Effect Size of Score

Both the scores of the control and treatment groups were measured using Univariate ANOVA (Table 7.5). The post-test score between the groups are the dependent variables with a significant value of *p* = 0.000. It shows that there is a statistically significant difference between CLM and HumAR. Also, it shows a moderate effect size in terms of strength difference and the influence of the variable between group scores by 0.603, with alpha *p* value = 0.000 (Cohen, 1978).

Table 7.5: Between-Subjects Effect Tests

Dependent Variable: Post-Test Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	811.200[a]	1	811.200	42.514	0.000	0.603	42.514	1.000
Intercept	17088.533	1	17088.533	895.581	0.000	0.970	895.581	1.000
Group	811.200	1	811.200	42.514	0.000	0.603	42.514	1.000
Error	534.267	28	19.081					
Total	18434.000	30						
Corrected Total	1345.467	29						

a. R Squared = 0.603 (Adjusted R Squared = 0.589) b. Computed using alpha =0.05

7.1.1.4 Reliability of the Instruments

A common practice to check item reliability is through the use of the Cronbach's Alpha (α) coefficient (Pallant, 2010). The acceptable value of Cronbach's Alpha must be greater than 0.7. This reliability test is to determine that item, are bound together in the underlying construct (Pallant, 2010). Table 7.6 indicates the value of the reliability statistics of each construct. The results show that the values of Cronbach Alpha are greater than 0.7. Hence, these values report that the scales have good internal consistency. However, in the Corrected-Item Total Correlation column, Self-Efficacy, two low-item correlation values of 0.155 and 0.205 are less than 0.3. This situation occurred because the items may be assessing something different from the scale (Pallant, 2010). Therefore, these items were removed (Pallant, 2010). In addition, the removal of the items can also be checked in Cronbach's Alpha, 'if Item Deleted' column. As displayed in Table 7.6, Self-Efficacy reported two affected items of value

0.929 and one item in features of HumAR, having a value of 0.981 higher than the total score of the Cronbach's Alpha (α) column. According to Pallant (2010), if this value is more than the score total, it must be considered to eliminate the items from the list. Meanwhile, there are no exceeding values in the item-total statistic in Cronbach's Alpha, 'if Item Deleted column' for the constructs: perceived learning effectiveness, satisfaction and motivation. These constructs can be described as correlating with the total score in the reliability statistic.

In the pre/ post-test result, to measure the relationship between the constructs and post-test, a linearity test through the ANOVA table has been prepared. Based on Table 7.7, there is a substantial correlation between the variables: bPLE, cS, dSE, eM and fLE, efficacy and post-test score. Each variable reported a significant correlation, with the value of deviation from the linearity results, showing values of more than 0.05.

Table 7.6: Validity of the questionnaire

Constructs	Affected Item/Total No of items	Cronbach's Alpha (α)	Inter-Item Correlation Matrix	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Perceived Learning Effectiveness	18 Items	α = 0.971	+ve	>0.3	<0.971
Satisfaction	15 Items	α = 0.957	+ve	>0.3	<0.957
Self-efficacy	2/13 Items	α = 0.916	+ve	<0.3 (0.155, 0.205)	0.929/0.916
Motivation	11 Items	α = 0.944	+ve	>0.3	<0.944
Features of HumAR	1/9 Items	α = 0.978	+ve	>0.3	0.981/0.978

Table 7.7: ANOVA Table Linearity between constructs

Variable	Between Groups	Sum of Squares	df	Mean Square	F	Sig.
bPLE * Post-Test_Score	Deviation from Linearity	2.862	11	0.260	0.490	0.885
cS * Post-Test_Score		2.856	11	0.260	0.754	0.678
dSE * Post-Test_Score		1.948	11	0.177	0.582	0.818
eM * Post-Test_Score		3.494	11	0.318	0.717	0.709
fLE * Post-Test_Score		3.831	11	0.348	0.520	0.864

Note: bPLE = Section B/ Perceived Learning Effectiveness; cS = Section C/Satisfaction; dSE = Section D/Self efficacy; eM = Section E/Motivation; fLE = Features of HumAR

7.1.1.5 Results and Discussion

Ubiquitous learning is now becoming a trend (Lee et al., 2012). There are many people from various fields speaking about opportunities for learning via ubiquitous means; at the workplace, in the field of education and from the comforts of home (Lee et al., 2012). The simplicity and mobility of the mobile device allow for more effective learning and knowledge retention (Balog & Pribeanu, 2010). With the use of HumAR, students should be able to enhance their learning environments and improve their ability in memory retention. In the course of the development of HumAR, several software and hardware validation stages were traversed for exploring benefits in usability and the learning process. HumAR has been evaluated through students' performance tests, survey questionnaires and expert reviews.

In determining the significance of mAR technology, pre/ post-usage-tests were conducted. Both the pre and post groups were evaluated using the same tests. Although the number of students in this preliminary study was small, there was nevertheless a substantial difference in the values between the two groups. Furthermore, the post-test results show a large effect size. It is thus concluded that each construct contributed and influenced the performance of the post-test result.

It appears that the mAR technology learning experience has been effectively delivered to the students. In using current technology, many higher institutions are changing their teaching methods. They are moving from instructed-learning to self-centred learning methods. Although there have been various technological interventions in education, the adoption of mAR technology is limited (Azuma et al., 2011). In addition, previous studies stated that mAR technology had been ignored in the learning environment, particularly at the university level (Chu et al., 2010; Tsai et al., 2012). Ironically, technology is widely regarded as a fundamental aspect of 21st-century education and has long been used as a means of effective teaching and learning strategies applied by educators at many levels. This study has identified that the role of mAR, as part of the teaching and learning process, has not been sufficiently investigated (Hwang et al., 2008). Billinghurst (2002) argues that this technology is still under-utilised because there are insufficient experts available who can develop the subject contents. They do not have the required level of skills needed to develop 3D modelling, the programming knowledge and a detailed understanding of the subject for content development (Dunser et al., 2012).

In general, researchers in educational technology are in agreement that more motivation studies of mAR as an effective learning method are needed (Lee, 2012; Margetis et al., 2012; Rogers, 2012; Tarng & Ou, 2012; Ternier & De Vries, 2011). In this sense, students' intrinsic and extrinsic motivations should be taken into attention. The use of mAR could be highly effective in motivating students' learning and nurture their ability to become passionately involved in their own learning process. HumAR can assist them in learning the human anatomy using enhanced materials which stimulate their interest and help them to retain information longer than usual. Based on the significant results obtained in the pre/ post-tests, mAR as a teaching and learning tool is considered vital in enabling effective and positive learning for the future. As such, higher education institutions essential to look at the potential of implementing mAR technology with other subjects, besides Human Anatomy, for a better understanding, excitement and retention of a topic.

7.2 Results of the Actual Study

7.2.1 Demographic Characteristics

The current research's initial number of samples is 309 undergraduate university students. However, following the data screening test, 49 students' data were dismissed based on the fact that 35 students submitted incomplete questionnaires and 14 students were categorised as outlier cases. Hence, the final sample totalled 260 students. The students were randomly divided into two equal groups (130 in each group). One group was subjected to the mAR learning mode (HumAR), while the other was the non-mAR mode (CLM). The participants' ages ranged from 18 to 28 years old. The mean age of the participants was 19.65 years old.

There were 22.3% (29) of male and 77.7% (101) of female participants in the CLM group and 30.8% (40) of male and 69.2% (90) of female participants in the HumAR group. Overall, the sample consisted of 26.5% (69) of male and 73.5% (191) of female students. Students without any prior experience (during their secondary school education) in Human Anatomy accounted for 51.9% (135 students) of the total respondents, while those with experience accounted for 48.1% (125 students). The same procedure of data collection or experiment session was organised throughout the experimentation. Therefore, there was no bias or gap between these groups. The demographic characteristics are presented in Table 7.8.

Table 7.8: Demographic Characteristics of Respondents (N=)

	Characteristics	N	%
Gender			
	Male	69	26.5%
	Female	191	73.5%
Group			

	Experimental	130	50.0%
	Control	130	50.0%
Experience			
	Yes	135	51.9%
	No	125	48.1%

7.2.2 Case Screening

The data has been thoroughly checked through several steps for case screening. These steps comprise of missing data, incomplete questionnaire and normality test. It is to determine any errors in the data set. In all, six participants have been taken out due to absenteeism in the pre/ post-test sessions. Next, 43 respondents have also been removed due to unengaged responses with a value of less than 0.5 in the Standard Deviation (SD) (Hair et al., 2010).

7.2.2.1 Missing data

There were five respondents with missing values in Table 7.9. All these missing values were from four different variables. The affected items were Perceived Learning (PL) (items 3 and 13), Motivation (MOT) (item 1), Self-Efficacy (SE) (item 8) and Features of HumAR Learning (FTR) (item 5). The Median Replacement method was used for the Likert-type data (Lynch, 2003).

Table 7.9: Missing values

		PL3	PL13	MOT1	SE8	FTR5
N	Valid	259	259	259	259	259
	Missing	1	1	1	1	1

7.2.2.2 Checking for the Outliers

Data analysis begins with the testing of data normality and outliers by examining its distribution. In this regard, Judd et al. (1995) state that outliers have to be identified and removed. Outliers are referred to as observations that possess a specific mixture of characteristics that can be clearly noted as diverging from other cases. This characteristic is attributed to an abnormally high or low value of a variable that stands out from general observation. Moreover, outliers are either beneficial or detrimental, but evaluating them is needed to gather further information that has been transmitted. Beneficial outliers show a distinct population characteristic, whereas problematic ones prevent the analysis' aims and goals that can adversely affect the statistical tests (Hair, 2006). They are primarily determined through the calculation of Mahalanobis distance between specific cases from the meeting point of all the variables (Tabachnick & Fidell, 2001). In this research, the Mahalanobis distance was used to study multivariate outliers to determine multivariate outliers in the dependent variables. Based on the analysis, 14 cases were abnormal, reaching the critical value of 20.090 and as such, they were dropped from the analysis.

7.2.2.3 Normality

A statistical analysis that is sensitive to non-normality in SEM was used to examine the study variables' causal structure. To this end, Tabachnick and Fidell (2007) propose that researchers must examine data skewness and kurtosis to test data normality. The ranges of acceptability for both lie between ±3.92 to ±2.62 respectively, as explained by Rose et al. (2015). The skewness and kurtosis values of the original data set with 260 respondents are presented in Table 7.10. Based on the table, all values of skewness and kurtosis fell within the acceptable range.

Table 7.10: Test of Normality Skewness and Kurtosis for the variables

Name of the Variable	Skewness	SD	Kurtosis	SD
Performance Achievement Post-test	-0.377	0.151	-0.843	0.301
Perceived Learning Effectiveness	-0.086	0.151	-0.136	0.301
Satisfaction	0.470	0.151	0.206	0.301
Motivation	0.526	0.151	0.036	0.301
Self-Efficacy	0.150	0.151	-0.612	0.301
mAR Features	-0.389	0.151	-0.401	0.301

7.2.3 General Exploration of Variables – Performance Achievement and Learning Outcome

The present section explains the main effect analysed for the groups in performance achievement, perceived learning effectiveness, satisfaction and self-efficacy. The proposed research questions regarding the above variables are assessed through descriptive analysis to determine the mean values, as well as the minimum and maximum values for both pre-test and post-test data. The research questions were also assessed with the help of inferential statistics.

Also, the initial step specifically involved the carrying out of the independent sample t-test, ANOVA and MANOVA to evaluate the differences between the two groups based on their pre-test scores, addressing students' performance achievement, perceived learning effectiveness, satisfaction and self-efficacy. The differences between the two groups' means in pre/ post-tests were compared through ANOVA and the multivariate analyses of independent sample variance were conducted prior to testing the proposed hypotheses, to identify whether the two groups are statistically equivalent prior to the beginning of the actual experiment. The study's dependent variables are performance achievement, perceived learning effectiveness, satisfaction and self-efficacy, while the independent variables are learning mode and motivation.

The Levene's test scores, as illustrated in Table 7.11, showed no significant differences between the groups in all five dependent variables, namely the performance achievement, perceived learning effectiveness, satisfaction, self-efficacy and learning outcomes at the following outcomes respectively: t(-0.814, $p = 0.417 > 0.05$), t(-0.471, $p = 0.638 > 0.05$), t(1.490, $p = 0.137 > 0.05$), t(0.409, $p = 0.683 > 0.05$) in pre-test scores. No significant differences were revealed for perceived learning outcomes between the two groups in pre-test scores with t(0.759, $p = 0.449 > 0.05$). The two groups' multivariate analysis of variance results are displayed in Table 7.12.

Table 7.11: Results of Levene's Test for the Research Variables Pre-test

Variable	F-value	Sig	t	df	Sig.
Performance Achievement	2.300	0.131	-0.814	258	0.417
Perceived Learning Effectiveness	2.187	0.140	-0.471	258	0.638
Satisfaction	0.312	0.577	1.490	258	0.137
Self-Efficacy	2.010	0.157	0.409	258	0.683
Learning Outcomes	0.353	0.553	0.759	258	0.449

Table 7.12: Results of MANOVA for between-Subjects Effects of the Research Variables Pre-test

Source	Dependent Variables total Pre-test	Type III Sum of Squares	df	Mean Square	F	P
Group	Performance Achievement	91.215	1	91.215	2.892	0.090
	Learning Outcomes	0.130	1	0.130	0.576	0.449
	Perceived Learning Effectiveness	0.056	1	0.056	0.221	0.638
	Satisfaction	0.940	1	0.940	2.221	0.137
	Self-Efficacy	0.122	1	0.122	0.167	0.683

*** $P < .05$*

Next, the variables, namely performance achievement, learning outcomes, perceived learning effectiveness, satisfaction and self-efficacy were analysed through MANOVA, where the assumptions of multivariate normality, homogeneity of variance-covariance were examined. All the assumptions were met, and the results revealed no significant differences (at the level of 0.05 significance) between both groups on all four variables.

The statistics in Table 7.13 presents the mean and standard deviation of the pre and post-test scores for the study's dependent variables. Accordingly, the experimental group's mean scores statistically increased after the training for all variables. With regards to the scores of learning outcomes, the experimental group's pre-test mean score was M = 2.932, SD = 0.483. That was lower, as compared to the controlled group (M = 2.977, SD = 0.466). On the other hand, the former has a higher post-test mean score (M = 4.081, SD = 0.443), as compared to the latter (M = 3.653, SD = 0.440), indicating that the former improved their mean score for learning outcomes over the period of the experiment.

Table 7.13: Summary Statistics for Learning Outcomes Scores (N=260)

Variable		**Experimental Group**	**Control Group**
Learning outcomes	Pre-test Mean	2.93	2.97
	SD	0.48	0.46
	Post-test Mean	4.08	3.65
	SD	0.44	0.44

As for the perceived learning effectiveness variable in Table 7.14, the controlled group scored lower in the pre-test (M = 3.092, SD = 0.48) as compared to the experimental group (M = 3.121, SD = 0.525), Based on the post-test scores however, the opposite holds true, with the experimental group obtaining higher scores (M = 4.226, SD = 0.624), in comparison to the controlled group (M = 3.635, SD = 0.638), in terms of perceived learning effectiveness. The summary of the perceived learning effectiveness scores is as follows.

Table 7.14: Summary Statistics for Perceived Learning Effectiveness Scores (N=260)

Variable		**Experimental Group**	**Control Group**
Perceived Learning Effectiveness	Pre-test Mean	3.12	3.09
	SD	0.52	0.48
	Post-test Mean	4.22	3.63
	SD	0.62	0.63

In terms of the satisfaction variable in Table 7.15, both the experimental and controlled group scores were different for the pre and post-tests. The experimental group scored higher in the mean post-test score (M = 3.917, SD = 0.5762), as compared to the mean pre-test score (M = 2.942, SD = 0.638). The similar holds true for the controlled group that obtained a mean pre-test score (M = 2.79, SD = 0.57) and a higher mean post-test score (M = 3.85, SD = 0.498).

Table 7.15: Summary Statistics for Satisfaction Scores (N=260)

Variable		Experimental Group	Control Group
Satisfaction	Pre-test Mean	2.94	3.06
	SD	0.63	0.66
	Post-test Mean	3.91	3.85
	SD	0.57	0.49

With regards to the variable of self-efficacy in Table 7.16, the experimental and control group obtained different mean scores in the pre-test, as compared to their post-test mean scores. In particular, the experimental group obtained a mean pre-test score of M = 2.733, SD = 0.885 and a mean post-test score of M = 4.10, SD = 0.655, while the controlled group obtained a mean pre-test score of M = 2.776, SD = 0.820 and a mean post-test score of M = 3.46, SD = 0.675.

Table 7.16: Summary Statistics for Self-Efficacy Scores (N=260)

Variable		Experimental Group	Control Group
Self-Efficacy	Pre-test Mean	2.73	2.77
	SD	0.88	0.82
	Post-test Mean	4.10	3.46
	SD	0.65	0.67

7.2.4 Testing Hypotheses based on Research Questions

The independent sample t-test was conducted to compare the significant differences between the two groups. The purpose was to seek any significant differences in the learning mode and motivation between the dependent variables, as measured by the pre and post-tests, perceived learning effectiveness, self-efficacy and satisfaction. The assumptions of these tests were performed based on the hypotheses testing of the research questions.

7.2.4.1 Testing Hypothesis of RQ 1

The statistical analysis started with the hypothesis of RQ1 is “Are there any significant differences in the learning outcomes, perceived learning effectiveness, satisfaction and self-efficacy between students’ learning in mobile-AR-based learning (mAR) and those learning via the CLM?”.

In order to determine whether the groups, (i.e. the mAR mode group where the students were exposed to mobile-AR-based learning, and the CLM mode group, where the students were exposed to current classroom practices) differ in the scale of learning outcomes, the independent sample t-test was employed. From the statistics in Table 7.17, the mean and standard deviation of the scores for the dependent variables among the participant groups are presented below. According to the table, the mAR mode group obtained learning outcomes' mean score of M = 4.081, SD = 0.443. That was greater, as compared to the score obtained by the CLM mode group (M = 3.653, SD = 0.440). Significant differences were found between them, from the independent t-test based on the significance level of 0.05, the difference being t = -7.819, df = 258, p = 0.000 < 0.05.

Table 7.17: Independent Sample t-test Results for Group Differences on Learning Outcomes

	Group	N	Mean	Std. Deviation	t	df	Sig
Learning Outcomes	CLM mode	130	3.653	0.440	-7.819	258	0.000
	mAR mode	130	4.081	0.443			

In addition to the above, the t-test was also employed to determine whether statistical differences exist between the mAR mode group and the CLM mode group when it comes to the perceived learning effectiveness of the respondents as shown in Table 7.18. In this regard, the scores for the mean and standard deviation of the dependent variables between the two groups are presented in the table below. The table shows that the mAR mode group obtained a mean score in perceived learning effectiveness of M = 4.226, SD = 0.624, which is greater, as compared to the CLM mode group (M = 3.635, SD = 0.638). Moreover, significant differences were found between the scores of the two groups, on the basis of the 0.05 significance level, with the difference being t = -7.541, df = 258, p = 0.000 < 0.05.

Table 7.18: Independent Sample t-test Results for Group Differences on Perceived Learning Effectiveness

	Group	N	Mean	Std. Deviation	t	df	Sig
Perceived Learning Effectiveness	CLM mode	130	3.635	0.638	-7.541	258	0.000
	mAR mode	130	4.226	0.624			

The independent sample t-test was employed to determine whether significant differences exist between the mAR mode group and the CLM mode group when it comes to the satisfaction scale. According to the scores from Table 7.19, where the mean and standard deviation is listed for the dependent variables, the mAR mode group scored a greater mean for satisfaction (M = 3.917, SD = 0.576) than the CLM mode group (M = 3.858, SD = 0.498). Nevertheless, the independent sample t-test results indicated no significant differences between the two groups at the significance level of 0.05. Specifically, the independent sample t-test showed that the groups did not significantly differ when it comes to satisfaction (*t* = -0.889, df = 258, *p* = 0.375 > 0.05).

Table 7.19: Independent Sample t-test Results for Group Differences on Satisfaction

	Group	N	Mean	Std. Deviation	t	df	Sig
Satisfaction	CLM mode	130	3.858	0.498	-0.889	258	0.375
	mAR mode	130	3.917	0.576			

With regards to statistical differences between the two groups based on self-efficacy, the independent sample t-test was also used. According to Table 7.20, where the mean and standard deviation scores for the dependent variable are listed, the mAR group displayed mean self-efficacy scores of M = 4.101, SD = 0.655. This is greater in comparison to the CLM mode group (M = 3.465, SD = 0.675). In this sense, the independent sample t-test results showed significant differences between the self-efficacy scores on the significance level of 0.05 at *t* = -7.708, df = 258, *p* = 0.000 < 0.05.

Table 7.20: Independent Sample t-test Results for Group Differences on Self-Efficacy

	Gender	N	Mean	Std. Deviation	T	df	Sig
Self-Efficacy	Male	130	3.465	0.675	-7.708	258	0.000
	Female	130	4.101	0.655			

After considering the results of the dependent variables separately and conducting ANOVA testing (Table 7.21), it is clear that statistical significance was noted in the learning outcomes at *F* (61.132, *p* = 0.000, < 0.05) perceived learning effectiveness at *F* (56.867, *p* = 0.000, < 0.05), satisfaction at *F*(0.791, *p* = 0.375, > 0.05) and self-efficacy at *F* (59.412, *p* = 0.000, < 0.05). The scores of the mean and standard deviation showed that the mAR mode group scored higher in learning outcomes (M = 4.081, SD = 443), perceived usefulness (M = 4.226, SD = 0.624), satisfaction (M = 3.917, SD = 0.576) and self-efficacy (M = 4.101, SD = 0.655), as compared to its counterpart controlled group, where the obtained means are: M = 3.653, SD = 0.440; M = 3.635, SD = 0.638; M = 3.858, SD = 0.498; M = 3.465, SD = 0.675, in the same order of the variables as mentioned.

Table 7.21: Results of ANOVA Between Subjects – Effect of Research Variables: P< .05

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Group	Learning outcomes	11.953	1	11.953	61.132	0.000
	Pcvd L.Effectve	22.665	1	22.665	56.867	0.000
	Satisfaction	0.230	1	0.230	0.791	0.375
	Self-Efficacy	26.337	1	26.337	59.412	0.000
Total	Learning Outcomes	62.399	259			
	Pcvd L.Effective	125.492	259			
	Satisfaction	75.146	259			
	Self-Efficacy	140.706	259			

P<0.05

The next step used one-way MANOVA on the scores obtained by the two groups based on four variables, i.e. learning outcomes, perceived learning effectiveness, satisfaction and self-efficacy. The first set of analysis produced significant main effects between the two groups and the dependent variables. Additionally, the homogeneity of the variance-covariance assumption that decreases MANOVA was tested through the use of box M test. After which, the results revealed that the homogeneity variance-covariance was not met. Moreover, a multivariate test showed significant differences between the two groups based on the mean scores obtained by the variables with the help of Pillais Trace criteria (F = 23.510, p = 0.000, < 0.05). The results of the comparison between the dependent variables' influence on the independent variable in terms of the groups showed significant differences, particularly for the mobile mAR mode group. The scores were significant for learning outcomes (F = 61.132, p = 0.000, η = 0.129), perceived learning effectiveness (F = 56.867, p = 0.000, η = 0.181) and self-efficacy (F = 59.412, p = 0.000, η = 0.187), except for satisfaction (F = 0.791, p = 0.375, η = 0.003), as depicted in Table 7.22.

Table 7.22: Results of MANOVA between Subjects – Effect of Research Variables: P< .05

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Group	Learning Outcomes	11.953	1	11.953	61.132	0.000
	Pcvd L.Effectve	22.665	1	22.665	56.867	0.000
	Satisfaction	0.230	1	0.230	0.791	0.375
	Self-Efficacy	26.337	1	26.337	59.412	0.000
Total	Motivation	3951.304	260			
	Pcvd L.Effectve	4143.201	260			
	Satisfaction	4004.967	260			
	Self-Efficacy	3862.875	260			

P<0.05

Based on the results, it can be concluded that, there are significant differences in the learning outcomes of Perceived Learning and Self-Efficacy for both groups. mAR showed greater positive differences than CLM mode in these two constructs. However, the result has discovered that Satisfaction as one of the dependent variables, has no significant difference between CLM and mAR learning mode in the learning outcomes.

7.2.4.2 Testing Hypothesis of RQ 2

The hypothesis of RQ2 is “Are there any significant memory retention differences in the performance achievements between students learning in the mAR mode versus the CLM mode?”.

To determine if the mAR mode group (where the students were exposed to the mobile-AR-based group) and the CLM mode group (where the students were exposed to current learning practices) differ in the scale of performance achievement, the independent sample t-test was employed. From the statistics results (Table 7.23), the mean and standard deviation of scores for the dependent variables among the participant groups are presented in the table below. The mAR mode group obtained performance achievement mean score of M = 22.207, SD = 5.226. That was greater, as compared to the score obtained by the CLM mode group (M = 17.200, SD = 6.992). Significant differences were found between them, from the independent t-test, based on the significance level of 0.05, the difference being t = -6.541, df = 258, p = 0.000 < 0.05. For further detail, a paired sample t-test was employed (Table 2.4). Overall the mean of group CLM and mAR showed increments in post-test. To highlight the memory retention difference between mAR and CLM, Table 7.25 shows, mAR group has greater M = -14.269, SD = 7.408 compared to CLM group was only M = -4.669, SD = 4.360. This result indicates, learning with mAR improved and retained the information longer. Both groups demonstrated they could retain the subject matter due to the p = 0.000 < 0.05 as shown in Table 7.25, however, with mAR technology intervention it assisted the memory better and lengthier which reflected the improvement in the mean between pre and post-test (Table 7.25).

Table 7.23: Result of Independent t-test on Performance Achievement in mAR and Non-mAR

	Group	N	Mean	Std. Deviation	T	df	Sig
Performance Achievement	CLM mode	130	17.200	6.992	-6.541	258	0.000
	mAR mode	130	22.207	5.226			

Table 7.24: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre_test_CLM	13.71	130	7.134	.626
	Post_test_CLM	18.38	130	6.009	.527
Pair 2	Pre_test_mAR	12.22	130	7.413	.650
	Post_test_mAR	26.48	130	5.169	.453

Table 7.25: Paired Sample Test

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig.(2-tailed)
					Lower	Upper			
Pair 1	Pre_test_CLM Post_test_CLM	-4.669	4.360	.382	-5.426	-3.913	-12.209	129	.000
Pair 2	Pre_test_mAR Post_test_mAR	-14.269	7.408	.650	-15.555	-12.984	-21.962	129	.000

7.2.4.3 Testing Hypothesis of RQ 3

The hypothesis of RQ3 is "Are there any significant differences in the performance achievements of intrinsically and extrinsically motivated students in the learning modes?".

The above research question was answered by an Independent t-test that compared the performance achievements in intrinsic and extrinsic motivations for both CLM and mAR learning modes. Based on the result, there was a significant difference of intrinsic motivation in the score for CLM (M=2. 48, SD=0.42) and mAR (M=2. 50, SD=0.43) learning modes, conditions t(258)=0.459, and p=0. 000. The same significant difference was found in the extrinsic motivation. The students were extrinsically motivated in the mAR score (M=3.66, SD=0.41) compared to for CLM (M=3.45, SD=0.40) and learning modes, conditions t(258)=0.459, p=0.000.

These results suggest that mAR students were intrinsically and extrinsically motivated and thus scored higher in the performance achievements compared to CLM students. Specifically, both results suggest that, when the students learned with mAR, they were intrinsically and extrinsically motivated as well as engaged in the learning process attentively.

7.2.4.4 Testing Hypothesis of RQ 4

The hypothesis of RQ4 is "Are there any significant differences in the learning outcomes for highly and poorly motivated students in the mAR mode?".

In order to determine the answer to the above question, ANOVA was conducted with learning outcomes as the dependent variable. The fundamental assumption of homogeneity of variance assumption that underlies ANOVA was not met. It was also clearly stated that the variance of the post-test scores of the learning outcomes for the two groups with high and poor motivations differed. Therefore, the Welch test is the alternative option for such a situation (Moder, 2010). The results showed significant differences in the post-test scores for highly motivated students (M = 4.214, SD = 0.310) and poorly motivated students (M = 3.941, SD = 0.518) in terms of learning outcomes with a Welch test value of (13.153, p = 0.000 < 0.05) (Table 7.26). Next, the ANOVA test results (Table 7.27) showed significant differences when it comes to learning outcomes between highly and poorly motivated students (F = 13.346, p = 0.000 < 0.05), indicating that highly motivated students scored greater post-test scores, compared to their counterparts in the learning outcomes.

Table 7.26: Results of Welch Test for the Learning Outcomes

	Statistics	df1	df2	Sig
Welch	13.153	1	102.539	0.000

Table 7.27: Results of ANOVA for between-subjects (Effect of the Research Variable: P< .05)

Source: Post-test	Dependent Variables	Type III Sum of Squares	df	Mean Square	F	P
Within Group	Learning Outcomes	2.418	1	2.418	13.346	0.000
Between Group	Learning Outcomes	23.195	128	0.181		
Total	Learning Outcomes	25.614	129			

P<0.05

7.2.4.4.1 Testing Hypothesis of RQ 4.1

The sub-hypothesis of RQ4 is "Are there any significant differences in the perceived learning effectiveness for highly and poorly motivated students in the mAR mode?".

A one-way ANOVA test was also used between the groups' scores on account of learning effectiveness as the dependent variable. The fundamental assumption of homogeneity of variance assumption that underlies ANOVA was violated, and it was not met. The variance of post-test scores of perceived learning effectiveness of the two groups based on high and poor motivation was different. Therefore, the Welch's test (Table 7.28) was conducted on account of a lack of homogeneity (Moder, 2010). No significant difference was found in the post-test scores for highly (M = 4.377, SD = 0.499) and poorly motivated students (M = 4.069, SD =

0.701) for perceived learning effectiveness, with the Welch test (8.272, p = 0.005 < 0.05). Meanwhile, ANOVA test results show a significant difference in perceived learning effectiveness between highly and poorly motivated students (F = 8.356, p = 0.005 < 0.05). As depicted in Table 7.29, the highly motivated students scored higher than their poorly motivated counterparts in the area of perceived learning effectiveness.

Table 7.28: Results of Welch Test for the Perceived Learning Effectiveness

	Statistics	df1	df2	Sig
Welch	8.272	1	113.611	0.005

Table 7.29: Results of ANOVA for between-subjects (Effect of the Research Variables: P< .05)

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Within Group	Pcvd L.Effective	3.083	1	3.083	8.356	0.005
Between Group	Pcvd L.Effective	47.231	128	0.369		
Total	Pcvd L.Effective	50.315	129			

P<0.05

7.2.4.4.2 Testing Hypothesis of RQ 4.2

The sub-hypothesis of RQ4 is "Are there any significant differences in the satisfaction for highly and poorly motivated students in the mAR mode?".

In testing satisfaction as a dependent variable between the groups, a one-way ANOVA test was conducted. The fundamental assumption of homogeneity of variance assumption that underplays ANOVA was achieved and according to the results, homogeneity of variance was met. The variance of the post-test scores of satisfaction between the two groups was similar, based on high and poor motivation. The ANOVA results showed no significant differences between highly and poorly motivated students (F = 1.834, p = 0.178 > 0.05), as depicted in Table 7.30. The results reveal that the post-test scores of highly motivated students are M = 3.980, SD = 0.574 and their counterparts are M = 3.843, SD = 0.574, in terms of the satisfaction variable.

Table 7.30: Results of ANOVA for between-subjects (Effect of the Research Variables: P<0.05)

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Within Group	Satisfaction	0.606	1	0.606	1.834	0.178
Between Group	Satisfaction	42.282	128	0.330		

Total	Satisfaction	42.888	129

P<0.05

7.2.4.4.3 Testing Hypothesis of RQ 4.3

The sub-hypothesis of RQ4 is "Are there any significant differences in the self-efficacy for highly and poorly motivated students in the mAR mode?".

In determining the answer to the above question, a one-way ANOVA test was carried out between the groups, in term of the members' self-efficacy (dependent variable). The fundamental assumption of homogeneity of variance that underplays ANOVA in this case was violated, and homogeneity of variance was not met, showing that the variance of the post-test scores of self-efficacy between the groups was not the same. An alternative option, the Welch's test (Table 7.31) (employed in inhomogeneous variance), as recommended by Moder (2002) was thus used instead. The results of ANOVA (Table 7.32) then revealed a significant difference in the post-test scores, in terms of self-efficacy of highly motivated students ($M = 4.286$, $SD = 0.431$) and poorly motivated students ($M = 3.912$, $SD = 0.784$), with the Welch test result 11.229, $p = 0.001 < 0.05$. Moreover, the ANOVA result showed a significant difference in terms of self-efficacy between highly and poorly motivated students ($F = 11.417$, $p = 0.001 < 0.05$), as depicted in Table 7.32. Highly motivated students obtained higher self-efficacy scores, as compared to poorly motivated students.

Table 7.31: Results of Welch Test for the Learning Outcomes

	Statistics	df1	df2	Sig
Welch	11.229	1	97.286	0.001

Table 7.32: Results of ANOVA for between-subjects (Effect of the Research variable: P<.05)

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Within Group	Self-Efficacy	4.542	1	4.542	11.417	0.000
Between Group	Self-Efficacy	50.920	128	0.398		
Total	Self-Efficacy	55.462	129			

P<0.05

7.2.4.5 Testing Hypothesis of RQ 5

The hypothesis of RQ5 is "Are there any significant differences in the performance achievements for highly and poorly motivated students in the mAR mode?".

In determining the answer to the above question, a one-way ANOVA test was run between the groups in term of the members' performance achievement (dependent variable). The fundamental assumption of homogeneity of variance (Table 7.33) that underplays ANOVA in this case was violated, and homogeneity of variance was not met, showing that the variance of the post-test scores of performance achievement between the groups was not the same, based on whether they are highly or poorly motivated students. Therefore, an alternative option, the Welch's test (employed in inhomogeneous variance), as recommended by Moder (2002), was used. The results for ANOVA in Table 7.34 then revealed a significant difference in the post-test scores, in terms of performance achievement of highly motivated students (M = 21.500, SD = 5.451) and poorly motivated students (M = 18.905, SD = 6.987), with the Welch test result of 10.472, $p = 0.001 < 0.05$). Moreover, the ANOVA result showed a difference in terms of performance achievement between highly and poorly motivated students ($F = 8.675$, $p = 0.004 < 0.05$), as depicted in Table 7.34. Students with high levels of motivation obtained higher performance achievement scores, as compared to their counterparts.

Table 7.33: Results of Welch Test for the Performance Achievement

	Statistics	df1	df2	Sig
Welch	10.472	1	191.430	0.001

Table 7.34: Results of ANOVA for between-subjects (Effect of the Research Variable: P< .05)

Source	Dependent Variables Post-test	Type III Sum of Squares	df	Mean Square	F	P
Within Group	Perform Achievement	372.802	1	372.802	8.675	0.004
Between Group	Perform Achievement	11087.394	258	42.974		
Total	Perform Achievement	11460.196	259			

P<0.05

7.2.4.6 Testing Hypothesis of RQ 6

The hypothesis of RQ6 is "Are there any significant interaction effects between the students' motivation level and the learning modes, related to performance achievements?".

The above research question was answered with the help of the two-way ANOVA test that determined the effects of student motivation and learning models on the performance achievement based on post-test scores, with the post-test scores of performance achievement as the dependent variable, and the student motivation and learning modes as the independent variables. In this regard, the Levene's test of equality of error variance revealed a significant result (0.000) that is lower than 0.05 and thus, a more significant level of 0.01 was employed. As shown in Table 7.35, the results showed insignificant interaction effects between student motivation and learning modes ($F = 2.706$, $p = 0.101 > 0.01$), despite the evidence showing that highly motivated students in the mAR mode scored higher in the post-test as compared to their poorly motivated counterparts in the CLM mode.

Table 7.35: Two-Way ANOVA of Performance Achievement Post-test by Motivation Level and Learning Mode

Source	Type III Sum of Square	df	Mean Square	F	Sig
Corrected Model	1736.830	3	578.943	15.243	0.000
Motivation Level	39.806	1	39.806	1.048	0.307
Group	559.885	1	559.885	14.741	0.000
Mot Level*Group	102.779	1	102.779	2.706	0.101
Error	46.328	256		0.181	
Total	3951.304	260			
Corrected Total	62.399	259			

7.2.4.7 Testing Hypothesis of RQ 7

The hypothesis of RQ7 is "Are there any significant interaction effects between students' motivation and the learning modes related to learning outcomes?".

The above question was answered with the help of the two-way ANOVA test that determined the effects of student motivation and learning models upon the learning outcomes based on the post-test scores, with the post-test scores of learning outcomes as the dependent variable, and student motivation and learning modes as the independent variables. In this regard, the Levene's test of equality of error variance revealed a significant result (0.004) that is lower than 0.05 and thus, a more significant level of 0.01 was employed. The results in Table 7.36 showed insignificant interaction effects of student motivation and learning modes ($F = 0.483$, $p = 0.488 > 0.01$), despite the evidence showing that highly motivated students in the mAR mode scored higher in the post-test as compared to their poorly motivated counterparts in the non-mAR mode.

Table 7.36: Two-Way ANOVA of Learning Outcomes Post-test by Motivation Level and Learning Mode

Source	Type III Sum of Square	df	Mean Square	F	Sig
Corrected Model	16.071	3	5.357	29.601	0.000
Motivation Level	3.724	1	3.724	20.576	0.000
Group	2.858	1	2.858	15.795	0.000
Motivation Level*Group	0.087	1	0.087	0.483	0.488
Error	46.328	256	0.181		
Total	3951.304	260			
Corrected Total	62.399	259			

7.2.4.7.1 Testing Hypothesis of RQ 7.1

The sub-hypothesis of RQ7 is "Are there any significant interaction effects between students' motivation and learning modes, related to perceived learning effectiveness?".

The effects of student motivation and learning modes on perceived learning effectiveness in the post-test scores were analysed using two-way ANOVA, where the perceived learning effectiveness post-test score was considered the dependent variable, and student motivation and learning modes were the independent ones. The results of the Levene's test of equality of error variance evidenced a significant result of 0.039, a value lower than 0.05 and hence, a more significant level of 0.01 was employed. The interaction effects of student's motivation and learning modes in Table 7.37 were found to be insignificant (F = 2.518, p = 0.114 > 0.01), but the results revealed that highly motivated students in the mAR mode group scored higher in the post-test, in comparison to the poorly motivated students in the non-mAR mode group. The table below shows the results of the two-way ANOVA test.

Table 7.37: Two-Way ANOVA of Perceived Learning Effectiveness Post-test by Motivation Level and Learning Mode

Source	Type III Sum of Square	df	Mean Square	F	Sig
Corrected Model	30.699	3	10.233	27.635	0.000
Motivation Level	7.932	1	7.932	21.421	0.000
Group	4.201	1	4.201	11.345	0.001
Motivation Level*Group	0.933	1	0.933	2.518	0.114
Error	94.793	256	0.370		
Total	4143.201	260			
Corrected Total	125.492	259			

7.2.4.7.2 Testing Hypothesis of RQ 7.2

The sub-hypothesis of RQ7 is "Are there any significant interaction effects between students' motivation and learning modes related to satisfaction?".

The effects of student motivation and learning modes on the satisfaction based on the post-test scores, with the satisfaction as the dependent variable and the former two (motivation and learning modes) as the independent variables, were analysed through the two-way ANOVA test. However, the results of the Levene's test of equality of error variance revealed insignificant results (F = 0.914, p = 0.340 > 0.01) at the level of 0.05 significance. The interaction effects of student motivation and learning modes were insignificant, despite the results showing that highly motivated students in the mAR mode group obtained higher scores in the post-test, as compared to their poorly motivated counterparts in the CLM mode group. The results of the two-way ANOVA test are listed in Table 7.38.

Table 7.38: Two-Way ANOVA of Satisfaction Post-test by Motivation Level and Learning Mode

Source	**Type III Sum of Square**	**df**	**Mean Square**	**F**	**Sig**
Corrected Model	0.831	3	0.277	0.954	0.415
Motivation Level	0.084	1	0.084	0.290	0.590
Group	0.193	1	0.193	0.664	0.416
Motivation Level*Group	0.265	1	0.265	0.914	0.340
Error	74.315	256	0.290		
Total	4004.967	260			
Corrected Total	75.146	259			

7.2.4.7.3 Testing Hypothesis of RQ 7.3

The sub-hypothesis of RQ7 is "Are there any significant interaction effects between students' motivation and learning modes related to self-efficacy?".

Two-way ANOVA was also employed for the analysis of the effects of student motivation and learning modes on the self-efficacy based on the post-test scores, where the latter was considered as the dependent variable and the two former ones, the independent variables. In this case, the result of the Levene's test of error variance was significant (0.002), but less than 0.05. Therefore, a more significant level of 0.01 was employed instead. The result (Table 7.39) showed insignificant effects of student motivation and learning modes (F = 0.458, p = 0.499 > 0.01), despite the evidence showing that highly motivated students in the mAR mode group obtained higher post-scores in comparison to their poorly motivated counterparts in the CLM mode group. With this, the independent variables showed no significant effects on the dependent one.

Table 7.39: Two-Way ANOVA of Self-Efficacy Post-test by Motivation Level and Learning Mode

Source	Type III Sum of Square	df	Mean Square	F	Sig
Corrected Model	34.245	3	11.415	27.449	0.000
Motivation Level	7.195	1	7.195	17.301	0.000
Group	6.674	1	6.674	16.049	0.000
Motivation Level*Group	0.190	1	0.190	0.458	0.499
Error	106.461	256	0.416		
Total	3862.875	260			
Corrected Total	140.706	259			

7.2.4.8 Summary of Findings of Null Hypotheses Testing

According to the analyses, this research has verified the research questions. There are some null hypotheses are rejected and supported. The results of null hypotheses testing are summarised in Table 7.40 as follows:

Table 7.40: Summary of Null Hypotheses Testing

Number of Null Hypothesis	Null Hypothesis Testing	Result
H_{01}	There is no significant difference in the learning outcomes among students in the mAR mode and students in the CLM mode.	• The result shows that there is a significant difference; therefore, H_{01} is not supported.
H_{02}	There is no significant difference in perceived learning effectiveness between students in the mAR mode and students in the CLM mode.	• The result shows that there is a significant difference; therefore, H02 is not supported.
H_{03}	There is no significant difference in the satisfaction among students in the mAR mode and students in the CLM mode.	• The result shows that there is no significant difference; therefore, H03 is supported.
H_{04}	There is no significant difference in the self-efficacy between students in the mAR mode and students in the CLM mode.	• The result shows there is a significant difference; therefore, H04 is not supported.
H_{05}	There is no significant difference in terms of memory retention in the performance achievement between students in the mAR mode and students in the CLM mode.	• The result shows that there is a significant difference; therefore, H05 is not supported.
H_{06}	There is no significant difference between students' intrinsic and extrinsic motivation in the performance achievement of students in the mAR mode.	• The result shows that there is a significant difference; therefore, H06 is not supported.
H_{07}	There is no significant difference in the performance achievement between	• The result shows that there is a significant difference; therefore, H07 is not supported.

	highly and poorly motivated students in the mAR mode.	
H_{08}	There is no significant difference in the perceived learning effectiveness for highly and poorly motivated students in the mAR mode.	• The result shows that there is a significant difference; therefore, H08 is not supported.
H_{09}	There is no significant difference in the satisfaction between highly and poorly motivated students in the mAR mode.	• The result shows that there is no significant difference; therefore, H09 is supported.
H_{10}	There is no significant difference in the self-efficacy between highly and poorly motivated students in the mAR mode.	• The result shows that there is a significant difference; therefore, H10 is not supported.
H_{11}	There is no significant difference in the learning outcomes for highly and poorly motivated students in the mAR mode.	• The result shows that there is a significant difference; therefore, H11 is not supported.
H_{12}	There is no significant interaction effect between the student's motivation and learning modes, which is related to performance achievement.	• The result shows that there is no significant interaction effect; therefore, H12 is supported.
H_{13}	There is no significant interaction effect between the student's motivation and learning modes, which is related to the learning outcome.	• The result shows that there is no significant interaction effect; therefore, H13 is supported.
H_{14}	There is no significant interaction effect between the student's motivation and learning modes, which is related to perceived learning effectiveness.	• The result shows that there is no significant interaction effect; therefore, H14 is supported.
H_{15}	There is no significant interaction effect between the student's motivation and learning modes, which is related to satisfaction.	• The result shows that there is no significant interaction effect; therefore, H15 is supported.
H_{16}	There is no significant interaction effect between the student's motivation and learning modes, which is related to self-efficacy.	• The result shows that there is no significant interaction effect; therefore, H16 is supported.

7.2.4.9 Summary of findings to research questions 1-7 and hypothesis testing 1-16

Table 7.41: Summary results of research questions 1-7

RO	RQ	Test	Dependent Variable	Independent Variable	Result
1	1	Main Effect	Learning Outcome	mAR>CLM	S
1	1.1	Main Effect	Perceived Learning Effectiveness	mAR>CLM	S
1	1.2	Main Effect	Satisfaction	mAR> CLM	NS
1	1.3	Main Effect	Self-efficacy	mAR> CLM	S
1	2	Main Effect	Performance Achievement	mAR> CLM	S
2	3	Main Effect	Performance Achievement	Intrinsic>Extrinsic Motivation	S
2	4	Main Effect	Learning Outcome	High>Poor Motivation	S
2	4.1	Main Effect	Perceived Learning Effectiveness Learning Outcome	High> Poor Motivation	S
2	4.2	Main Effect	Satisfaction Learning Outcome	High>Poor Motivation	NS
2	4.3	Main Effect	Self-efficacy	High>Poor Motivation	S
2	5	Main Effect	Performance Achievement	High>Poor Motivation	S
2	6	Interaction Effect	Performance Achievement	Motivation Level>Learning Mode	NS
2	7	Interaction Effect	Learning Outcome	Motivation Level>Learning Mode	NS
2	7.1	Interaction Effect	Perceived Learning Effectiveness	Motivation Level>Learning Mode	NS
2	7.2	Interaction Effect	Satisfaction	Motivation Level>Learning Mode	NS
2	7.3	Interaction Effect	Self-efficacy	Motivation Level>Learning Mode	NS

Note: RQ = Research Question; RO = Research Objective; mAR = mobile Augmented Reality; S = Significant; NS = Not Significant

7.3 Summary

This chapter provides the discussion of results, comparing mAR-based learning to that of conventional classroom learning. The motivation effects are examined in this chapter for the students in the mAR mode group, as well as the interaction effect of motivation level and learning modes on the dependent variable. The findings show that students' performance achievement, learning outcomes, perceived learning effectiveness and self-efficacy were greater in the mAR mode group, as compared to the CLM mode group. In addition, satisfaction has a negative result for both groups. As for students' learning outcomes in the mAR mode group, significant differences were found between the highly motivated and poorly motivated students, based on their performance achievement, learning outcomes, perceived learning effectiveness and self-efficacy. No significant interaction effects were found between the learning modes, students' motivation and dependent variable. Further results of this chapter are reported in Chapter 9. The findings of the remaining research questions, RQ 8 and RQ 9, are elaborated and discussed in the next section.

CHAPTER 8
RESULTS & DATA ANALYSIS - mAR TECHNOLOGY ENHANCING STUDENTS' LEARNING OUTCOMES

8.0 Overview

Besides examining the effectiveness of learning using mAR, this research aims to develop a theoretical model to explain the way mAR improves learning quality. Learning quality includes the experience of the learner, learning environment, content, learning process and learning outcomes. It also indicates to provide robust empirical findings for future mAR-based learning development studies, which will be key to education. The relevant constructs have been highlighted, and their relationships were tested. In the model development, mAR technology is emphasised, together with the learning outcome. This involves the relationship of the learning experience process, which includes students' characteristics and interactions towards the learning features. The moderating impact of students' learning characteristics of the learning mode is also tested. The chapter provides a discussion of the model development results to examine the way mAR improves students' learning outcomes. Structural Equation Modelling (SEM) was employed to achieve such a feature and to conduct an evaluation of the model in terms of fit. The chapter first describes the sample characteristics and explicates the discriminant validity. The structural model and the overall fit are then analysed. This is followed by the presentation of the moderating impacts of the student learning characteristics of the learning mode during the learning process.

8.1 Analysis of the Research Model's Constructs

The developed research model consists of five latent variables. A latent variable refers to one that cannot be directly measured and thus, is represented by the measure of more than three observed variables. On the other hand, an observed variable is a distinct term obtained from the respondents in reaction to the items in the questionnaire. The five latent variables comprise two exogenous variables and three endogenous variables. Hair (2006) describes an exogenous variable as a latent, multi-item equivalent to an independent variable. He further adds that it is not affected by any other variables. Meanwhile, endogenous variables are latent multi-item variables that are equivalent to dependent variables and are influenced by other variables.

In SEM, Anderson and Gerbing (1988) state the superiority of a two-step method over a single step method. First, the measurement models are evaluated only after they were evidenced to possess proper measures of the variables, as explained in Chapter 4. The second step entails the assessment of the structural model based on the variables' relationship. Prior to conducting the SEM data analysis, the constructs' reliability and validity are first tested through discriminant validity as depicted in the next table.

SEM also offers various fit indices. The model's goodness-of-fit is determined by three indices of the fit model, i.e. absolute, comparative and parsimonious fit. The measurement model in the present study tested several fit indices, as opposed to just a single one; as Byrne (2016) states, no one fit index is better than the other indices as each may react in a different way to the size of the sample. Such an index is one that meets the multivariate normal distribution assumption, the complexity of the model and the parameter estimation method (Byrne, 2001; Byrne, 2016; Hair Jr et al., 2006; Hu & Bentler, 1998; Joreskog & Sorbom, 1988).

In this regard, the $\chi 2$ test is considered to be largely dependent on the size of the sample and that the chi-square statistics are impractical, albeit a dependable indicator of goodness-of-fit (Byrne, 2016). As such, the inclusion of chi-square statistics in this study is only for informative purposes. The primary condition to judge the fit model is the fit coefficient, where RMSEA values that are equal to or lower than 0.10 indicate reasonable model fit and those lower than 0.06 indicate a very close fit (Hair et al., 1998). A measure of the overall covariation in the data is offered by the CFI, while the model fit for the entire sample size is represented by the TLI. All of the index measures possess values that fall between 0 and 1. Moreover, the co-variation between the two indicators can improve the model fit to the data (Ruehlman et al., 2005). This is supported by Byrne (2016) who states that the integration of the covariance between two items will enhance the model fit and therefore, through the co-variation between two items, the result will show a good data fit.

Furthermore, on the basis of the suggestions provided by the researchers, a CFI value over 0.80 reflects a sound data-model fit (Hair et al., 1998; Hwang, 2007). Then, the TLI should be higher than 0.80; the ratio should be lower than 5, and the significance of the factor loading should be greater than 0.30. All of these measurements are utilised to identify the factor structure (Hair et al., 1998; Kelloway, 1998; Kline, 1998).

8.2 Measurement Model – Exploratory Factor Analysis (EFA)

This section presents the measurement model for each factor in the research. All factors were analysed by Exploratory Factor Analysis (EFA). Data analysis was conducted with the help of component analysis with Varimax rotation. Prior authors like Tabachnick and Fidell (2001), Hair et al. (1998), Stevens (2002) and Nunnally (1978) established the criteria for the determination of factor structures. The first criterion is to include the components that have a Cronbach's Alpha value of 0.70, Kaiser-Meyer-Olkin (KMO) value of 0.50, Bartlett's test of sphericity of less than 0.05 and the screen test. Five separate exploratory analyses were carried out through Varimax rotation to measure the study constructs, i.e. motivation, perceived learning, self-efficacy, satisfaction and mAR features. Stevens (2002) presents a cut-off for statistical significance of factor loading upon which the sample size is based on. Furthermore, Stevens (2002) argues that the factor loading ranging from 0.29 - 0.38 is acceptable for 200 - 300 participants as samples. Nevertheless, for a parsimonious outcome to a cross-loading of 0.30 for more than a single factor, only the higher amount for every variable would be employed to determine the set of variables comprising a specific factor.

8.2.1 Motivation (MOT)

The motivation survey from the motivation scale proposed by Abd Wahab (2007) was adopted, where the instruments are extracted from prior studies of motivation questionnaires relating to factors (extrinsic and intrinsic) gauging students' motivation. The intrinsic motivation factor consists of 7 items that indicate internal enforcements such as self-gratitude and a sense of achievement, while the extrinsic motivation factor consists of 6 items relating to external learning enforcement. Thus, the total items come up to 13, and they were rated from 1, depicting 'Strongly Disagree' to 5, depicting 'Strongly Agree'. Such a measurement type was employed, owing to its ease of administration and its extensive use in different environments, such as Asia, Middle East, Europe, among others. Moreover, the motivation measure has also been utilised in multicultural populations after which it indicated good reliability and validity coefficients (Abd Wahab, 2007). It showed that items 5 and 10 loaded less than the indicated value and were deleted. The internal consistency reliability measure of the instrument is 0.854 (Cronbach's Alpha value).

Based on the EFA, the study was successful in identifying the factor structure of motivation and matched it with prior theorised conceptual factors – a two-factor solution was present (intrinsic and extrinsic) with an eigenvalue of two. Thus, in this research, the final factor loading identified a two-factor solution after entering the items of motivation to the principal component analysis, with eigenvalues greater than 1. Two factors emerged, with one accounting for 39.38% of the variance and the other accounting for 70.48%. The KMO index and Bartlett's sphericity test were found to have the values of 0.871 and a chi-square value of 1838.694 (df = 55, p = 0.000) respectively. Also, the Cronbach's Alpha of both dimensions was at 0.854, with all alphas yielding the suggestive value of 0.70. The factor loading of the 11 items on the motivation scale, the percentage of variance accounted for and the internal consistency reliability measure (Cronbach's Alpha) are presented in Table 8.1.

Table 8.1: Exploratory Factor Analysis of the Motivation Measurement

Results for Motivation Scale

Variable	**Item**	**Factor Loading**	**Total Variance**
Intrinsic	1	0.770	39.38
	2	0.880	
	3	0.871	
	4	0.863	
	5	0.817	
	6	0.868	
Extrinsic	1	0.787	70.48
	2	0.781	
	3	0.796	
	4	0.864	
	5	0.882	
KMO	0.871		
Df	55		
Sig	0.000		
Alpha	0.854		

8.2.2 Perceived Learning Effectiveness

The perceived learning survey from a measure proposed by Subramanian (2007) and Liaw (2008) was adapted for this thesis. The survey addressed four factors, i.e. perceived usefulness, the perception of use, interactive learning and behavioural intention. Every one of these mentioned factors consists of observed variables; for instance, perceived usefulness consists of five items, perceptions of use consists of four items and interactive learning and behaviour intention consist of five items each (19 items in all). The items were rated from 1, depicting 'Strongly Disagree' to 5, depicting 'Strongly Agree'. Such a measurement is employed owing to the ease of its administration, the less time required and the fact that it has been administered in various settings, including in multicultural samples where it showed good reliability and validity coefficients. The deletion of one item could heighten the Alpha coefficient and accordingly, item number 9 was removed. The value of Cronbach's Alpha internal consistency is 0.736.

In other words, the EFA test in Table 8.2 successfully identified the perceived learning effectiveness structure and evidenced its consistency with the past theorised conceptual factors; for example, the four factors namely perceived usefulness, the perception of use, interactive learning and behavioural intention. The perceived learning effectiveness survey items were first entered into the principal component analysis after which a four-factor solution having eigenvalues of over 1 is obtained. This indicated that item 18 loaded less than the indicated value and was immediately dropped. Consequently, the four factors remained with the first factor explaining 21.71% of the variance, the second explaining 40.67%, the third explaining 57.21% and the last explaining 72.32%. Added to the above values, the KMO index, as well as the Bartlett's test of sphericity was computed and the following results were obtained: a KMO index value of 0.853 and a chi-square value of 2431.436 (df = 136, p = 0.000). As for the reliability test, the Cronbach's Alpha, obtained for the dimensions of perceived learning effectiveness, is 0.736. The factor loading of the 17 items in the scale, along with the percentage variance accounted for by every individual factor, is listed in the table below. It is evident from the table that the Cronbach's Alpha internal consistency for the whole measure is 0.736.

Table 8.2: Exploratory Factor Analysis of the Perceived Learning Effectiveness Measurement

Results for Perceived Learning Effectiveness Scale			
Variable	**Item**	**Factor Loading**	**Total Variance**
Perceived usefulness	1	0.84	21.71
Perceived usefulness	2	0.82	
Perceived usefulness	3	0.85	
Perceived usefulness	4	0.87	
Perception of use	1	0.81	40.67
Perception of use	2	0.76	
Perception of use	3	0.87	
Perception of use	4	0.85	
Interactive learning	1	0.84	57.21
Interactive learning	2	0.90	
Interactive learning	3	0.87	

Interactive learning	4		0.84	
Interactive learning	5		0.81	
Behavioural intention	1		0.85	72.32
Behavioural intention	2		0.82	
Behavioural intention	3		0.85	
Behavioural intention	4		0.86	
KMO		0.805		
Df		136		
Sig		0.000		
Alpha		0.736		

8.2.3 Self-efficacy (SE)

Butler's (2011) self-efficacy survey has been adopted in this study, and the survey was related to a single factor. The instrument consists of 9 items ranged from 1, depicting 'Strongly Disagree' and 5, depicting 'Strongly Agree'. The measurement is chosen for its good coefficient of reliability and validity and in this context, an item was dropped to increase the Alpha coefficient value to 0.910.

In the EFA of the factor structure of self-efficiency, the researcher found it to be inconsistent with the past theorised conceptual factor. The final factor loadings highlighted two-factor solutions where item number 9 loaded on other factors lower than the suggested number of items. Hence, the item was dropped. The self-efficacy survey items were then entered into the principal component analysis after one-factor solution having eigenvalue greater than 1 was obtained, where the single factor accounted for 61.882% of the variance. Moreover, the values of the KMO index and Bartlett's sphericity test was found to be 0.916 and chi-square value of 1210.202 (df = 28, p = 0.000) respectively. The Cronbach's Alpha value was 0.91, with a suggestion value of 0.70. The factor loadings for all 8 items and their percentage of variance are presented in Table 8.3.

Table 8.3: Exploratory Factor Analysis of Self-Efficacy Measurement

Results for Self-Efficacy Scale			
Variable	**Item**	**Factor Loading**	**Total Variance**
Self-Efficacy	1	0.825	61.88
Self-Efficacy	2	0.856	
Self-Efficacy	3	0.830	
Self-Efficacy	4	0.621	
Self-Efficacy	5	0.818	
Self-Efficacy	6	0.708	
Self-Efficacy	7	0.836	
Self-Efficacy	8	0.770	

KMO	0.916
Df	28
Sig	0.000
Alpha	0.918

8.2.4 Satisfaction (SAT)

With regards to the satisfaction questionnaire, it was adapted from a satisfaction measure created by Chen et al. (2010) and Liaw (2008), which in turn was extracted from prior studies, relating satisfaction to three factors measuring students' satisfaction. The factors are student, interface and content. There were 13 overall items that were rated from 1, depicting 'Strongly Disagree' to 5, depicting 'Strongly Agree'. The choice of measurement is attributed to the ease of its administration and the extensive use in different settings (Chen et al., 2010; Liaw, 2008). Items number 2 and 5 were dropped to maximise the Alpha coefficient. In this regards, the Cronbach's Alpha internal consistency reliability measure was found to be 0.811.

Therefore, through the EFA, the factor structure of satisfaction was found to be inconsistent with the prior theorised conceptual factors. The final factor loading identified two factors having eigenvalues of 1, i.e. content and personalisation after the satisfaction survey items were entered into the principal component analysis. The first factor explained 39.46% of the variance, whereas the second factor accounted for 71.75%. The KMO and Bartlett's sphericity test obtained the values of 0.844 and chi-square value of 1859.203 (df = 55, p = 0.000) respectively. Also, the Cattell's scree test of data reinforced the two-factor solution. Moreover, all of the alpha values in the reliability test suggested a value of 0.70. The factor loading of all 11 items in the scale, the percentage of variance that accounted for the individual factors and the internal consistency reliability values (0.811) are presented in Table 8.4.

Table 8.4: Exploratory Factor Analysis of Satisfaction Measurement

Reliability Results for Satisfaction Scale			
Variable	**Item**	**Factor Loading**	**Total Variance**
Content	1	0.836	39.46
Content	2	0.854	
Content	3	0.853	
Content	4	0.856	
Content	5	0.823	
Personalization	1	0.779	71.75

Personalization 2		0.882	
Personalization 3		0.867	
Personalization 4		0.871	
Personalization 5		0.823	
Personalization 6		0.876	
KMO	0.884		
Df	55		
Sig	0.000		
Alpha	0.885		

8.2.5 mAR-Features (mARF)

The mAR-features survey related to one factor was created for this study. The entire survey consisted of 9 items, where all items were measured through a scale ranging from 1, depicting 'Strongly Disagree' and 5, depicting 'Strongly Agree'. Such a measure was utilised owing to its good reliability and validity coefficients. Nevertheless, four items, specifically 3, 5, 8 and 9 loaded less than 0.40 and were thus excluded from further analysis. The internal consistency reliability obtained through the Cronbach's Alpha value is 0.891.

Five items were used to measure the mAR features, as illustrated in Table 8.5. The exploratory principal component analysis revealed a single factor solution, where the factor accounted for 70.07% of the variance, with a KMO index of 0.876 and Bartlett's sphericity test of chi-square value = 705.924 (df = 10, p = 0.000). In addition, the Cattell's data scree-test supported a single factor solution.

Table 8.5: Exploratory Factor Analysis of mAR-Features Measurement

Results for mAR Features Scale			
Variable	**Item**	**Factor Loading**	**Total Variance**
mAR-Features	1	0.820	70.07
mAR-Features	2	0.826	
mAR-Features	3	0.830	
mAR-Features	4	0.870	
mAR-Features	5	0.838	
KMO	0.876		
Df	10		
Sig	0.000		
Alpha	0.891		

8.3 Confirmatory Factor Analysis (CFA)

8.3.1 Motivation (MOT)

The CFA ran on the motivation evidenced by the validity of the measure, where the first run of the model generated good data fit and the items loaded the suggested value (Appendix H). Two factors of the motivation measure generated a better fit with the following values (Table 8.6): chi-square chi-square = 113.981, df = 43, ratio = 2.651, RMSEA = 0.080, CFI = 0.961, TLI = 0.950, composite reliability = 0.80 and average variance extracted = 0.68. Table 8.6 presents the CFA model results, along with the factor loading, while Table 8.7 presents the fit indices for the measurement of motivation.

Table 8.6: Confirmatory Factor Analysis Factor loadings for Motivation Survey

Variable	Item No.	Factor Loading
Intrinsic	1	0.69
Intrinsic	2	0.68
Intrinsic	3	0.72
Intrinsic	4	0.87
Intrinsic	5	0.90
Intrinsic	6	0.72
Extrinsic	7	0.87
Extrinsic	8	0.84
Extrinsic	9	0.83
Extrinsic	10	0.78
Extrinsic	11	0.85

Table 8.7: Overall Measurement Model Fit for Motivation Construct

Fit Index	Value	Composite Reliability	Variance Extracted	Items
The Root Mean Square Error of Approximation (RMSEA)	0.080	0.80	0.68	11
Comparative Fit Index (CFI)	0.961			
Tucker Lewis Index (TLI)	0.950			
Ratio or Normed (χ^2 = chi)	2.651			

8.3.2 Perceived Learning Effectiveness

The CFA test on perceived learning effectiveness verified the validity of the measure. The initial run of the model generated a good fit with the data and all the item loadings matched with the suggested value (Appendix H). Thus, a four-factor model of the number measure was deemed to generate a better fit with the following values (Table 8.9): chi-square = 193.276, df = 113, ratio = 1.710, RMSEA = 0.052, CFI = 0.966, and TLI = 0.959, composite reliability =

0.79 and average variance extracted = 0.76. The resulting CFA model, in terms of factor loading and fit indices, for the perceived learning effectiveness variable is presented in Table 8.8 and Table 8.9.

Table 8.8: Confirmatory Factor Analysis Factor Loading for Perceived Learning Effectiveness Scale

Variable	Item	Factor Loading
Perceived usefulness	1	0.77
Perceived usefulness	2	0.76
Perceived usefulness	3	0.81
Perceived usefulness	4	0.83
Perception of use	1	0.74
Perception of use	2	0.64
Perception of use	3	0.86
Perception of use	4	0.81
Interactive learning	1	0.82
Interactive learning	2	0.91
Interactive learning	3	0.86
Interactive learning	4	0.76
Interactive learning	5	0.73
Behavioural intention	1	0.78
Behavioural intention	2	0.76
Behavioural intention	3	0.81
Behavioural intention	4	0.83

Table 8.9: Overall Measurement Model Fit for Perceived Learning Effectiveness Construct

Fit Index	Value	Composite Reliability	Variance Extracted	Items
The Root Mean Square Error of Approximation (RMSEA)	0.052	0.79	0.76	17
Comparative Fit Index (CFI)	0.966			
Tucker Lewis Index (TLI)	0.959			
Ratio or Normed (χ^2 = chi)	1.710			

8.3.3 Self-Efficacy (SE)

On the whole, the CFA of the self-efficacy measure ensured the validity of the measurement (Appendix H), where the first run of the model generated good data fit and all the items achieved the suggested value that is greater than 0.30 (Table 8.10). The one-factor model of the self-efficacy measure showed better fit with the following values: with chi-square = 2.161, df = 19, ratio = 2.161, RMSEA = 0.067, CFI = 0.982, TLI = 0.973, composite reliability = 0.75 and average variance extracted = 0.86 (Table 8.11).

Table 8.10: Confirmatory Factor Analysis Factor loadings for Self-Efficacy Survey

Variable	Item	Factor Loading
Self-efficacy	1	0.80
Self-efficacy	2	0.81
Self-efficacy	3	0.81
Self-efficacy	4	0.56
Self-efficacy	5	0.79
Self-efficacy	6	0.66
Self-efficacy	7	0.82
Self-efficacy	8	0.69

Table 8.11: Overall Measurement Model Fit for Self-Efficacy Construct

Fit Index	Value	Composite Reliability	Variance Extracted	Items
The Root Mean Square Error of Approximation (RMSEA)	0.067	0.75	0.86	8
Comparative Fit Index (CFI)	0.982			
Tucker Lewis Index (TLI)	0.973			
Ratio or Normed (χ^2 = chi)	2.161			

8.3.4 Satisfaction (SAT)

The CFA of the satisfaction variable comprise of thirteen items, with the initial result of the model supporting a good data fit (Appendix H), where all the items loaded have a suggested value that is greater than 0.30 (Table 8.12). In sum, the two-factor model of satisfaction generated a better fit with the following values: chi-square = 95.177, df = 43, ratio = 2.213, RMSEA = 0.068, CFI = 0.972, TLI = 0.964, composite reliability = 0.89 and average variance extracted = 0.74 (Table 8.13).

Table 8.12: Confirmatory Factor Analysis Factor Loading Results for Satisfaction Scale

Variable	Item	Factor Loading
Content	1	0.61
Content	2	0.60
Content	3	0.61
Content	4	0.80
Content	5	0.99
Personalization	1	0.72
Personalization	2	0.87
Personalization	3	0.84
Personalization	4	0.84
Personalization	5	0.78
Personalization	6	0.86

Table 8.13: Overall Measurement Model Fit for Satisfaction Construct

Fit Index	Value	Composite Reliability	Variance Extracted	Items
The Root Mean Square Error of Approximation (RMSEA)	0.068	0.89	0.74	11
Comparative Fit Index (CFI)	0.972			
Tucker Lewis Index (TLI)	0.964			
Ratio or Normed (χ^2 = chi)	2.213			

8.3.5 mAR-Features (mARF)

The CFA of mARF evidenced a valid measurement, where the first run of the model generated a good data fit and the item achieved the suggested value of more than 0.30 (Table 8.14) (Appendix H). A single-factor model of the mARF measure generated a better fit with the following values: chi-square = 12.508, df = 5, ratio = 2.502, RMSEA = 0.076, CFI = 0.989, TLI = 0.979, composite reliability = 0.79 and average variance extracted = 0.80 (Table 8.15).

Table 8.14: Confirmatory Factor Analysis Factor loadings for mAR Features Survey

Variable	Item	Factor Loading
mAR-Features	1	0.76
mAR-Features	2	0.77
mAR-Features	3	0.78
mAR-Features	4	0.85
mAR-Features	5	0.80

Table 8.15: Overall Measurement Model Fit for Algebra Construct

Fit Index	Value	Composite Reliability	Variance Extracted	Items
The Root Mean Square Error of Approximation (RMSEA)	0.076	0.79	0.80	5
Comparative Fit Index (CFI)	0.989			
Tucker Lewis Index (TLI)	0.979			
Ratio or Normed (χ^2 = chi)	2.502			

8.4 Discriminant Validity

Table 8.16 presents the correlations between the model's variables. All the constructs appear to have satisfactory discriminant validity, as estimated by the correlations that were not significantly high. In this regard, correlations around 0.90 should not be ignored, as it is a great cause for concern (Pallant, 2005). If such a case is encountered, one of the strongly correlated variable pairs should be dropped, or they should be combined them into one measure (Pallant, 2005). In this research, all the variables have low to moderate relations with the other variables, supporting the fact that the relationships of all values failed to achieve the recommended values as presented in the Table 8.16.

In addition, past studies state that the model fit can be enhanced through co-variation between the indicators (Ruehlman et al., 2005). Also, the integration of covariance between two items would enhance the model fit (Byrne, 2016). Thus, by using the covariate between two items, the results showed a good data fit.

Moreover, the following values were found: CFI of 0.966, TLI of 0.960, RMSEA of 0.050, a ratio of 1.635 (less than 5), indicating that all the values that were based on the criteria established provided a sound data-model fit. It was also evident that the discriminant validity is met, and it is accepted that the identified construct and the model have achieved discriminant validity (Appendix I).

Table 8.16: Results of Implied Correlation between the Variables in the Model

	1	2	3	4	5
Self-Efficacy	1.000				
mAR-Features	0.177	1.000			
Satisfaction	0.108	0.151	1.000		
Motivation	0.450	0.118	0.264	1.000	
Perceived Learning Effectiveness	0.754	0.198	0.130	0.534	1.000

*** Correlation is significant at the 0.01 level (2-tailed).*
** Correlation is significant at the 0.05 level (2-tailed).*

8.5 Analysis of the Structure Model

After the measurement models had been assessed, the next step was to evaluate the structural model. The hypothesised model was evaluated on the basis of two conditions, i.e. overall goodness-of-fit, as well as the feasibility and significance of the estimated model coefficients. A model is acceptable if it meets the acceptable fit, contains valid paths and explains a moderate-high proportion of the dependent variables' variance. Table 8.17 displays the standardised loading, Critical Ratio (C.R) and the goodness-of-fit of the hypothesised model. The table presents the standardised loading for every path of the dependent variable that is included in the model. The entire estimates fell within an acceptable range, with a correlation coefficient that is less than one, no negative covariance and in the directions that are expected. On the basis of the level of 0.05, all C.R. obtained values were lower than 1.96, except for one value, thus indicating the significance of the estimated coefficients.

The goodness-of-fit measure initially showed a poor fit model and thus, two indicators as suggested by Ruehlman et al. (2005) were employed to enhance the model fit. As mentioned, this was supported by Byrne (2016), stating that the covariance between the two items would enhance model fit and thus, the covariate between each item as presented in the model was utilised. In this case, the outcome reflected a good data fit. The goodness-of-fit measure showed an acceptable model fit. The model fit is indicated by the following: chi-square goodness-of-fit of 67.494, normed chi-square of 1.976, TLI of 0.954 and RMSEA of 0.061. Thus, the goodness-of-fit measures showed good model fits the data (Figure 8.1). Moreover, the mAR-features significantly precede the learning outcomes (beta = 0.14, $p < 0.05$) but not motivation (beta = 0.65, $p > 0.05$). According to the results, motivation is not an antecedent variable to the learning outcomes (beta = 0.10, p > 0.05).

Table 8.17: Standardised Loading, C.R. and goodness-of-fit Measure for the Hypothesised Model

Hypothesis	**Path**		**Standardised**	**C.R.**	**Sig**
	From	**to**	**Loading**		
H1	mAR-Features	Learning Outcomes	0.14*	2.019	Yes
H2	mAR-Features	Motivation	0.65	1.367	No
H3	Motivation	Learning Outcomes	0.10	1.672	No
Goodness-of-fit Measures					
Chi-Square (χ2)		67.694			
Normed Chi-square		1.976			
CFI		0.971			
TLI		0.954			
RMSEA		0.061			

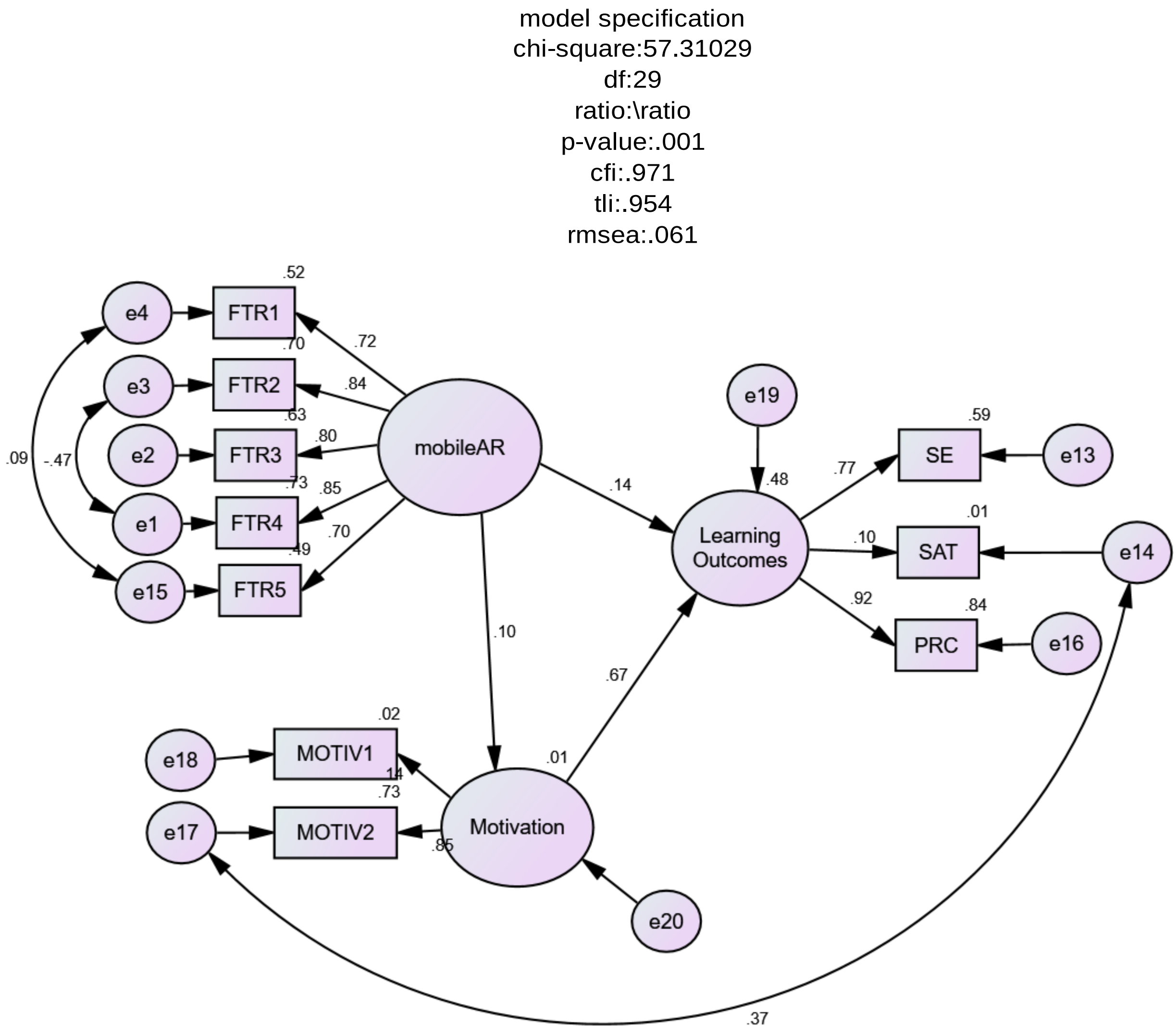


Figure 8.1: Structural Equation Model showing the Standardised Loading for Path

8.6 Moderating Effects of Students' Characteristics

Generally, in the examination of the moderating variable effects, there are two most common statistical methods used. The first is the hierarchical regression analysis where this type of analysis entails the creation of interaction terms between the moderator and predictor variables (Hair, 2006). This is primarily conducted by multiplying the predictor variables with the moderator variables. However, according to Hair et al. (2006), this method is complicated as the interaction terms sometimes lead to issues in model convergence and a distortion of standard errors. This kind of complication, however, can be managed if the sample size is higher than 300. However, the sample size of this study is 260. Therefore, the method may generate inaccurate outcomes. When the sample used is small, there will be a lower intensity of power in detecting the moderator variable (Frazier et al., 2004). Also, it is recommended that the multi-group method is more suitable for this purpose (Frazier et al., 2004; Hair et al., 2006). Therefore, to examine the moderator's effect on the influence of the independent variable on the dependent variable, the AMOS multiple-group analysis was employed. In addition, Arbuckle (2005) reinforces the notion that the method of a single analysis for many groups has two benefits. First, it provides a test for the significance of the differences between the groups. Second, if there is a lack of group differences, or if the differences are confined to a few model parameters, the analysis of several groups will provide a more accurate parameter of simultaneous estimations. Meanwhile, to examine the moderating impacts of experience and age on the relationship between the mAR-features, motivation and learning outcomes, prior authors (Hair, 2006; Yi & Hwang, 2003) recommend the use of the AMOS multiple-group analysis. In this research, the entire sample was categorised into two groups, utilising individual factors with the inclusion of experience and age, where the experience was divided into groups namely experienced students, that have initial knowledge in Human Anatomy (135 students) and those with no experience of initial knowledge in Human Anatomy (125 students). The hypotheses developed for the moderating effect of experience are examined by comparing the path coefficients between the two groups for every moderating through the t-value. T-values over 1.96 has over 95% confidence, indicating that the coefficient has a moderating effect.

In the analysis, the overall model values fell within the acceptable range (CMIN/ DF = 1.886, CFI = 0.944; TLI = 0.921 and RMSEA = 0.059). The next step involves the determination if there are significant differences in the path coefficient. Table 8.18 shows that experience does not have a moderating effect on the relationship between the mAR features and learning outcomes, or the one between motivation and learning outcomes. Specifically, the path coefficient of the no-experience group is insignificant between the mAR features and learning outcomes ($\beta = 0.11$, $p = 0.391$, $p > 0.05$). Similarly, the path coefficient of the no-experience group is insignificant between motivation and learning outcomes ($\beta = 0.85$, $p = 0.082$, $p > 0.05$). Besides, the path coefficient of the no-experience group is insignificant between the mAR features and motivation ($\beta = -0.15$, $p = 0.347$, $p > 0.05$). In retro specs, the mAR features refer to the characteristics of HumAR, that consists of; 1)The realism of the 3-D images in the HumAR application motivates me to learn; 2)The smooth of images in the HumAR application make learning more motivating and interesting; 3)The ability to change the view in 360°

positions of the 3-D objects in the HumAR application allows me to learn better; 4)The ability to manipulate the objects (e.g.: rotate, scale, move) within the virtual environment makes me learning more motivating and interesting; and 5)The ability to manipulate the objects in real time helps to enhance my understanding.

Moreover, the path coefficient of the experience group of students showed insignificant effects between the mAR features and learning outcomes (β = 0.15, p = 0.283, $p > 0.05$), between motivation and learning outcomes (β = 0.55, p = 0.054, $p > 0.05$) and between mAR features and motivation (β = 0.29, p = 0.232, $p > 0.05$). Therefore, the hypothesised null moderating effect of experience is supported.

Table 8.18: Results of Experience as Moderating Variables Effects

Hyp	**Path**	**Effect**	**Experience**			
			No-Experience-mAR		**Experience-mAR**	
			B	**p**	**B**	**p**
H1	mAR-Features—› Learning Outcomes	Strength	0.11	0.391	0.15	0.283
H2	Motivation—› Learning Outcomes	Strength	0.85	0.082	0.55	0.054
H3	mAR-Features—› Motivation	Strength	-0.15	0.347	0.29	0.232

the p-value is statistically significant at the 0.05 level (two-tailed)

With regards to the moderating effect of age, the comparison of the path coefficients between the two groups for each moderator was carried out using the t-value, where the t-value over 1.96 is considered over 95% confidence, thus showing the coefficient's moderating impact.

In the analysis, the overall model values fell within the acceptable range (CMIN/ DF = 1.955, CFI = 0.940; TLI = 0.912 and RMSEA = 0.061). Table 8.19 defines if age is a moderator variable. On the basis of the values stated in Table 8.19, age does not moderate the relationship between the mAR features and learning outcomes, or between that of motivation and learning outcomes. The coefficient of older students is insignificant between the mAR-learning outcomes relationship (β = 0.24, p = 0.069, $p > 0.05$), as well as between motivation and learning outcomes (β = 0.76, p = 0.089, $p > 0.05$). The age path coefficient is also insignificant between the mAR-feature and motivation (β = -0.19, p = 0.256, $p > 0.05$).

On the other hand, with regards to younger students, the path coefficient is also found to be insignificant between the mAR features and learning outcomes (β = -0.089, p = 0.907, $p > 0.05$) and between motivation and learning outcomes (β = 0.89, p = 0.501, $p > 0.05$). The same holds true for the path coefficient of younger students between the mAR features and motivation (β = 0.55, p = 0.354, $p > 0.05$). Hence, the moderating effect of age is rejected.

Table 8.19: Results of Age as Moderating Variables Effects

Hypothesis	Path	Effect	Experience			
			Older		Younger	
			B	p	B	p
H1	mAR-Features—› Learning Outcomes	Strength	0.24	0.069	-0.089	0.907
H2	Motivation—› Learning Outcomes	Strength	0.76	0.089	0.89	0.501
H3	mAR-Features —› Motivation	Strength	-0.19	0.256	0.55	0.354

the p-value is statistically significant at the 0.05 level (two-tailed)

The hypotheses results of the research questions 8 and 9 and the null hypotheses number 17 until 21 are summarised in Table 8.20, wherein it is indicated whether each hypothesis is supported or not. The details of the results are discussed in Sections 8.5 and 8.6.

8.6.1 Summary of findings to research questions 8-9 and null hypothesis testing 17-21

Table 8.20: Summary results of research question 8-9

RO	RQ	Test	Independent Variable	Dependent Variable	Result
3	8	Model fitness	mAR-Features> Motivation	Learning Outcome	MSF
3	8	Antecedent Relationship	mAR-Features	Learning Outcome	S
3	8	Antecedent Relationship	mAR-Features	Motivation	NS
3	8	Antecedent Relationship	Motivation	Learning Outcome	NS
4	9	Moderating Effect	Experience	mAR-Features	NS
4	9	Moderating Effect	Experience	Motivation	NS

4	9	Moderating Effect	Experience	Learning Outcome	NS
4	9	Moderating Effect	Age	mAR-Features	NS
4	9	Moderating Effect	Age	Motivation	NS
4	9	Moderating Effect	Age	Learning Outcome	NS

Note: RQ = Research Question; RO = Research Objective; mAR = mobile Augmented Reality; MSF = Model Significantly Fit; S = Significant; NS = Not Significant;

The summary results of the null hypotheses associated with the model are written as follows:

H_{17}: The dimensions are not a fit for the model of mobile Augmented Reality (mAR) effectiveness.

- The result indicates that the dimension is fit for the model. Therefore, the hypothesis H_{17} is not supported.

H_{18}: mAR features are not significant antecedents to the learning outcomes in the model of mobile Augmented Reality (mAR) effectiveness.

- The result shows that there is a significant antecedent. Therefore, the hypothesis H_{18} is not supported.

H_{19}: Motivation is not a significant antecedent to the learning outcomes in the model of mobile Augmented Reality (mAR) effectiveness.

- The result shows that motivation is not a significant antecedent. Therefore, the hypothesis H_{19} is supported.

H_{20}: Experience has no moderating effect between students' learning characteristics of the learning mode, with regards to the learning outcomes.

- The result shows that experience has no moderating effect. Therefore, the hypothesis H_{20} is supported.

H_{21}: Age has no moderating effect between students' learning characteristics of the learning mode, with regard to learning outcomes.

- The result shows that age has no moderating effect. Therefore, the hypothesis H_{21} is supported.

8.7 Summary

This chapter's objectives are to assess all constructs, the relationships and to develop a model. Also, described the methods used in assessing the hypotheses. The first section explained the analysis of measurement model with EFA. Each construct was assessed in obtaining an adequate range of factor loading value. This is followed by the determination of the fit of the hypothesised model with the help of Structural Equation Modelling (SEM). Each construct once again has been thoroughly analysed through CFA measurements. The reliability and validity of the measurements were grouped after the convergent and discriminant validity outcomes. Therefore, a model was developed based on this validity assurance. An evaluation of the model has revealed the answers to the eighth and ninth research questions of this research.

Moreover, students' characteristics like experience and age were found not to moderate the relationships between mAR features, motivation and learning outcomes. The structural model assessment also showed a good model fit. This supports the fact that the mAR features have a direct impact on learning outcomes, but not motivation. Finally, further results reported in this chapter are discussed in Chapter 9.

The model contributes to the mAR literature on how to enhance the cognitive ability and affective learning outcomes. Educators have constantly looked for new, innovative and alternative, especially in effective ways in the context of the learning environment for their students. Therefore, it is significant to recognise that mAR plays a substantial role in shaping the student's learning. The findings can be beneficial to the academia to embed mAR in the learning environment, also, can use the model's findings as appropriate groundwork to initiate other related subject fields and help to fill the gap in the mAR learning area.

CHAPTER 9
DISCUSSIONS AND CONCLUSIONS

9.0 Overview

The main aims of this research are to 1) investigate the effectiveness of mAR in influencing the learning outcomes and the performance achievements of students, and to 2) in improving the motivation of the students in the learning process, thus in improving the memory retention. This research has advanced to the development stage of a theoretical model, to evaluate the ability of mAR in improving the learning outcomes that guide a further growth in learning.

This thesis examined the impact that the two main learning modes have on learning outcomes. The Mobile Augmented Reality-Based Learning Environment (mAR mode) was compared (through pre-test, post-test and a questionnaire) with the Current Learning Method (CLM mode), on how they influence learning effectiveness, self-efficacy, satisfaction and performance achievement. Furthermore, the potential impact of the learning modes, features associated with mAR, as well as the level of student motivation, was investigated through a theoretical model, which was developed using the required dimensions and antecedents of mAR effectiveness.

The cohort of this study involved 260 Science undergraduate students, with an age range of 18 to 28, enrolled in both public and private universities in Malaysia. The students were recruited into one of two learning modes: mAR and CLM. The learning mode and motivation (high and low), as well as learning characteristics in terms of age and experience, were assessed as independent variables. The dependent variable was the learning outcome measured by perceived learning effectiveness, self-efficacy and satisfaction.

In this final chapter, the empirical results are discussed, along with the major outcomes and impact of this thesis. This chapter has been divided into four sections. Firstly, this discussion section revises how mAR influences the performance and learning outcomes among students. Secondly, the chapter continues with an explanation of how student motivation can affect learning outcomes and performance achievement. In the third section of this chapter, the model fit is discussed in light of how mAR enhances learning outcomes. Then, this chapter ends with conclusions that provide a summary of the research contributions, limitations and recommendations for future investigations.

9.1 Effects of the Learning Modes

9.1.1 The Effect of Learning Modes on Performance Achievement (Cognitive Learning Outcome)

This section explores the control (CLM group) and treatment group (mAR group) with regards to performance achievement (cognitive learning outcome). In determining the ability of the participants prior to assessing their cognitive outcome, students were subject to a pre-test to establish a baseline of the starting point of pre-existing knowledge on the topic without using technology to intervene. Each group of 130 students participated in the pre and post-test exercises. The measurement of achievement was gauged through the percentage increment of performance among students in the scores of their pre and post-tests, without any technological intervention.

The pre-test, taken before exposure to the content of the unit, showed that the average result for both groups was uniform, indicating that the initial knowledge of the subject matter was consistent and participants have similar abilities. The percentage difference was shown to be positive for both groups in the post-test phase. Moreover, that difference was statistically significant as presented in Section 7.2.4.2. Upon comparison, the result of the mAR group's learning achievement was significantly higher, with a double mean increment as compared to the CLM group. This result specifies that mAR exposure gives benefits in areas of attention, confidence and other relevant dimensions. Hence, it is concluded that mAR is the best learning method for solving problems that occur within and outside the classroom environment, particularly when it comes to memorisation (Kucuk et al., 2016). The mAR learning mode also effectively influences students' memory (Shirazi & Behzadan, 2015). Students showed higher scores in comparison to their CLM counterparts; a common phenomenon explained and proven through the cognitive load theory (Sweller, 2011).

Most of the information is not consciously internalised, but when the student decides to address the information obtained in the sensory memory, it is transformed into working memory (Young et al., 2014). Young et al. (2014) discuss that working memory is the entire amount of mental activity that is carried out to process information. In this context, the learning process calls for the working memory to facilitate the comprehension of curricula to integrate to-be-learned information to the suitable schema development that will consequently turn into long-term memory. However, the working memory capacity is limited; thus, based on the cognitive load theory, learning is confined when such capacity is exceeded by the demands of the learning tasks. This indicates that every branch of the memory processing capacity is limited in terms of the accommodation of information. For instance, a branch may be full, while the other may still have space, and that limited working memory capacity can be extended through the use of two or more channels instead of just a single channel (Paas & Sweller, 2012; Sweller, 1998). Despite its limited capacity in the working memory, learning with mAR can eliminate this duration limits when working memory deals with familiar information and it will be stored in the long-term memory. This condition obviously reflects that the mAR learning activities provide the flexibility that allows students to learn anytime and anywhere they want (Paas & Sweller, 2012). By experiencing the repetition of the visual object, it shifted the object into a familiar experience, then stored the experience in the long-term memory. Therefore, better performance achievement can be achieved with less cognitive effort, which is consistent with the outcome of studies by Kucuk et al. (2016) and Paas and Sweller (2012) thus, supports an evolutionary upgrade of cognitive load theory. This premise is evidenced by the performance displayed by the students in the mAR group. To further support the prototype, an element of interactivity provided by HumAR on devices of the mAR learning group show that the level of memory load for every task, as well as the knowledge level, have been significantly influenced.

Additionally, learning with the help of mAR enabled the retrieval of information frequently through AR learning. mAR allows learners to access learning content flexibility at any time of the day they find suitable, irrespective of their location according to the markers (Bujak et al., 2013; Kamphuis et al., 2014) because the mobile device is always with them. By this means, mAR will always be carried and repetition of the learning content can be easily retrieved. This repetition or frequency of visual information can strengthen the memory length, as claimed in the cognitive load theory (Diegmann et al., 2015; Young et al., 2014). In the mAR learning group, HumAR provides various multimedia visual features that help individuals retain information longer (Section 7.2.4.2). In addition, HumAR provides interactive 3D graphics, audio, video and texts to facilitate easy learning. It is evident that the repeated use of the visual sensory system in the mAR group appears to accelerate the transformation of sensory memory to working memory. This cognitive measure was significant and indicating that the students learning using interactive concept can efficiently respond to the individual learning styles. It has been attested that regardless of the learning styles; auditory learning, visual-textual learning, visual-graphical learning and kinaesthetic learning (Laks, 2015) (Section 2.5.3), are all benefitted from learning using mAR and possessed a more positive on cognitive gains compared to CLM. Therefore, the cognitive problem and retention of data have been alleviated. The fusion of the real world and virtual world have shown that students respond favourably to the mAR environment.

Moreover, the above premise is also supported by the post-test quiz from both groups of students, where the mAR group outscored their CLM counterparts. On the basis of the scores, the labels of the anatomical landmarks on the bones quiz were almost perfect. It can, therefore, be stated that learning through HumAR has highlighted the structured memory administration of an object and the mAR mode approach is invaluable in enhancing learning outcome, particularly in terms of visualisation and memorisation (Juan et al., 2014).

Drake (2014) suggests that the Human Anatomy curricula and teaching require active and contextual learning, as well as assessments of competencies in the current pedagogical goal. This can be solved with more multimodal learning approaches (Drake, 2014; Jamali et al., 2013; Whelan et al., 2015). These improvements can resolve issues relating to the retention of information and lessen the focus on learning basic Sciences in laboratories (current learning method) (Whelan et al., 2015). As a consequence, the majority of learning institutions adopt mAR technology-centred teaching to supplement traditional and lecture-based Human Anatomy education (Juanes et al., 2014; Rodriguez et al., 2015), on account of the ability of mAR to facilitate user visualisation and to obtain the needed information concerning individual bones - its element of being always with the user and its documented potential to employ facilities that help students experience real-world learning, as compared to current learning methods.

This research also supports the contribution of mAR in enhancing academic achievement, where information is carried out by users on a mobile device, allowing for on-demand and frequent evaluation of information. In fact, the challenges in terms of resource and learning- based, which have been reported in the literature (Section 2.4.1) are decreased. As a result, the limited time of the laboratory operation hours, storage of the cadavers, moral issues, quality and a limited quantity of cadavers, limited lab opening hours and low retention of information (Chien et al., 2010; Ganguly, 2010; Whelan et al., 2015) are no longer an issue.

Students are free to revise their knowledge at any time and place with mAR. In this regard, information can frequently be accessed, particularly in subjects that require laboratory referral. mAR also stimulates learning interests among students in a way that this method is effective in dealing with hands-on interactivity that guides them towards achieving successful learning.

Based on the post-test results, a higher score was achieved by the mAR group of students. It implies the capability of mAR to provide more active student involvement in the learning process. In conclusion, with regards to RQ2, the null hypothesis (H_{05}) (Section 3.2) concerning performance achievement that proposed no significant difference in the memory retention between the mAR and non-mAR mode was rejected. In other words, mAR is an effective learning tool that updates, retains information and reflects achievement in higher learning institutions.

9.1.2 The Effects of Learning Modes on Learning Outcomes/Affective Learning Outcomes

A significant relationship was found between the mAR and CLM groups. This finding addresses the first research question of this thesis (Section 1.4), as a collective result, the predictors were combined as a proxy for the learning outcomes. The results of the analyses revealed that the learning modes positively influenced learning outcomes, thereby indicating important divergences in the learning model and effects. The null hypothesis proposed is therefore not supported (Section 7.2.4.1).

As previously discussed in Section 3.3.3, there is a probability that the use of a specific application in learning can improve student achievement. Therefore, to verify how mAR impacts behaviour, information quality, comprehension, competence and other factors that form the learning outcome metrics, perceived learning effectiveness, self-efficacy and satisfaction were analysed separately. Every construct was identified and analysed independently to determine which construct contributed the most. Both perceived learning effectiveness and self-efficacy were found to have the highest significant difference, while satisfaction demonstrated a negative result for both learning groups. The detailed discussions are explained as follows.

9.1.2.1 Perceived Learning Effectiveness

Chang et al. (2014) discovered that perception in the mAR group has a significant positive influence, assisting students mainly in their comprehension of the subject matter. According to Albrecht et al. (2013), activating the mAR concept serves to encourage participants to boost interest in the curriculum that can empower students' authority in learning by providing them with an accessible and reliable reference. Considering these advantages, the students believed that the application of this technology in their respective learning environments encourages them to set a higher indicator of success, thus facilitating them to excel and become more competitive at what they do. This is proven when the results showed that learning effectiveness made a considerable difference depending on the learning modes, where mAR students obtained a significantly greater mean in the survey compared to their CLM counterparts. In particular, perceived learning effectiveness was measured using four determinants: perceived usefulness, the perception of use, learning interaction and behavioural intention. The results indicate that both perceived usefulness and perception of use significantly influenced behavioural intention in using technology in the learning context. Indeed, this research has found that behaviour was also influenced by the mAR interactions, between the student and learning content, where these interactions increased the students' cognitive and learning ability in comprehension, memory and imagination. This has supported the view that the interaction value is one of the justifications for practising mAR for learning (Chiang et al., 2014).

9.1.2.2 Self-Efficacy

The results showed that mAR students obtained greater results in self-esteem compared to the CLM students, where the former successfully completed tasks with confidence. This is evidenced that mAR supports learning via digital object manipulation, especially in developing a layer of interactivity that helps to clarify an object accurately. Digital manipulation also covers tasks that can be accessed by students for objects augmentation like magnification, enhancement of objects, animation and textural rendering. In relation to these capabilities, it is easier to comprehend and visualise complex objects. It indirectly allows students to hone their cognitive skills, such as in comprehending the significant elements of conceptual complexity, the use of learned objects in their reasoning and inferences and competently applying knowledge to new situations in a versatile manner. On the basis of the interactivity results, it appears that when learning interaction is increased for students, the development of personal knowledge increases as the majority of learning processes take place within a social context via the mutual creation of understanding. Eventually, students' self-esteem is encouraged by this interaction. This finding supports the study of Chiang et al. (2014) in that the learning abilities of interactions between the student and their learning aids, as well as the interaction amongst students, enable them to identify and resolve their problems through cooperation and teamwork.

9.1.2.3 Satisfaction

As seen from the results, there were no differences in the satisfaction levels between mAR and CLM. Although the mean group of mAR showed higher values than the CLM group, both groups shared the same levels of dissatisfaction. The dissatisfaction was attributed to two causes, content and intention to use, which were found to hold a lesser impact in both learning modes. Nevertheless, mAR mode students showed relatively more positive monitoring and higher gratification towards the content in comparison to CLM students. As expected, mAR students experienced conditions that enabled the content to be learnt with ease (Chiang et al., 2014).

Similarly, with the intention to use, both CLM and mAR groups were not well-delineated in effect. However, CLM learning requires a greater effort to obtain knowledge of the subject. In terms of satisfaction, for the CLM group, the static material and a lack of interaction led to a sedentary learning environment, which consequently resulted in a decline of results. Contrastingly, in the case of mAR, device hardware specification and requirements, i.e. minimum speed limit and low resolution, affected the context (Section 5.2.2). Limitations in the operation of the device diminished the level of contentment on the subject matter in this mode. The result is aligned with prior studies dedicated to mobile AR production design, where device performance was found to have a key role in ensuring the application's efficiency and the resultant effect on the outcome (Ke & Hsu, 2015) (Section 5.2.1). However, the inclination to learn with the help of mAR technology showed better results as compared to CLM. Furthermore, feedback from students showed that the time constraint was among the factors that negatively contributed to the dissatisfaction. In summary, no statistically significant differences in satisfaction were found in both mAR and CLM learning modes from the results and feedback responses, because of the quality of the learning resource

(Markwell, 2003) that related to the devices' performance that produced a delayed of virtual objects projection on the mobile device's screen during the process of learning.

9.2 The Effects of Student Motivation

In this section, the differences in motivation level and its impact on performance achievement and learning outcomes are discussed. The level of motivation is categorised into high and poor motivation. Motivation is described as the movement and desire to do something; where an individual who is not inspired to act is therefore called unmotivated, while one who is motivated or activated towards the action is deemed to be motivated (Ryan & Deci, 2000). The primary difference is found to be in the form of intrinsic motivation. This motivation is considered to be doing something that is inherently interesting and enjoyable, whereas extrinsic motivation refers to doing something because it leads to a separable outcome.

9.2.1 Motivation Levels in Performance Achievement/ Cognitive Learning Outcomes Using Mobile AR-based Technology

An analysis of the experimental results showed a significant difference in the motivation level of the two groups. The results revealed evidence of high and poor levels of motivation, with the former returning a mean of over 19.00 and the latter being lower than 19.00. Higher motivation level in students was taken to indicate a greater impact on learning via the use of mAR, where highly motivated students outperformed their unmotivated counterparts. In addition, the students using the mobile augmented reality-based learning approach displayed a greater motivation level in terms of attention, confidence and relevance dimensions, in contrast to those who were exposed to the current learning methods.

The technology allowed students to learn with ease and leads to an increase in the motivation level for learning. In this regard, the importance of diversity in the materials utilised in class was among the factors that motivated the students (Rocio & Ortega, 2015). In relation to this, it is shown that learning through mAR facilitates the focus of students in examining anatomical characteristics, as it supplements the reference frequently during and after the laboratory hours. Learning with the help of HumAR highlights the detailed descriptions of bone landmarks and associated real-world learning objects in the environment.

Furthermore, Ryan and Deci (2000) detailed motivation types (high or low) to be either extrinsic or intrinsic motivation. Intrinsic motivation is a significant phenomenon for educators where learning and achievement can be motivated or undermined by practices employed by parents and teachers (Ryan & Stiller, 1991). Intrinsic motivation leads to both optimum learning and creativity. More importantly, this type of motivation has the opposite connotation to that of extrinsic motivation. Extrinsic motivation details the factors and forces that motivate or hinder learning. Nevertheless, what is equally relevant is that the emphasis of current reviews is extrinsic motivation, although past studies recorded it in a more negative light (Hassanzadeh & Mahdinejad, 2014; Lemos, 2014; Zhang et al., 2015). Therefore, the present research was to seek if the mAR environment indicates a consistent result with the negative result in extrinsic part. The findings of this section contributed and proved that extrinsic was reported declined in the past studies. The phenomenon implies that both intrinsic and extrinsic motivations are the common factors for success.

With intrinsic motivation, it brings the issues about behaviour acceptance, healthy states, active minds, curiosity, learning readiness and exploration that are not confined to childhood but continue throughout one’s life (Tripathi & Chaturvedi, 2014). With regards to this, learning is considered intimately linked with others in a social activity – contextual in nature, where facts and theories cannot be isolated to what has already been learned, beliefs and prejudices, as well as fear and knowledge concerning the subject matter. This facilitates individuals to act on inherent interests developed with their knowledge and skills.

An analysis of the results of the current study reveals that intrinsic motivation in students’ learning via the mAR mode showed a greater mean than the non-mAR students. In the literature review, the majority of studies dedicated to mAR concentrate on the significance of mAR technology, its effectiveness, attention, behaviour and motivation, without delving in detail into the intrinsic and extrinsic aspects (Albrecht et al., 2013; Catenazzi & Sommaruga, 2013; Chang et al., 2014; Chiang et al., 2014; Juanes et al., 2014; Ke & Hsu, 2015). The findings of this research have then effectively contributed to alleviating the paucity of studies concerning the impact of students’ intrinsic or extrinsic motivation on learning effects in the context of mAR learning.

It was also found that large effect sizes existed in the group differences in the performance achievement of students, indicating that mAR supports students’ task performance, improves their learning results and encourages interactions that precipitate effective learning. This, in turn, leads to improving the intrinsic motivation within students in their learning environment. Learning with mAR generates internal drivers such as consistent behaviour and ownership creation, with regards to the learning material which produces strong beliefs in the readiness to learn and explore in the learning surroundings, and finally, high-performance achievement. The implication of these findings is that learning with mAR was found to motivate and enrich the cognitive ability in the learning process and improves the performance achievement of the learning outcomes.

Similarly, extrinsic motivation showed significant differences in terms of performance achievement in mAR learning. The extrinsic motivation played a significant role in the learning environment, despite a relatively lower rate of results compared to intrinsic motivation. Nevertheless, it still returned a large and positive effect. As mentioned in prior studies (Lepper et al., 2005), extrinsic motivation recorded weak or negative outcomes of correlation in performance achievement. However, it was evident that the analyses of motivation in these prior studies were particularly conducted in a group. A weak correlation was in fact shown by Lemos (2014), although Lemos (2014) analysis was conducted separately and not in a group. This evidence reinforces the fact that extrinsic motivation may be related to adaptive learning patterns under specific situations, according to the assessed outcomes, student age or classroom context. This may also give way to internal behavioural performance as contended by Zhang et al. (2015).

In relation to the effect of external factors upon extrinsic motivation, on the basis of the results obtained, it can be stated that the use of mobile embedded AR technology constitutes such an external factor. This is due to the interest and interactive multimedia existing in the learning environment is one of the integrated ideals within mAR learning. In addition, the patterns of behaviour relied on the learning mode being utilised, when the students were immersed in their mAR experience in the mAR learning mode. On the other hand, the majority of students who used the mAR mode provided positive responses and attitudes towards its acceptance and were motivated to use technology for learning. Similar results were revealed in online-based learning with extrinsic motivation, predicting performance achievement in indirect successful learning via mAR learning strategies (Zhang et al., 2015). This leads to the conclusion that extrinsic motivation can transform work into pleasure.

The results of the experiments also showed that the mAR method was linked to extrinsic motivation as it enhanced the learning performance of students in their educational activities. mAR is mainly related to real-world contexts with technological learning resources being readily accessible. The results can be attributed to the spatial and temporal continuity principles of the Theory of Multimedia Design, as derived by Mayer and Fiorella (2014) and Mayer (2014). The theory suggests that scenario-based learning presents important materials in the form of images, texts and videos in a well-coordinated and organised way. This could improve motivation and learning performance.

When learning with mAR, the students learn from the scenarios that present the real-world targets and the supplementary digital materials in an integrated and organised way. In contrast, the real-world targets and supplementary materials are used separately in a disorganised way in traditional mobile learning methods. Students observing real-world targets are required to relate the materials provided by the mobile device or printed draft and attempt to organise the information on their own. This hinders the target of a clear view of learning and high-order thinking. Such conditions affect students' motivation levels and as such, it can be stated that external factors do impact the extrinsic motivation in the learning environment and context.

9.2.2 Motivation Levels in Learning Outcomes/Affective Learning Outcomes Using Mobile AR-based Technology

Referring to the data analyses, the motivation level of the students indicated considerable differences in learning through the use of mAR. Although the results revealed significantly higher scores for both perceived learning effectiveness and self-efficacy, there was no statistically significant difference in the mean scores of satisfaction among students using the mAR mode.

Based on the results, mAR is effective in motivating the affective behaviour of the students, their motivation levels and their perception of their learning experience. The greater the perception of learning effectiveness, the more mAR is considered as an educational tool that improves learning (making it interesting and motivating). mAR technology assists students in understanding the fundamental concepts of the learning material, identifying the core learning issue, as well as making conclusions and generalisations. In addition, students find that learning activities using mAR are meaningful, and the learning experience is interesting. These learning perceptions are crucial to achieving positive learning outcomes.

The implications of these findings are that mAR supports the affective learning in formal and informal learning. It provides a strategic learning method for the students. With a presence of high fidelity and immediacy of control, it builds the student's self-esteem by quickly grasping the subject learned. It is important to realise that learning with mAR has been verified by an improved cognitive progress, as seen in previous studies (Chin et al., 2016; de Freitas & Levene, 2004; Delanghe, 2001; Green & Bavelier, 2003). Indeed, the solution content was also delivered efficiently with mAR. Certainly, the findings have also alleviated and improved the issue of memory decline in learning in previous literature (Ganguly, 2010; Whelan et al., 2015). With the affirmative factors above, they have contributed in obtaining the results of learning effectiveness, self-efficacy and satisfaction.

9.2.2.1 Perceived Learning Effectiveness

Perceived learning effectiveness, as a determinant, was confirmed by the strong relationship between perceived ease of use, the perception of use and behavioural intention. The results show the level to which the students are convinced that mAR technology use will be free of effort in the learning context. The 'Strongly Agree' response was ticked in items including "*using mAR enhances my effectiveness in understanding the topic*", "*mAR makes it easier and understandable to do my lab work*", and "*mAR is a useful learning tool*" (Appendix C, Section B). The result showed that perceived ease of use not only measured the present intentions towards technology use, but the prediction of future intention for such use as well. The latter is valuable to management as it assists them in comprehending the acceptance of the use of technology in future years.

In addition, the items, "*it was easy for me to become skilful in my course using mAR*", "*mAR can assist learning performance*" and "*mAR can assist learning efficiency*" (Appendix C, Section B) obtained a high score in their representation of perception of use. mAR enables users to consider the potential of using technology in classrooms, where students can learn Science, Human Anatomy, Geography or Astronomy through their interactions with the content, as opposed to just reading the textbook (Bressler & Bodzin, 2013; FitzGerald et al., 2012; Fleck & Simon, 2013; Schall et al., 2013). Following the experiments, an indirect significant perception of use was found to be the highest contributor to perceived learning effectiveness.

Moreover, according to the findings, the positive behaviours of students can considerably influence their level of motivation and their behavioural intention towards learning. It can, therefore, be concluded that learning through mAR increases a student's confidence level in learning. According to the survey results, items such as, "*I intend to use mAR to assist my learning*" and "*I intend to use mAR content to assist my learning*" obtained a standard deviation higher than 0.8, indicating that perceived ease of use and perception of use are significant predictors of behavioural intention of students towards mAR use.

As stated in previous studies (Albrecht et al., 2013; Chiang et al., 2014; Juan et al., 2014), using different establishing metrics i.e. perceived usefulness, the perception of use and interactive learning, the perceived learning effectiveness variable is constructed. These metrics proves that mAR supports the speed of learning and improves the cognitive progress of the students in their learning. This is also supported by numerous studies, which state that because of perceived learning effectiveness, students can increase their cognitive and learning abilities, such as comprehension, memory and imagination (Chin et al., 2016; de Freitas & Levene, 2004; Delanghe, 2001; Green & Bavelier, 2003; Tillon et al., 2011).

9.2.2.2 Self-Efficacy

A significant result was revealed between the level of student motivation and self-efficacy, where self-efficacy is considered to be the perceived capability of individuals to perform the required tasks and to realise learning goals (Bandura, 1997). The self-efficacy of individual influences his task choices, task performance level and the amount of effort he expends into the performance of tasks, as well as his perseverance in performing it (Bandura, 1997). In the experiment, students were given tasks, in which they were requested to match and provide a description of the disarticulated lower limb bones consisting of the pelvis, femur, tibia, fibula, tarsus, metatarsals and phalanges.

Using HumAR to assist learning, students provided positive responses in the survey form (Appendix C, Section C). The positive feedback obtained from these responses can be aligned with the feedback concerning learning using mAR and its positive influence on the student's capability of completing tasks, as well as the increase in motivation level. The items that received the positive feedbacks, are as follows: "*I think HumAR is very useful for students nowadays, who use technology, so I suggest to expose students to this application as it is useful and through it memorization is easier*", "*Overall this is a good effort given by authority to enhance/ improve the students' understanding, hopefully, it can be expanded to other subjects such as biochemical, microbiology, parasitology, reproduction and genetics", "HumAR is highly recommended to all Human Anatomy students as it can help them in understanding Human Anatomy faster and easier" and "I really enjoy using this application*". These items were supported by the strongest agreement including, "*I feel confident using the mAR system", "I feel confident operating mAR functions"* and "*I feel confident using mAR learning contents*". In summary, each of the items under self-efficacy construct obtained a satisfactory agreement score.

9.2.2.3 Satisfaction

Satisfaction in this research refers to the critical measure of the success and effectiveness of the information system. It is described as the level to which an individual believes that an experience brings about positive feelings (Chen & Chen, 2010). Prior studies dedicated to AR and mobile services are of the consensus of the significance of the quality constructs in mAR use. With regards to system quality, Wang and Chen (2011) examined the perception among consumers towards mobile services and revealed that the system quality significantly and directly influences satisfaction and intention to use. They found out that because the cost constraint and poor performance quality of the resolution device influenced the insignificant differences in satisfaction. In a related study, Alam and Shahi (2015) described, as satisfaction is related to emotions and feelings in the environment, it significantly impacts the personal, social and work lives of the respondents, which in turn influences their behaviour and motivation levels, which in the end leads to failure.

Consistent with the above research, are the studies conducted by Delone and McLean (2003) and Ocker and Yaverbaum (1999), where they stated that system quality, output information quality, intention to use, as well as user response, in light of satisfaction, have an influence on the individual's behaviour and motivation level. Finally, several prior studies, for example, Chiang et al. (2014), Chu et al. (2010) and Di Serio et al. (2013) indicated that effective learning strategies and supplemented learning technology can significantly improve the motivation of the student. Students' motivation is one of the most important factors in determining the success of a teaching and learning process and the application of technology, like mAR in the classroom, can assist students to stay motivated for a long period.

9.3 Interaction Effects

The next subsections address the interaction effects between student's motivation and the learning mode, which are related to performance achievement (cognitive learning outcomes) and learning outcomes (affective learning outcomes).

9.3.1 Interaction Effect of Student's Motivation Levels and Learning Modes on Performance Achievement/ Cognitive Learning Outcomes

The findings revealed an absence of significant interaction at the level of student's motivation in both learning modes and performance achievement. The negative interaction effect was examined through the independent variables: (i) high and poor motivation levels and (ii) learning modes (mAR mode and non-mAR mode), while the dependent variable is performance achievement. It was found that the influence of the learning mode does not depend on the level of motivation (high or poor). Every factor was independent of the effects of each other, in terms of the performance effect. Regardless of the evidence showing that the students who are highly motivated in the mAR mode obtained higher scores in the post-test, in comparison to their poorly motivated CLM counterparts, the results only confirmed a main positive effect, with no mention of the interaction effect between the motivation level and learning modes on performance achievement. This main positive effect was discussed in Section 9.2.1.

9.3.2 Interaction Effect of Student's Motivation Level and Learning Modes on Learning Outcomes/ Affective Learning Outcomes

This research focuses on the learning outcomes since no significant interaction was found between the motivation level and learning modes on affective learning outcomes (perceived learning effectiveness, self-efficacy and satisfaction). This shows that the learning mode effects on learning outcomes were not dependent on the level of motivation of the student. Nevertheless, between the two learning modes, the mAR learning mode was found to have a significant composition of highly motivated students, as evidenced and measured through their learning outcomes. The justification for better affective learning outcomes amongst the students under the mAR mode is discussed in Section 9.2.2.

9.4 Theoretical Model for Evaluating How mAR Enhances Learning/ Model Discussion

This research investigates the way mAR improves the learning outcomes of students, through the identification of relevant constructs i.e. motivation, mAR features, perceived learning effectiveness, self-efficacy and satisfaction, and the causal relationships that influence the learning process and outcomes. The constructs are then analysed to determine whether they significantly precede both constructs in a way that they meet the model fit.

Until this part of the research, a robust maximum likelihood approach was employed for the determination of the goodness-of-fit indices between the data and specified model with the latent variables. According to the goodness-of-fit indices, the model achieved a good fit to the data, based on the recommended value. A structural equation was employed to estimate the final model's facilitation of the perception of the mAR learning environment.

9.4.1 Causal Path

The model also includes an interaction latent variable, where the positive result supports the causal path from the mAR features to learning outcomes, although no relationship was found from the mAR features to motivation, and from motivation to learning outcomes. This section discusses the results in detail.

9.4.1.1 mAR Features

On the basis of the results, mAR features directly and significantly antecede the learning outcomes, a finding that was reported and justified on the premise that mobile learning with technology can improve learning outcomes. Therefore, the hypothesis was rejected. Baran (2014) highlights the unpleasant of learning with mobile technologies from prior authors and attributes them to the challenges that teachers face when adopting mobile technologies, the pressure to provide students with technology and the needs of a technology education program (Newhouse et al., 2006; Sansone, 2014; Schuck et al., 2013).

Despite the above, some studies reported positive results (Catenazzi & Sommaruga, 2013; Chiang et al., 2014; Fuxin, 2012) (Section 7.2.4), where the authors revealed that mobile learning with AR technology could lead to enhanced learning, and it can be used by both students and instructors. In this study, it is evident that mAR is successful in the cognitive and affective learning environments. In this case, mAR also revamps a new look for the current learning method, to the extent it avoids dullness and hinders rote learning from occurring in the classroom. Technology entices human beings and so does this method of learning in the 21st century, through the application of mAR. As noted, up until this point in the discussion, the result of this research shows that mAR features significantly influence learning outcomes, where the results show it to be an antecedent factor in the latent interaction relationship. This positive relationship is supported by perceived learning effectiveness, self-efficacy and satisfaction.

On the other hand, the results can also be attributed to the perceived enjoyment experienced by students in the mAR-based learning environment. The responses gathered from the questionnaire survey revealed that students appear to enjoy mAR-based learning, especially with regards to its ability in providing 3D realistic images, image smoothness, 360^{o} view, the manipulation of the object and the improvement of real-time understanding. In the mAR learning environment, the features function to satisfy two fundamental demands for seemingly realistic pattern simulations. Firstly, the portable device, along with the multimedia elements, makes mAR an optimum choice in different learning environments. Secondly, mAR features enable reality to be augmented and adapted to learning situations. Therefore, it becomes possible to introduce realistic elements into the learning setting, like the details of the physical human bones (articulated or disarticulated). With the combination of reality and virtual display in real time, the learning environment is made exciting and hence, it provides a new learning experience for the students. Such an approach aims to motivate students to be the objects in their learning process, enabling them to identify the human anatomy positions in its entirety.

In relation to this, a new experience can also be attributed to the explanation that mAR features were found to impact significantly perceived enjoyment and in turn, contribute to the perceived usefulness, ease of use and behavioural intention. This result is consistent and supported by (Lee et al., 2015). The facilitated fun in learning affects both students' mood and their ability to learn, in light of cognitive learning (Section 7.2.4.1). Learning with the help of mAR eventually minimises the pressure among the students to learn, as learning and exploration occur at the same time. In this context, students are interested in participating in learning the subject's content at hand and getting involved in their own learning process, in an environment that is characterised by mixed reality. These findings support what other researchers have argued in terms of immersing participation in mixed reality environments such as AR and mAR (Di Serio et al., 2013). Moreover, the results also proved prior research claim of uncertainties concerning the emotions and cognitive effects, in light of learning through mAR technology. Refers to Albrecht et al. (2013) there are doubts in emotional and cognitive effects in a study using mAR. This has had a profound impact on the recipient. Hence, this is combined with a personal experience in a simulated context.

mAR is capable of mobilising the learning environment notwithstanding the location and timing, and it is flexible as it can be based on the needs of students (Bujak et al., 2013; Kamphuis et al., 2014). In relation to the results of this research, the mobility of mAR and its multimodal interface give the students the option of clicking and viewing the application as required. In summary, this self-centred method of learning can support the student in keeping well-informed with the subject both formally and informally. In relation to this, the mAR learning tool also enables educators to develop innovative teaching curricula that entail a deep understanding of complex objects.

Besides that, in a recent study, Leue et al. (2014) state that the information content impacts the user to accept the AR applications and contend that AR adopters look for robust and high-quality information that is relevant in their context. With regards to the satisfaction of the learning outcome, the student interface and intention to use were considered. Owing to the sufficient subject matter content provided, HumAR makes it easier for students to learn, particularly when preparing themselves for a lecture, during the lecture or lab session. Among the many benefits of the HumAR prototype application is its facilitation of an experience that adapts to the real environment, and such an aspect is important to the context of the users. In other words, the customised content is organised and made consistent with the introductory curriculum of Human Anatomy.

Additionally, creating a mobile user interface that reflects a user's experience is among many other challenges to be faced and overcome, especially in terms of natural interaction characterised as having augmented entities. The causal path of mAR features to the learning outcomes can also be attributed to mAR-based learning, as a cognitive tool with a 3D interactive feature that assists in students' understanding, development of new knowledge, making generalisations and reaching the conclusions of the lessons. Also, it provides students with a holistic learning experience.

Students want to be in control of their learning process (Lee, 2011), as such control entails the personal interaction and manipulation of objects in the learning environment that builds the student's self-esteem and self-efficacy. This explanation can be related to the survey items (Appendix C, Section F) that achieved a great degree of agreement from the students. These include "*The ability to manipulate objects (rotate, scale move) within the virtual environment makes learning more motivating and interesting*", "*The ability to change the view in position of the 3D objects in HumAR computer application allows me to learn better*" and "*The ability to manipulate the objects in real time helps to enhance my understanding*". Being able to control and have ownership on a particular matter contributes to a high level of gratification in learning in the long term. Also, mAR has shifted the location and timing of education, and the described mAR features make learning strategies easily manageable (Bujak et al., 2013; Kamphuis et al., 2014; Kucuk et al., 2016), which improved the learning curve to learn faster and easier with mAR. Also, it improves the content understanding and acquires better level of spatial abilities (Diegmann et al., 2015).

This research examined the relationship between mAR features and motivation. The results show no significant relationship between these two predictors. This means that unmotivated students can still increase their affective learning outcomes and that mAR features are independent of the motivation of students in the learning environment.

9.4.1.2 Motivation

In contrast, the results show that motivation is not an antecedent relationship to the learning outcomes, although there is a direct effect of motivation on affective (Section 7.2.4.3) and cognitive learning outcomes (Section 7.2.4.4). Based on the results, it was found that motivation is not the most significant predictor of affective learning outcomes, although the mAR learning mode reported higher motivation levels. It can be concluded that motivation is an independent and important aspect of affecting learning outcomes, as revealed by Briggs (1984) and Gabrielle (2016), but rejected by Martin and Briggs (1986) and Tennyson (1992). Keller (2010) motivation theory is also rejected by the findings. The negative antecedent can be attributed to the direction and magnitude of behaviour in terms of people's goals, how they pursue them and how they can focus on achieving such goals (Keller, 2010). One of the possible explanations of the negative relationship is also based on the influence of the environment on sensory simulation, as illustrated by ARCS motivation theory and concepts. The environmental characteristics are divided into three, namely attention, relevance and confidence. These three psychological characteristics have an impact on motivation, learning, performance and attitudes.

As for the condition of acceptance of the ARCS model, satisfaction is considered the actual outcome in the environmental characteristics of the individuals. The result of technology integration, in relation to intrinsic and extrinsic aspects, is reflected in the performance and learning outcomes. This shows that feelings and attitudes are dependent on the negative and positive experience of what has been received (Keller, 2010). Meanwhile, motivation was also affected by the level of how the learning materials are presented. Furthermore, the device challenges the user's confidence and may make the user unmotivated. Based on the theory, a relationship exists between satisfaction and attention. Based on the positive mAR experience, this would influence the behaviour and perceptions towards the learning outcomes. A contradicting result was reported in terms of model indices, where it was found that the motivation factor did not influence learning outcomes.

9.5 Moderating Effects – Student's Characteristics (Age and Experience)

In general, technology use has a positive impact on the student's learning environment and the promotion of the interest to learn. Aside from examining the effects of mAR technology on the learning environment in light of the main effects, interaction effects, direct effects, and antecedent relationship, the moderating effects of age and experience in mAR adoption (in the context of learning environment), was also tested. The effects of these two variables on the independent and dependent variables were examined and according to the results, both age and experience do not moderate the effect of mAR features, motivation and learning outcomes.

Furthermore, it was revealed that the experience of the students in learning Human Anatomy did not affect a feature of mAR, motivation and learning outcomes. Generally, irrespective of prior experience and performance, the learning outcomes were not affected. This negative result states that experience does not ensure the usability and its relationship to the perception level and technology adoption. However, this result contrasts with the educational technology studies that were conducted (Lin, 2011; Luo & Peng, 1999), which revealed that experience plays a moderating role in the influence on students' performance achievement. The experience positively moderated the performance achievement because of the cumulative result of perceive ease of use and continuance intention on the attitude. On the other hand, this research shows experience does not influence the strength of the relationship between mAR features, motivation and the learning outcomes. The students are not particularly affected by with conditions that affect the relationship between mAR features, motivation and learning outcomes. For example, no experience students in human anatomy knowledge increase the failure rate in the performance for students with poor motivation level but the performance is not related to the failure rate for students who have poor motivation level and inexperience in the subject matter. Additionally, the experience does not change the direction of the relationship between mAR features, motivation and learning outcomes.

Similarly, for age, no moderating effect was found in the comparison between mAR features, as well as motivation and learning outcomes, indicating that age differences did not discourage students from learning and understanding the subject matter through mAR. Other studies are also in support of this result (Anthony et al., 2014; Tarhini et al., 2014). Although a significant negative impact was found in this research for age and experience, the learning mode did matter, particularly when students were learning through mAR-based systems. Such systems improve learning more than the CLM-based systems (Section 7.2.4.2), as illustrated in several studies (Albrecht et al., 2013; Luley et al., 2012; Nincarean et al., 2013).

9.6 Conclusions

9.6.1 Summary of the Research and Contributions

The main aim of this research to investigate the effectiveness of mAR in influencing the learning outcomes, performance achievement of students, and in improving the motivation of the students in the learning process, thus in improving the retention of memory.

Firstly, this research investigated the effectiveness of mAR in the learning environment, in comparison to the current learning mode, in the context of a laboratory session. It also examined the main impact and interactions that influence the cognitive outcomes on performance achievement, as well as the affective learning outcomes, specifically perceived learning effectiveness, satisfaction and self-efficacy. In order to study such factors in a tangible manner, a prototype application, using a multimodal concept called HumAR, was developed. The prototype illustrates the human skeletal system, specifically the lower limb, which includes the pelvis, femur, fibula, tibia, tarsals, metatarsals and phalanges, in a class curriculum. HumAR was tested and validated with three alternative pilot tests, as well as expert reviews from the academic, technology and user fields before the actual data collection phase. HumAR was employed to reinforce the data collection phase, in light of the understanding of students who used mAR technology.

Secondly, this research extended to the development stage of a theoretical model to evaluate the ability of mAR in improving the learning outcomes that guide a further consideration of growth in learning. The research centred on the development of the theoretical model of determinants for effective mAR-based learning and to understand how mAR is capable of enhancing and improving the quality of student learning, and also the characteristics of students that would profit from this technology. The model provides an insight into the relationship among important determinants that work together to shape learning in an mAR-based learning environment. A model of the VLE was adopted as a platform to build an initial model for the mAR-based learning environment. Through this research, the model has been developed and evaluated. The findings confirm that mobile AR technology could be leveraged upon and used as an optimum learning tool, exemplifying the use of technology in an educational context. With regards to the model outcome through the goodness-of-fit analysis, all the results confirmed to be appropriate and good fit. The results also show a positive causal path from the mAR features determinant, in the area of information retention and enhanced learning outcomes. With regards to the moderating effects of student characteristics (age and experience) on the structural path towards mAR features, motivation and learning outcomes were examined. After which, it was found that both age and experience did not moderate the path. Therefore, both were deemed not to influence the learning outcomes, motivation and mAR learning model. Overall, the value of the moderating determinants was accepted by the results.

Thus, the present research findings contribute to the understanding of cognitive and affective learning that result in a classroom, student or self-centred learning, where the latter takes place in mAR-based learning environments. The findings establish that mAR-technology enhances learning effectiveness and improves the learning environment, performance achievement and learning outcomes. Mobile AR technology also gives the students a chance to have facilitated access to the subject matter and mobilises the learning environment anytime (Bujak et al., 2013; Kamphuis et al., 2014). This enables learning flexibility, particularly as this is needed in higher education. Additional, mobile learning using mAR offers convenience and brings the learning environment to the students, and this is important in learning complex subject matters like the human skeletal system. Learning with mAR, brings impact to the state of mind, especially to increase concentration, attention and motivation. The HumAR's convenient features assist in the retention of knowledge as the topic can frequently be revised. Students do not have to be confined to learning and reviewing the physical human skeletal system based on laboratory availability. mAR facilitates the understanding of students by supporting abstract ideas during the courses and enables students to learn in a limited period. Therefore, the present research findings contribute to the literature and are dedicated to the issue of the effectiveness of mAR application, in the context of the learning environment.

The findings in this research offer empirical evidence on the advantages of mAR as an appropriate learning tool that enhances student motivation. Moreover, the studies reviewed in the literature show a paucity of systematic studies concerning university students learning and training through mAR. The research shows that mAR accommodates individual differences and the interaction effects of students with high or poor motivation learning levels. The manner in which individuals interact with different learning environments are explained, and such information may assist instructors in identifying self-centred treatments that can accommodate individual learning.

Additionally, the research findings can also assist educational administrators and educational policy makers in gauging the importance of mAR as a learning tool. This helps mainly to overcome the issue of educators being criticised for lack of real-life experience that is being exposed to students at the university level. Furthermore, academia can use the model's findings as appropriate groundwork to initiate other related studies, and this will help to fill the gap in the mAR learning area.

9.6.2 Research Constraints

Similar to other research, owing to specific limitations, the generalisation of the findings is restricted.

- The first limitation pertains to the study sample consisting of just undergraduate university students and with regards to the subject, the anatomy of the lower limb. The obtained results are mainly dependent on the Human Anatomy learning setting. Consequently, in this case, different learning contexts may lead to varying perceptions, behaviours and effects.
- The second limitation is that of the samples, which were confined to the context of Malaysia. For research, different cultural backgrounds of subjects (i.e. students) could impact the way they practise and perceive learning with the help of technology (Tarhini et al., 2015).
- The third limitation pertaining to the HumAR application prototype is related to the Android mobile Operating System (OS). The application can only be used by Android users. Moreover, the application has not been made available on the online Android store.
- The fourth limitation is related to the low-cost tablets prepared for data collection. The low-performance hardware devices lead to a sense of dissatisfaction with regards to mAR technology use in learning.
- The fifth limitation is that almost half of the research participants were not familiar with or used mAR before. Therefore, this novel technology may create a sense of fresh

enjoyment that could influence the students' perception of the factors evaluated in this survey.

9.6.3 Recommendations for Future Research

The research presented has significantly advanced the knowledge of the educational technology environment in cognitive and affective learning outcomes in higher education. The findings contribute to the understanding of the learning outcomes of the mAR-based learning environment and the merit of using mAR for learning. The findings imply that mAR enhances the learning materials and improves the retention of memory after the laboratory session. Also, mAR maximises the benefits of the self-centred approach in the learning process. Nevertheless, due to limited time and funds, there are some concerns (that may not fall within the scope of this research) which could impact this research. Within this final section of this research, several recommendations that are considered to be worthy of future research are outlined as follows:

- The first recommendation pertains to the study length, where a prolonged study of learning through mAR technology could be invaluable as the impact of such technology on student learning may accumulate over time. This research recommends that the post-test should be delayed to measure the retention rate as compared to the current learning method. Furthermore, investigating students in mAR-based learning over a few semesters or years might reduce the innovation effect amongst the students.
- Second, a replication of this research is recommended with students from different cultural backgrounds, in order to study the effect of cultural differences on the behavioural intention to use mAR-based learning in an accurate manner, to enable a possible generalisation of the findings.
- Third, the technology can also be tested on subjects other than Science and Human Anatomy. This is where future work can be expanded to other disciplines of knowledge or other learning programs. This extension may unearth more mAR technology benefits and new experiences in the learning environment.
- The last recommendation relates to the examination of the effect of mAR on individual students, as opposed to a collective group of students. This is particularly important

in a research where the influence of mAR is examined independently, assisting individual students in tackling their right and suitable preferences in learning.

In conclusion, this research has achieved a significant contribution by bringing mAR to one step closer to understanding the merit of it in higher education. This research has met the aims; investigate the effectiveness of mAR in influencing the learning outcomes and the performance achievements of students; and, in improving the motivation of the students in the learning process. This research has advanced to the development stage of a theoretical model, to evaluate the ability of mAR in improving the learning outcomes that guide a further growth in learning.

These research findings contribute to the mAR literature on how to enhance the cognitive ability, affective learning outcomes and are dedicated to the issue of the effectiveness of mAR application in the context of a learning environment. Furthermore, academia can use the model's findings as appropriate groundwork to initiate other related studies, and this will help to fill the gap in the mAR learning area.

APPENDICES

Appendix A: Pre/ Post-Test Quiz

(Pilot and Actual Study)

Respondent no. [ ][ ][ ]

Pre-Test Quiz

- Lower Limb -

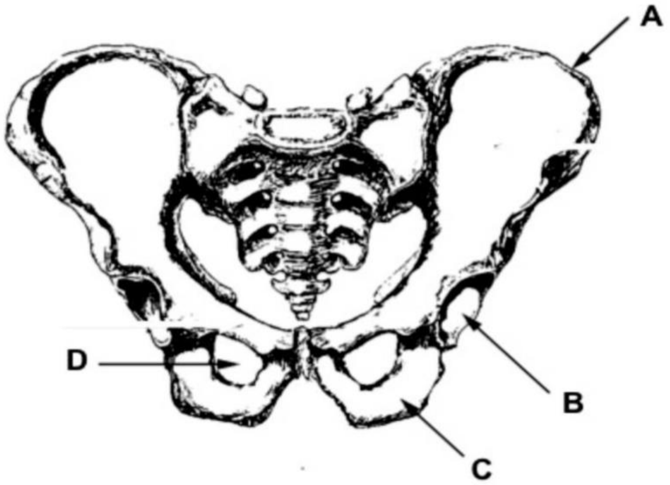
Note : Lower limb is subdivided by the hip joint, knee joint, and ankle joint into the regions: hip, thigh, leg and foot.

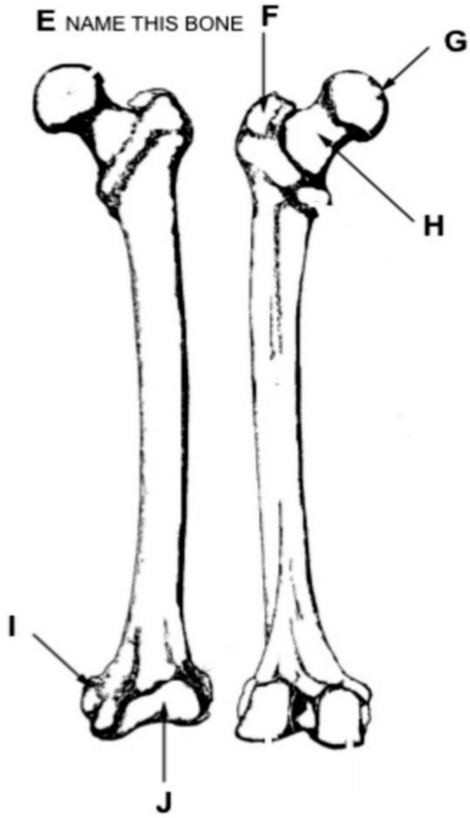
Part A

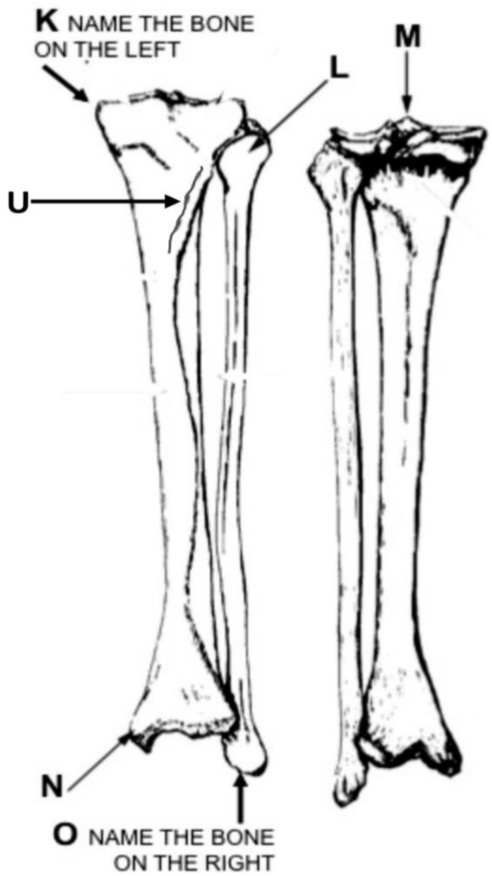
*Kindly refer to question on the next page. Please write **ONLY ONE** answer in the column label provided.*

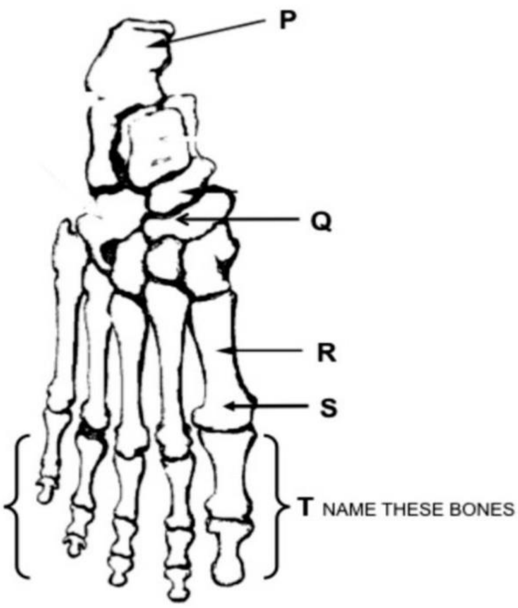
Label	Bone Part
	Iliac Crest
	Acetabulum
	Ischial Tuberosity
	Obturator Foramen
	Femur
	Fovea
	Greater Trochanter
	Femoral Neck
	Medial Epicondyle
	Trochlea
	Tibia
	Head Of Fibula
	Intercondylar Eminence
	Medial Malleolus
	Fibula
	Calcaneous
	Navicular
	Metatarsal Shaft
	Metatarsal Distal Head
	Phalanges
	Soleal Line

Please write ***ONLY ONE*** *answer in the column label provided.*









Pre-Test Quiz

- Lower Limb -

Part B

Please choose only ***ONE ANSWER*** *from each of the multiple choice questions below:-*

1. Pubis is
   a. the anteroinferior part of the bone that approaches the opposite os coxae at the midline
   b. marks the point of union of the ilium and the pubis just lateral to the arcuate line
   c. wide notch just inferior to the posterior inferior iliac spine
   d. the posterior terminus of the iliac crest

2. __________ for attachment of the sacrospinous ligament, is located just inferior to the greater sciatic notch.
   a. Ischium
   b. Arcuate line
   c. Retroauricular surface
   d. Ischial spine

3. What is the purpose of femoral neck is to
   a. elevate ridge that runs along the posterior shaft surface
   b. connects the head with the shaft
   c. excavate space between the distal and posterior articular surfaces of the condyles
   d. centre of the head of the femur

4. Shaft of the femur also known as
   a. Capitis
   b. Aspera
   c. Diaphysis
   d. Distal femur

5. At the ankle joint, the tibia and fibula articulate with the
   a. Cuboid
   b. Calcaneus
   c. Talus
   d. Cuneiform

6. Styloid process is
   a. the most proximal projection of bone, forming the posterior part of the head.
   b. located just posterior to the distal articular surface.
   c. the long, fairly straight segment of bone between the expanded proximal and distal ends.
   d. the inferior most projection of the fibula.

7. ___________ is the proximal tibial surface on which the femur rests.
   a. medial condyle
   b. tibial plateau
   c. fibular notch
   d. facet for fibula

8. All the following pass through the metatarsals **EXCEPT**
   a. Metatarsal base - proximal end of the metatarsal, articulates with either cuboid or cuneiforms
   b. Metatarsal shaft (diaphysis) - is the concave section of bone between the proximal base and distal head
   c. Metatarsal head - the distal end of the metatarsal, articulates with the proximal phalanx
   d. Metatarsal navicular - has a strong, concave proximal surface that articulates with the head of the talus and articulates anteriorly (distally) with the cuneiforms

9. "Is the saddle-shaped articular surface of the body. Its sides are the medial and lateral malleolar surfaces, which articulate with the tibia and fibula respectively."

   Statement above refers to
   a. calcaneus
   b. trochlea
   c. sustentaculum tali
   d. phalanx

10. ___________ has the second largest of the tarsals and is situated between the tibia and fibula superiorly and the calcaneus inferiorly.
    a. Talus
    b. Cuboid
    c. Cuneiforms
    d. Navicular

11. Which of the following statement is **TRUE** about tibial tuberosity?
    a. Prominent tuberosity protruding from the cranial aspect of the proximal end of the tibia onto which the patellar ligament inserts
    b. The long, fairly straight segment of bone between the expanded proximal and distal ends
    c. The distolateral corner of the tibia. It is a triangular non-articular area
    d. The raised area on the proximal tibial surface between articular facets (condyles)

~ end of session, thank you ~

Appendix B: Survey Questionnaire – CLM

(Actual Study/Pilot Study)

Current Learning Method (CLM)

Murdoch UNIVERSITY

Respondent no. ☐☐☐

SURVEY FORM

.: An investigation into the effectiveness of learning using Conventional Learning Method (CLM) :.

SECTION A. General Background Information

*This section is to gather your background information. Unless specified in the question, please select and tick (√) **only ONE appropriate answer** for each of the following questions.*

1. Age : __________years old

2. Education : Subject : ____________________
   Faculty : ____________________
   University : ____________________

3. Gender : ☐ Male ☐ Female

4. Do you have a smart phone? *(Note: smart phone is a device that lets you make telephone calls, with extra features that you might find on a personal digital assistant or computer such as send and receive e-mail or edit Office documents or other apps).*

   ☐ Yes, *please state brand / type* : ____________________

   ☐ No

5. Which device do you usually use to get information? *(Note: A tablet is a portable personal computer with a touch screen interface, equipped with camera, microphone and sensor. The tablet form is typically smaller than a notebook computer, but larger than a smartphone).*

   ☐ Smart phone ☐ Tablet ☐ Smartphone & Tablet

6. How often do you attend classes at college/university in a week?
   ☐ Always ☐ Frequently ☐ Sometimes ☐ Seldom ☐ Never

7. Have you previously studied the Human Anatomy unit in Biology?
   ☐ Yes, please state when and what year : ____________________
   ☐ No

8. Which medium do you use **THE MOST** to acquire information about the Human Anatomy unit?
   ☐ Museum ☐ Lab ☐ Textbook
   ☐ Reference book ☐ Desktop computer ☐ Laptop
   ☐ Smartphone ☐ Tablet

Murdoch UNIVERSITY

Respondent no. ☐☐☐

SURVEY FORM

.: An investigation into the effectiveness of learning using Conventional Learning Method (CLM) :.

SECTION B. Perceived Learning Effectiveness

*This section relates to your perception on learning with this type of Conventional Learning Method (CLM) for learning environment. Please tick (√) **only ONE box** that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

1	The use of CLM increases my memory of the subject.	1	2	3	4	5
2	By using CLM my effectiveness towards understanding the topic is enhanced.	1	2	3	4	5
3	CLM makes it easier and more understandable to do my lab work.	1	2	3	4	5
4	The CLM contents are informative.	1	2	3	4	5
5	The CLM is a useful learning tool.	1	2	3	4	5
6	The CLM contents are useful.	1	2	3	4	5
7	Learning from the CLM was easy for me.	1	2	3	4	5
8	I found the CLM flexible to interact with.	1	2	3	4	5
9	It was easy for me to become skillful in my unit using CLM.	1	2	3	4	5
10	I found the CLM easy to use.	1	2	3	4	5
11	CLM can assist my learning efficiency.	1	2	3	4	5
12	CLM can assist my learning performance.	1	2	3	4	5
13	CLM can assist my motivation to learn.	1	2	3	4	5
14	I would like to share my CLM experience with others.	1	2	3	4	5
15	I believe CLM can assist student-learner interaction.	1	2	3	4	5
16	I intend to use CLM to assist my learning.	1	2	3	4	5
17	I intend to use CLM as an independent learning tool.	1	2	3	4	5
18	I intend to use CLM on a regular basis in the future.	1	2	3	4	5

SURVEY FORM

.: An investigation into the effectiveness of learning using Conventional Learning Method (CLM) :.

SECTION C. Satisfaction

This section relates to your satisfaction with the Conventional Learning Method (CLM) for learning environment. Please tick (√) ***only ONE box*** *that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

19	The CLM is effortless to use.	1	2	3	4	5
20	The CLM provides up-to-date content.	1	2	3	4	5
21	The CLM provides content that exactly fits my needs.	1	2	3	4	5
22	The CLM provides sufficient content.	1	2	3	4	5
23	The content provided by the CLM can help to achieve the learning objectives.	1	2	3	4	5
24	The CLM enables me to learn the content I need.	1	2	3	4	5
25	The CLM enables me to choose what I want to learn.	1	2	3	4	5
26	I am satisfied with the CLM functions.	1	2	3	4	5
27	I am satisfied with the CLM interaction.	1	2	3	4	5
28	The CLM enables me to control my learning progress.	1	2	3	4	5
29	Even though it is not required, I will continue to use the CLM for self-learning.	1	2	3	4	5
30	I enjoy using the CLM to learn.	1	2	3	4	5
31	I would recommend this CLM to other people.	1	2	3	4	5
32	As a whole, I am satisfied with the CLM.	1	2	3	4	5
33	As a whole, the CLM is successful.	1	2	3	4	5

SECTION D. Self efficacy

This section relates to your capabilities with Conventional Learning Method (CLM) for learning environment. Please tick (√) ***only ONE box*** *that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

34	I feel confident using the CLM.	1	2	3	4	5
35	I feel confident operating CLM functions.	1	2	3	4	5
36	I feel confident using CLM learning contents.	1	2	3	4	5
37	I believe that I can understand the difficult material presented in this unit.	1	2	3	4	5
38	I am certain that I will receive excellent grades in the unit.	1	2	3	4	5
39	I am confident I can understand the complex material presented by my lecturer in this unit.	1	2	3	4	5
40	Using the CLM, I can look for additional information whenever I do not understand something.	1	2	3	4	5
41	I understood the physical objects very well during a laboratory session.	1	2	3	4	5
42	I understand most ideas when using CLM.	1	2	3	4	5
43	I am applying prior lecture content to a laboratory session.	1	2	3	4	5
44	I can spread out my studying instead of cramming into a single session.	1	2	3	4	5
45	I understand passages in textbooks that I found previously difficult.	1	2	3	4	5
46	I am studying enough to understand content thoroughly.	1	2	3	4	5

SECTION E. Motivations

*This section relates to your learning motivation using this Conventional Learning Method (CLM) for learning environment. Please tick (√) **only ONE box** that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

47	I learn and practice the human anatomy material because I enjoy the challenge.	1	2	3	4	5
48	Learning using CLM can improve and initiate changes in the way I do everyday tasks.	1	2	3	4	5
49	I learn using CLM, as it gives me satisfaction in accomplishing my understanding.	1	2	3	4	5
50	Learning using the CLM method has a positive impact on my education.	1	2	3	4	5
51	Compared with other students in this class, I expect to do well.	1	2	3	4	5
52	I am confident I can understand the ideas taught in this unit.	1	2	3	4	5
53	I expect to do very well in this class.	1	2	3	4	5
54	Compared with others in the class, I think I'm a good student.	1	2	3	4	5
55	I am sure I can do an excellent job on the problems and tasks assigned for this class.	1	2	3	4	5
56	My study skills are excellent compared with others in this class.	1	2	3	4	5
57	I know that I will be able to learn the material for this class easily.	1	2	3	4	5

SECTION F. Features of the Conventional Learning Environment

This section relates to your perceptions about the Conventional Learning Method (CLM) for learning. Please tick (√) ***only ONE box*** *that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

58	The realism of the images in the CLM motivates me to learn.	1	2	3	4	5
59	The smooth of images in the CLM make learning more motivating and interesting.	1	2	3	4	5
60	The accuracy of the images in the CLM helps to enhance my understanding.	1	2	3	4	5
61	The ability to change the view in 360° position of the objects in the CLM allows me to learn better.	1	2	3	4	5
62	The ability to change the view position of the objects in the CLM makes learning more motivating and interesting.	1	2	3	4	5
63	The ability to manipulate the objects (eg: rotate,scale,move) within the CLM environment makes learning more motivating and interesting.	1	2	3	4	5
64	The ability to manipulate the objects in CLM helps to enhance my understanding.	1	2	3	4	5
65	The ability to see through the label of each object can improve my memory.	1	2	3	4	5
66	I prefer to use CLM as my learning tool to enhance my understanding.	1	2	3	4	5

SECTION G. Suggestions and Comments

This section relates to any improvements, recommendations or comments in terms of Conventional Learning Method (CLM) and Human Anatomy unit you think should be considered in future research. Please write in the space provided.

Any suggestion(s) / comment(s) regarding use of the Conventional Learning Method (CLM) in studying Human Anatomy.

____

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~ Thank you for your time ~

Appendix C: Survey Questionnaire – HumAR

(Actual Study/Pilot Study)

Human Anatomy with Mobile Augmented Reality (HumAR)

Murdoch UNIVERSITY

Respondent no.

SURVEY FORM

.: An investigation into the effectiveness of learning using mobile-Augmented Reality (mAR) :.

SECTION A. General Background Information

*This section is to gather your background information. Unless specified in the question, please select and tick (√) **only ONE appropriate answer** for each of the following questions.*

1. Age : __________years old

2. Education : Subject : ____________________
   Faculty : ____________________
   University : ____________________

3. Gender : ☐ Male ☐ Female

4. Do you have a smart phone? *(Note: smart phone is a device that lets you make telephone calls, with extra features that you might find on a personal digital assistant or computer, such as send and receive e-mail or edit Office documents or other apps).*

   ☐ Yes, *please state brand / type* : ____________________

   ☐ No

5. Which device do you usually use to get information? *(Note: A tablet is a portable personal computer with a touch screen interface, equipped with camera, microphone and sensor. The tablet form is typically smaller than a notebook computer, but larger than a smartphone).*

   ☐ Smart phone ☐ Tablet ☐ Smartphone & Tablet

6. How often do you attend classes at college/university in a week?

   ☐ Always ☐ Frequently ☐ Sometimes ☐ Seldom ☐ Never

7. Have you previously studied the Human Anatomy unit in Biology?

   ☐ Yes, please state when and what year : ____________________

   ☐ No

8. Which medium do you use **THE MOST** to acquire information about the Human Anatomy unit?

   ☐ Museum ☐ Lab ☐ Textbook

   ☐ Reference book ☐ Desktop computer ☐ Laptop

   ☐ Smartphone ☐ Tablet

Murdoch UNIVERSITY

SURVEY FORM

.: An investigation into the effectiveness of learning using mobile-Augmented Reality (mAR) :.

SECTION B. Perceived Learning Effectiveness

This section relates to your perception on learning with this type of prototype Human Anatomy mobile-Augmented Reality (HuMAR) application. Please tick (√) ***only ONE box*** *that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

1	The use of HuMAR increases my memory of the subject.	1	2	3	4	5
2	By using HuMAR my effectiveness towards understanding the topic is enhanced.	1	2	3	4	5
3	HuMAR makes it easier and more understandable to do my lab work.	1	2	3	4	5
4	The HuMAR contents are informative.	1	2	3	4	5
5	The HuMAR application is a useful learning tool.	1	2	3	4	5
6	The HuMAR application contents are useful.	1	2	3	4	5
7	Learning to operate the HuMAR application was easy for me.	1	2	3	4	5
8	I found the HuMAR application flexible to interact with.	1	2	3	4	5
9	It was easy for me to become skillful in my unit using HuMAR.	1	2	3	4	5
10	I found the HuMAR application easy to use.	1	2	3	4	5
11	HuMAR can assist my learning efficiency.	1	2	3	4	5
12	HuMAR can assist my learning performance.	1	2	3	4	5
13	HuMAR can assist my motivation to learn.	1	2	3	4	5
14	I would like to share my HuMAR experience with others.	1	2	3	4	5
15	I believe HuMAR can assist student-learner interaction.	1	2	3	4	5
16	I intend to use HuMAR to assist my learning.	1	2	3	4	5
17	I intend to use HuMAR as an independent learning tool.	1	2	3	4	5
18	I intend to use HuMAR on a regular basis in the future.	1	2	3	4	5

Murdoch UNIVERSITY

SURVEY FORM

.: An investigation into the effectiveness of learning using mobile-Augmented Reality (mAR) :.

SECTION C. Satisfaction

This section relates to your satisfaction with this type of prototype Human Anatomy mobile-Augmented Reality (HuHUMAR) application for learning. Please tick (√) ***only ONE box*** *that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

19	The HuMAR application is effortless to use.	1	2	3	4	5
20	The HuMAR application provides up-to-date content.	1	2	3	4	5
21	The HuMAR application provides content that exactly fits my needs.	1	2	3	4	5
22	The HuMAR application provides sufficient content.	1	2	3	4	5
23	The content provided by the HuMAR application can help to achieve the learning objectives.	1	2	3	4	5
24	The HuMAR application enables me to learn the content I need.	1	2	3	4	5
25	The HuMAR application enables me to choose what I want to learn.	1	2	3	4	5
26	I am satisfied with the HuMAR application functions.	1	2	3	4	5
27	I am satisfied with the HuMAR interaction.	1	2	3	4	5
28	The HuMAR application enables me to control my learning progress.	1	2	3	4	5
29	Even though it is not required, I will continue to use the HuMAR application for self-learning.	1	2	3	4	5
30	I enjoy using the HuMAR application to learn.	1	2	3	4	5
31	I would recommend this HuMAR application to other people.	1	2	3	4	5
32	As a whole, I am satisfied with the HuMAR application.	1	2	3	4	5
33	As a whole, the HuMAR application is successful.	1	2	3	4	5

SECTION D. Self efficacy

*This section relates to your capabilities with this type of prototype Human Anatomy mobile-Augmented Reality (HuMAR) application for learning. Please tick (√) **only ONE box** that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

34	I feel confident using the HuMAR system.	1	2	3	4	5
35	I feel confident operating HuMAR application functions.	1	2	3	4	5
36	I feel confident using HuMAR application learning contents.	1	2	3	4	5
37	I believe that I can understand the difficult material presented in this unit.	1	2	3	4	5
38	I am certain that I will receive excellent grades in the unit.	1	2	3	4	5
39	I am confident I can understand the complex material presented by my lecturer in this unit.	1	2	3	4	5
40	Using the HuMAR application, I can look for additional information whenever I do not understand something.	1	2	3	4	5
41	I understood the physical objects very well during a laboratory session.	1	2	3	4	5
42	I understand most ideas when using HuMAR.	1	2	3	4	5
43	I am applying prior lecture content to a laboratory session.	1	2	3	4	5
44	I can spread out my studying instead of cramming into a single session.	1	2	3	4	5
45	I understand passages in textbooks that I found previously difficult.	1	2	3	4	5
46	I am studying enough to understand content thoroughly.	1	2	3	4	5

SECTION E. Motivations

*This section relates to your learning motivation using this prototype Human Anatomy mobile-Augmented Reality (HuHUMAR) application. Please tick (√) **only ONE box** that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

47	I learn and practice the human anatomy material because I enjoy the challenge.	1	2	3	4	5
48	Learning using HuMAR can improve and initiate changes in the way I do everyday tasks.	1	2	3	4	5
49	I learn using HuMAR, as it gives me satisfaction in accomplishing my understanding.	1	2	3	4	5
50	Learning using the HuMAR method has a positive impact on my education and career.	1	2	3	4	5
51	Compared with other students in this class, I expect to do well.	1	2	3	4	5
52	I am confident I can understand the ideas taught in this course.	1	2	3	4	5
53	I expect to do very well in this class.	1	2	3	4	5
54	Compared with others in the class, I think I'm a good student.	1	2	3	4	5
55	I am sure I can do an excellent job on the problems and tasks assigned for this class.	1	2	3	4	5
56	My study skills are excellent compared with others in this class.	1	2	3	4	5
57	I know that I will be able to learn the material for this class easily.	1	2	3	4	5

SECTION F. Features of the mobile-Augmented Reality Learning Environment

*This section relates to your perceptions about the features of the prototype Human Anatomy mobile-Augmented Reality (HuMAR) application for learning. Please tick (√) **only ONE box** that best describes your opinion for each of the following questions according to the following graded scale.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

58	The realism of the three-dimensional (3-D) images in the HuMAR computer application motivates me to learn.	1	2	3	4	5
59	The smooth changes of images in the HuMAR computer application make learning more motivating and interesting.	1	2	3	4	5
60	The accuracy of the 3-D images in the HuMAR computer application helps to enhance my understanding.	1	2	3	4	5
61	The ability to change the view in 360° position of the 3-D objects in the HuMAR computer application allows me to learn better.	1	2	3	4	5
62	The ability to change the view position of the 3-D objects in the HuMAR computer application makes learning more motivating and interesting.	1	2	3	4	5
63	The ability to manipulate the objects (eg: rotate,scale,move) within the virtual environment makes learning more motivating and interesting.	1	2	3	4	5
64	The ability to manipulate the objects in real time helps to enhance my understanding.	1	2	3	4	5
65	The ability to see through the label of each object can improve my memory.	1	2	3	4	5
66	I prefer to use prototype HuMAR application as my learning tool to enhance my understanding.	1	2	3	4	5

SECTION G. Suggestions and Comments

This section relates to any improvements, recommendations or comments in terms of prototype Human Anatomy mobile-Augmented Reality (HuMAR) application and Human Anatomy unit you think should be considered in future research. Please write in the space provided.

Any suggestion(s) / comment(s) regarding use of the HuMAR application in studying Human Anatomy.

____

____

____

____

____

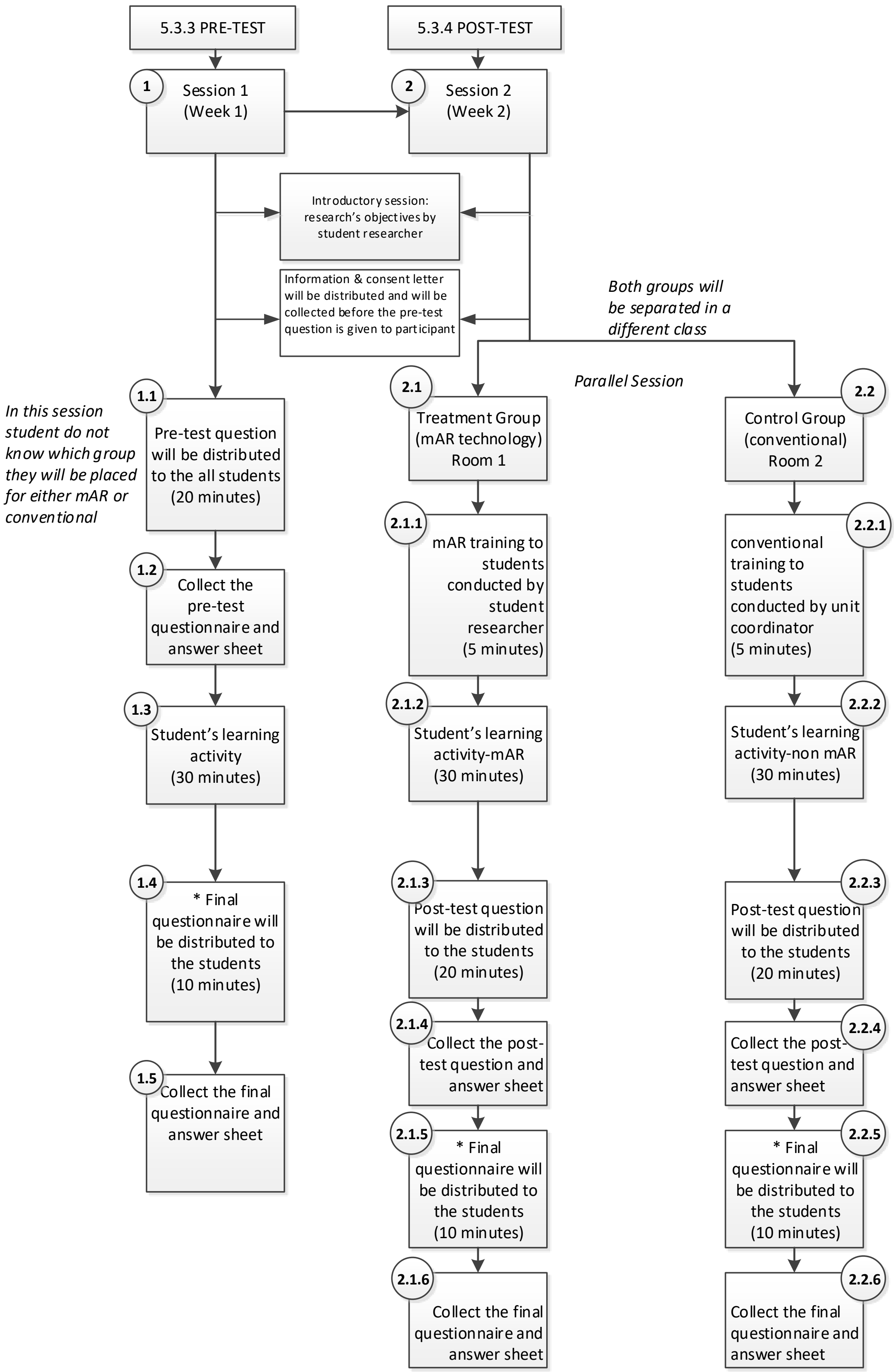
____

~ Thank you for your time ~

Appendix D: Procedure of Data Collection

(Actual Study/Pilot Study)

Data Collection Procedure



Appendix E: Information Letter

Information Letter

www.murdoch.edu.au

An Investigation of the Effectiveness of Learning Using mobile-Augmented Reality (mAR)

Dear Participant,

We invite you to participate in a research looking at the effectiveness of learning using mobile-Augmented Reality (mAR) that can help your understanding on the Human Body Anatomy topic using the mobile-Augmented Reality (mAR) learning environment.

mAR is a technology that augments reality with either two or three-dimensional computer generated images (CGI), objects and/users' information. mAR application is implemented on mobile.

This research is part of my Doctor of Philosophy (PhD) in Information Technology, supervised by Dr. Mohd Fairuz Shiratuddin, Associate Professor Dr. Kevin Wong and Dr. Charlotte Oskam at Murdoch University.

Nature and Purpose of the Research
The main aim of this research is to investigate the effectiveness of using mobile-Augmented Reality (mAR) in learning. In order to achieve the main aim, the objectives are to investigate:

- The significant differences in the learning outcomes between mobile-AR-based learning (mAR mode) and the conventional classroom learning practice (Non-AR mode).
- The effects of learners' motivations toward using mobile-AR-based technology in learning.
- The moderating effects of student learning characteristics of the learning mode in regards to learning outcomes.
- The fitness of dimensions and antecedents in the model framework of mobile-Augmented Reality (mAR).

If you consent to take part in this research, it is important that you understand the purpose of the research and the tasks that you will be required to complete. Please ask if you have any questions, and that all of your questions have been answered to your satisfaction before you agree to participate.

If you decide to participate in this research, you are required to complete the following tasks:

- To complete pre/post-test question regarding your knowledge in Human Body Anatomy subject.
- To volunteer in difference learning method using Conventional Learning Method (CLM) and/or mobile-Augmented Reality (mAR) learning environment session.
- To complete a final questionnaire regarding your experiences in difference learning method and motivation of learning environment using Conventional Learning Method (CLM) and/or mobile-Augmented Reality (mAR) learning environment session.

  The pre/post-test results will not be used in the final grading of the unit. Withdrawal from participating in the survey will not disadvantage yourself in obtaining the learning objectives of the unit.

  The final questionnaire consists of seven parts:
  Section A: Background Information
  Section B: Perceived Learning Effectiveness
  Section C: Satisfaction
  Section D: Self efficacy
  Section E: Motivation
  Section F: Features of the Conventional Learning Method (CLM) and/or mobile-Augmented Reality Learning Environment (mAR)
  Section G: Suggestions and Comments

CRICOS Provider Code: 00125J
ABN 61 616 369 313

This CLM/mAR learning environment will take place in the lab/class of Foundation in Science and Foundation in Allied Science unit. It is estimated that the CLM/mAR learning environment session should take around 25 minutes. The pre/post-test questionnaire will take approximately 20 minutes for each session. Final questionnaire will take around 15 minutes to complete.

Voluntary Participation and Withdrawal from the Research

Your participation in this research is entirely voluntary. You may withdraw before completing the questionnaire at any time without discrimination or prejudice. Withdrawal requests after the completion of the questionnaire will not be possible. The reason it is not possible to withdraw after the questionnaire has been returned because there is no identity recorded against the questionnaire. All information is confidential and your personal details will not be used in any publication arising from the research. The researcher respects the privacy of our survey respondents and the information that you provide in this survey will be used for the purpose of a research report about experiences of using mAR for learning.

Benefits of the Research

While there is no guarantee that you will personally benefit from this research, the knowledge gained from your participation may help others in the future. Possible benefits could be the following:

- Enhance the learning experience of students as well as improve the learning outcomes.
- Learn the Human Body Anatomy anytime and anywhere without acquiring real models that must be referred from an osteology laboratory after operation hours.
- Extend the understanding of body parts in 3D modelling.
- Provide exposure to students and educators of the importance of mAR technology as an educational learning tool.
- Determine the suitability of mAR technology as a learning tool as well as enhances the motivations of the students' learning, thus, increase their learning outcomes in higher education.

If you have any questions about this project, please feel free to contact either myself, Siti Salmi Jamali, s.jamali@murdoch.edu.au, +61401099936, or my supervisors Dr. Mohd. Fairuz Shiratuddin, f.shiratuddin@murdoch.edu.au, +61893602794, Associate Professor Dr. Kevin Wong, k.wong@murdoch.edu.au, +61893606100, Dr. Charlotte Oskam, c.oskam@murdoch.edu.au, +61893606349. My supervisors and I are happy to discuss with you regarding any concerns that you may have about this research.

Once data have been analysed, any significant findings will be published through journals, conference papers and links to the main thesis. Summary of collective result of the whole set of data (not individual) will be sent to participants who have requested it by email.

If you are willing to consent your participation in this research, please complete the Consent Form. Your assistance with this research project is greatly appreciated. Thank you.

Sincerely,

Ms Siti Salmi Jamali
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School of Engineering and Information Technology,
Murdoch University
Room No: SC 2.034A
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(+61) 401099936
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Dr Mohd Fairuz Shiratuddin
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This research has been approved by the Murdoch University Human Research Ethics Committee (Approval 2013/135). If you have any reservation or complaint about the ethical conduct of this research, and wish to talk with an independent person, you may contact Murdoch University's Research Ethics Office (Tel. 08 9360 6677 (for overseas studies, +61 8 9360 6677) or e-mail ethics@murdoch.edu.au). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

CRICOS Provider Code: 00125J
ABN 61 616 369 313

Appendix F: Participant Consent Letter

Murdoch UNIVERSITY

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Invitation to participate, Informed Consent and Questionnaire

An Investigation of the Effectiveness of Learning Using mobile-Augmented Reality (mAR)

1. I voluntarily agree to take part in this research.
2. I have read the Information Letter provided and been given a full explanation of the purpose of this research, the procedures involved and of what is expected of me.
3. I understand that I will be asked to:
    - answer in pre/post-test questions;
    - participate in the Conventional Learning Method (CLM) and/or mobile-Augmented Reality (mAR) learning environment;
    - answer the final questionnaire.
4. The researcher has answered all my questions and has explained the possible problems that may arise as a result of my participation in this research.
5. I understand I am free to withdraw from the research during the data collection period of time without needing to give any reason. Withdrawal requests after the completion of the questionnaire will not be possible. The reason it is not possible to withdraw after the questionnaire has been returned because there is no identity recorded against the questionnaire.
6. I understand I will not be identified in any publications arising out of this research.
7. All data provided by me will be analysed anonymously using code numbers.
8. I understand that all information provided by me is treated as confidential and will not be released by the researcher to a third party unless required to do so by law.

Name of participant: ________________________

Email of participant: ________________________

Signature of Participant: ____________________ Date: ....../....../..........

I confirm that I have provided the Information Letter concerning this research to the above participant; I have explained the research and have answered all questions asked of me.

Signature of researcher: ________________________ Date: ....../....../......

CRICOS Provider Code: 00125J
ABN 61 616 369 313

Appendix G: Lecturer Consent Letter

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Invitation to participate and Informed Consent

An Investigation of the Effectiveness of Learning Using mobile-Augmented Reality (mAR)

1. I voluntarily agree to take part in this research.
2. I have read the Information Letter provided and been given a full explanation of the purpose of this research, the procedures involved and of what is expected of me.
3. I understand that I will be asked to:
   - allow the execution of this research during class time
4. The researcher has answered all my questions and has explained the possible problems that may arise as a result of my participation in this research.
5. I understand I am free to withdraw from the research during the data collection period of time without needing to give any reason.
6. I understand I will not be identified in any publications arising out of this research.
7. I understand that all information provided by me is treated as confidential and will not be released by the researcher to a third party unless required to do so by law.

Name of lecturer: ________________________

Email of lecturer: ________________________

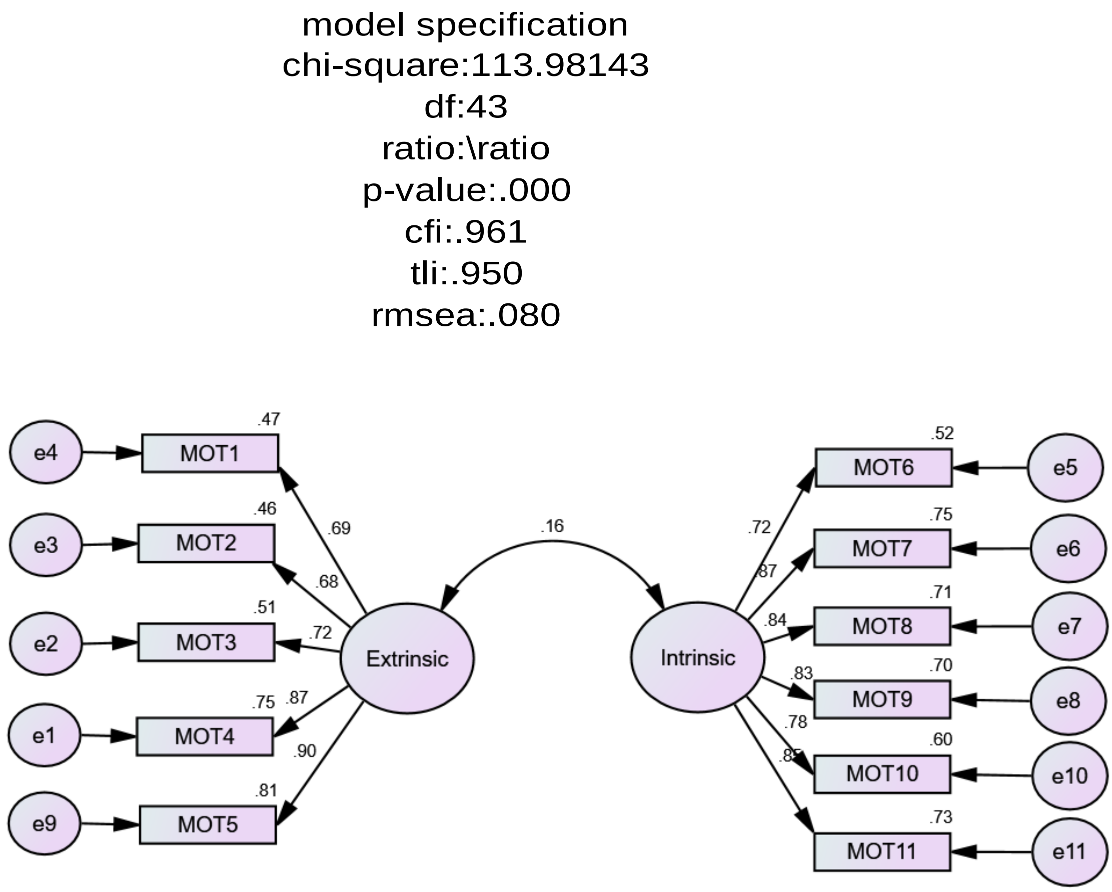
Signature of Lecturer: ________________________ Date: ……./……./…….

I confirm that I have provided the Information Letter concerning this research to the above participant; I have explained the research and have answered all questions asked of me.

Signature of researcher: ________________________ Date: ……./……./…….

Appendix H: Confirmatory Factor Analysis (CFA)

Section 8.3.1 Confirmatory Factor Analysis (CFA) – Motivation



CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	23	113.981	43	.000	2.651
Saturated model	66	.000	0		
Independence model	11	1871.205	55	.000	34.022

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.939	.922	.961	.950	.961
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

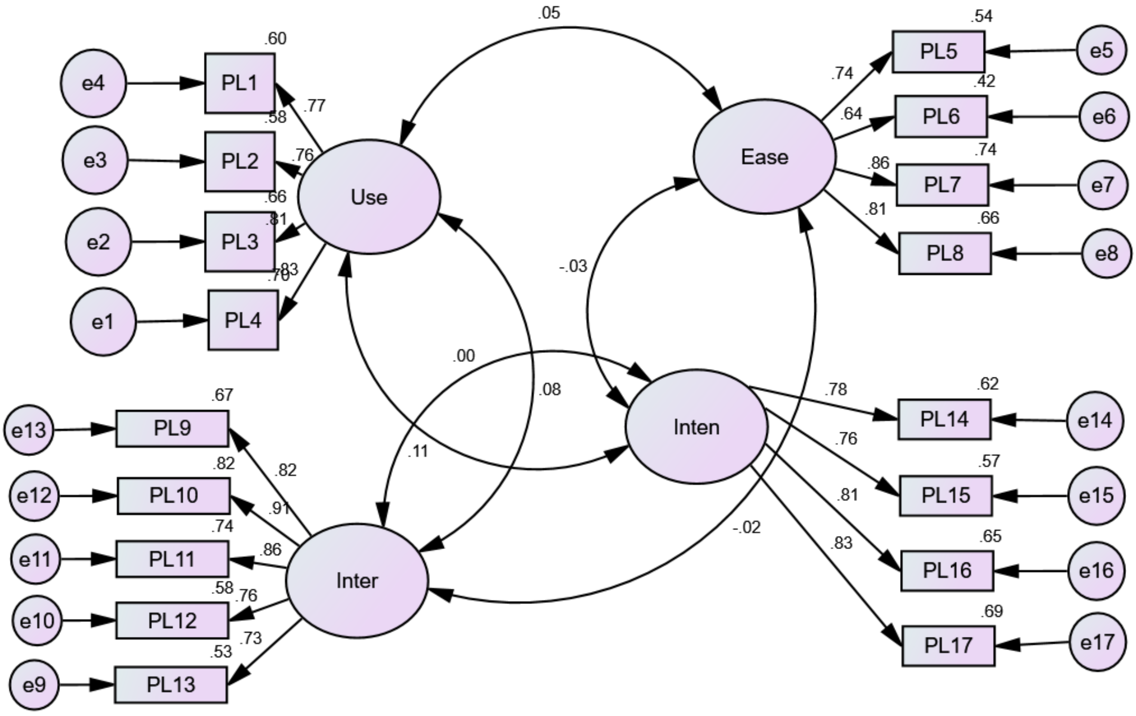
RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.080	.062	.098	.004

Model	RMSEA	LO 90	HI 90	PCLOSE
Independence model	.357	.343	.371	.000

Section 8.3.2 Confirmatory Factor Analysis (CFA) - Perceived Learning Effectiveness

model specification
chi-square:193.276113
df:113
ratio:\ratio
p-value:.000
cfi:.966
tli:.959
rmsea:.052



CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	40	193.276	113	.000	1.710
Saturated model	153	.000	0		
Independence model	17	2494.027	136	.000	18.338

Baseline Comparisons

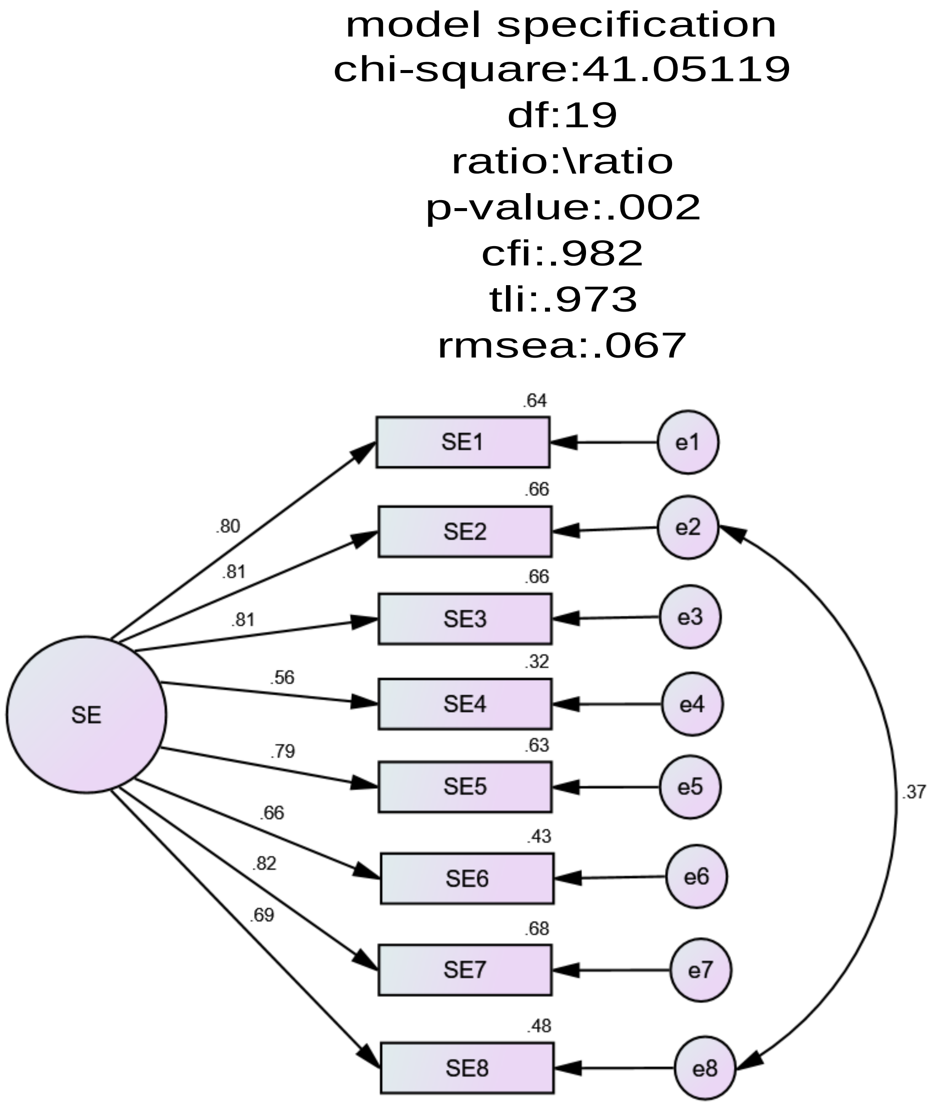
Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.923	.907	.966	.959	.966

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.052	.040	.065	.365
Independence model	.259	.250	.268	.000

Section 8.3.3 Confirmatory Factor Analysis (CFA) – Self Efficacy



CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	17	41.051	19	.002	2.161
Saturated model	36	.000	0		
Independence model	8	1226.780	28	.000	43.814

Baseline Comparisons

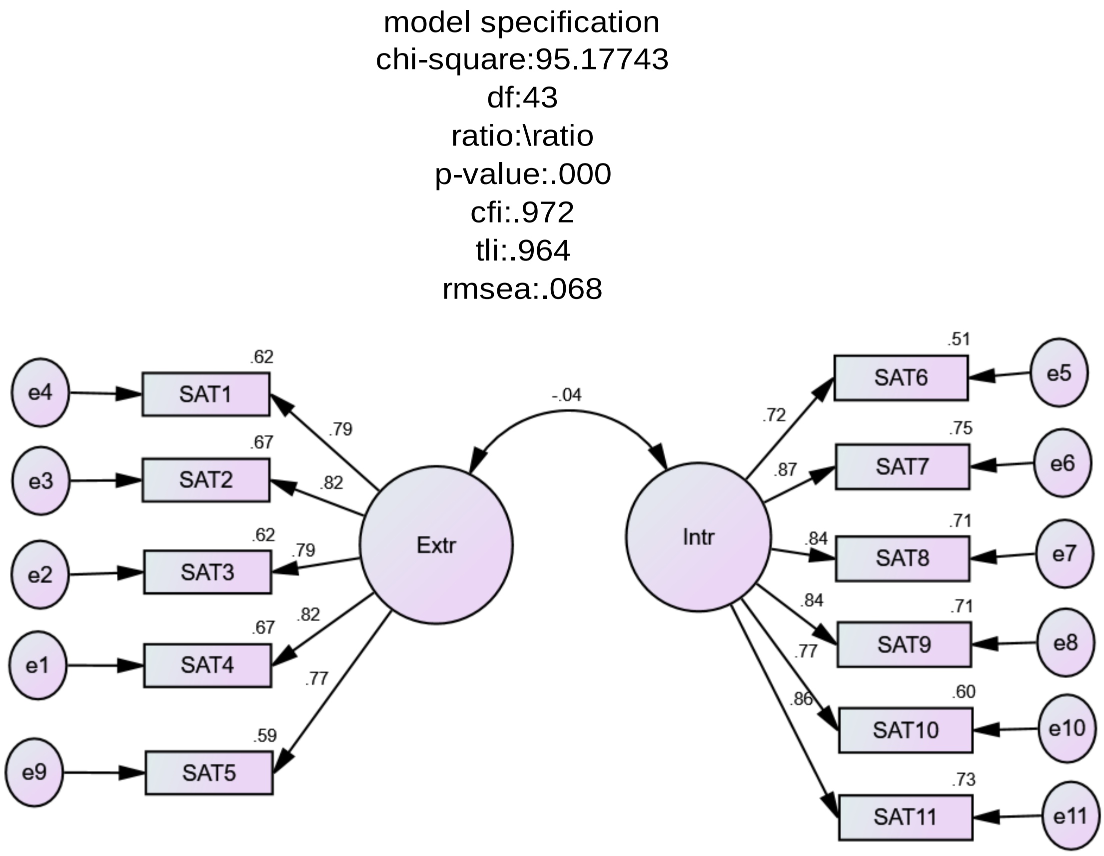
Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.967	.951	.982	.973	.982

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.067	.039	.095	.148
Independence model	.407	.387	.426	.000

Section 8.3.4 Confirmatory Factor Analysis (CFA) – Satisfaction



CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	23	95.177	43	.000	2.213
Saturated model	66	.000	0		
Independence model	11	1892.077	55	.000	34.401

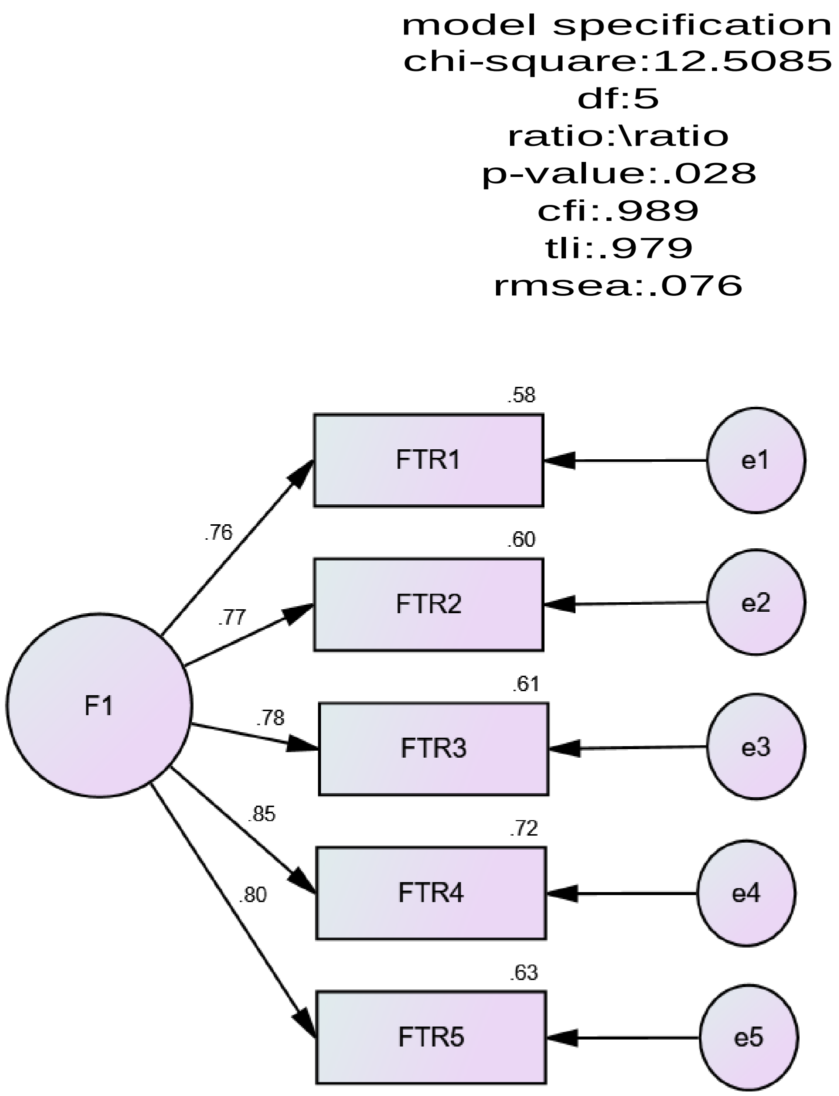
Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.950	.936	.972	.964	.972
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.068	.050	.087	.051
Independence model	.359	.345	.373	.000

Section 8.3.5 Confirmatory Factor Analysis (CFA) – mAR-Features



CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	10	12.508	5	.028	2.502
Saturated model	15	.000	0		
Independence model	5	712.805	10	.000	71.280

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.982	.965	.989	.979	.989

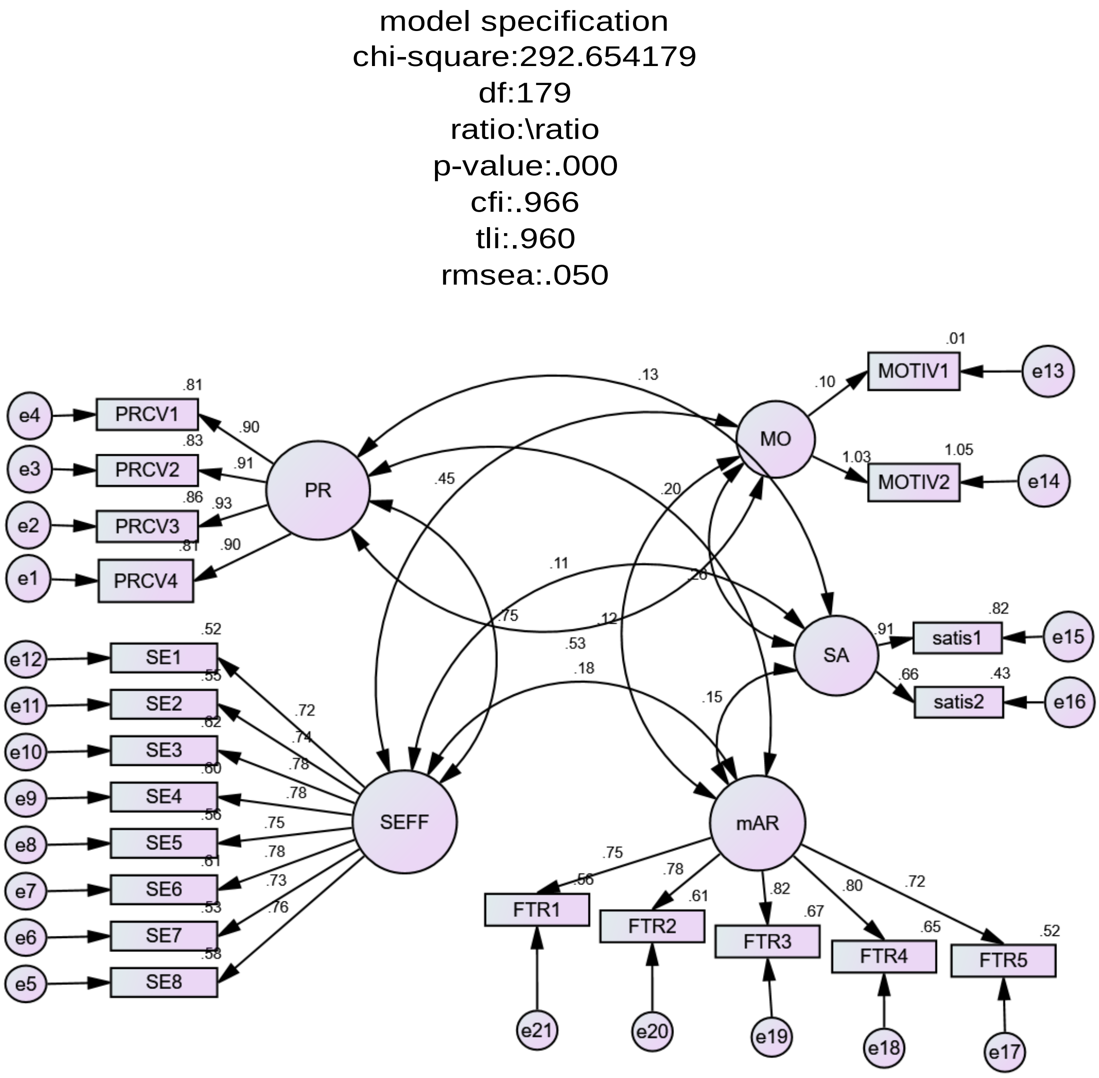
Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.076	.023	.130	.171
Independence model	.521	.489	.554	.000

Appendix I: Correlation between Variables for Hypothesis Model

Section 8.4 Discriminant Validity - Correlation between variables for hypothesis model



Correlations: (Group number 1 - Default model)

	Estimate
PRC <--> SE	.754
mAR <--> SE	.177
SAT <--> mAR	.151
MOTV <--> SAT	.264
PRC <--> MOTV	.534
PRC <--> mAR	.198
PRC <--> SAT	.130

	Estimate
MOTV <--> SE	.450
MOTV <--> mAR	.118
SAT <--> SE	.108

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	52	292.654	179	.000	1.635
Saturated model	231	.000	0		
Independence model	21	3520.268	210	.000	16.763

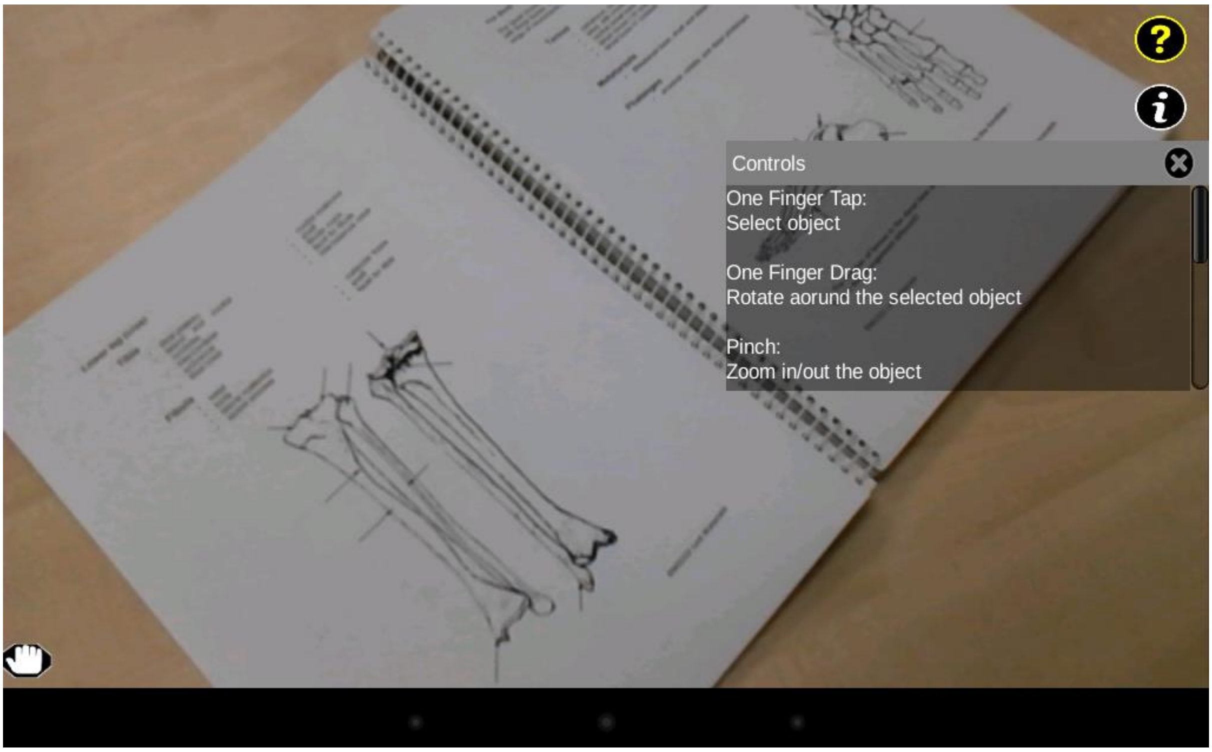
Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.917	.902	.966	.960	.966
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

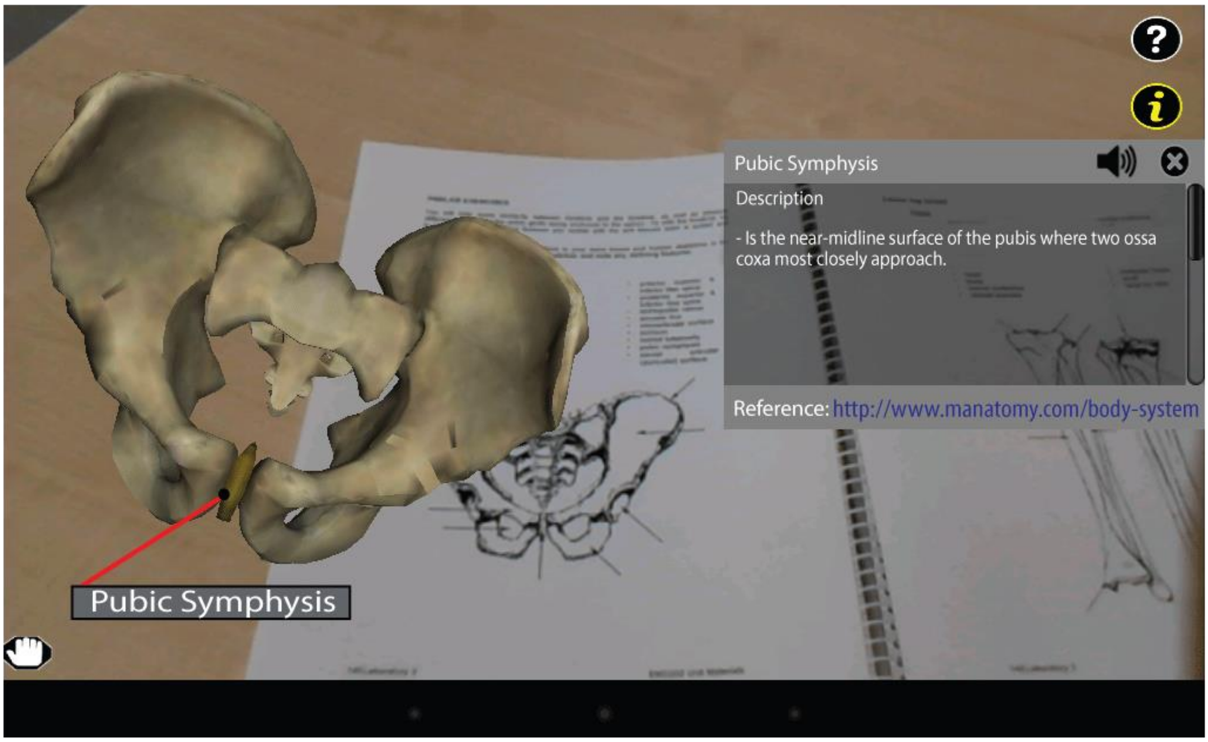
RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.050	.039	.060	.519
Independence model	.247	.240	.254	.000

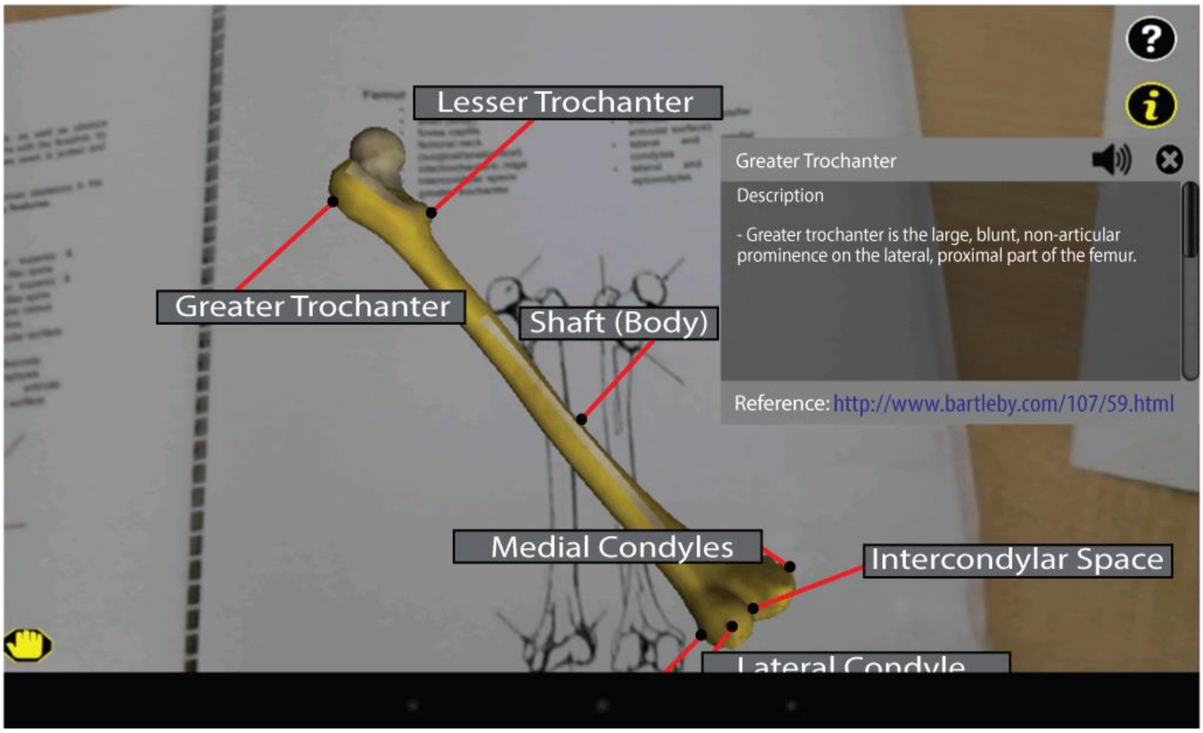
Appendix J: Screenshots of the HumAR Application



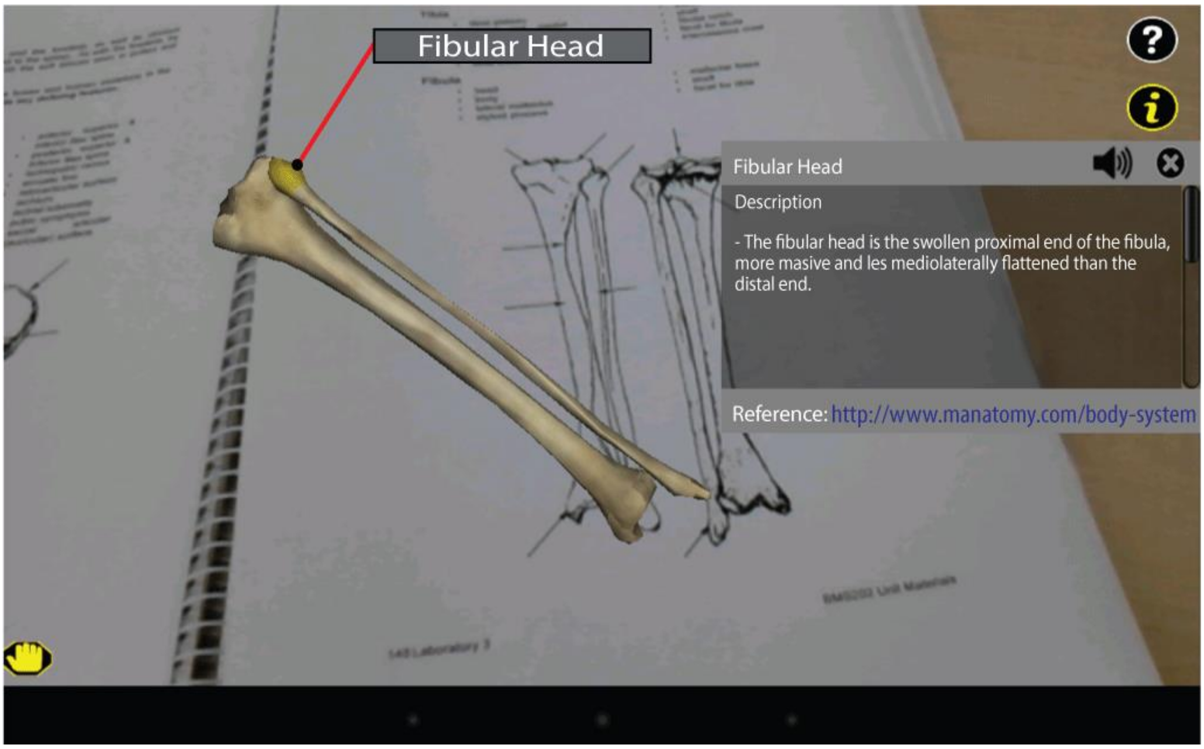
Screenshot of *Help*/*Control* page of HumAR



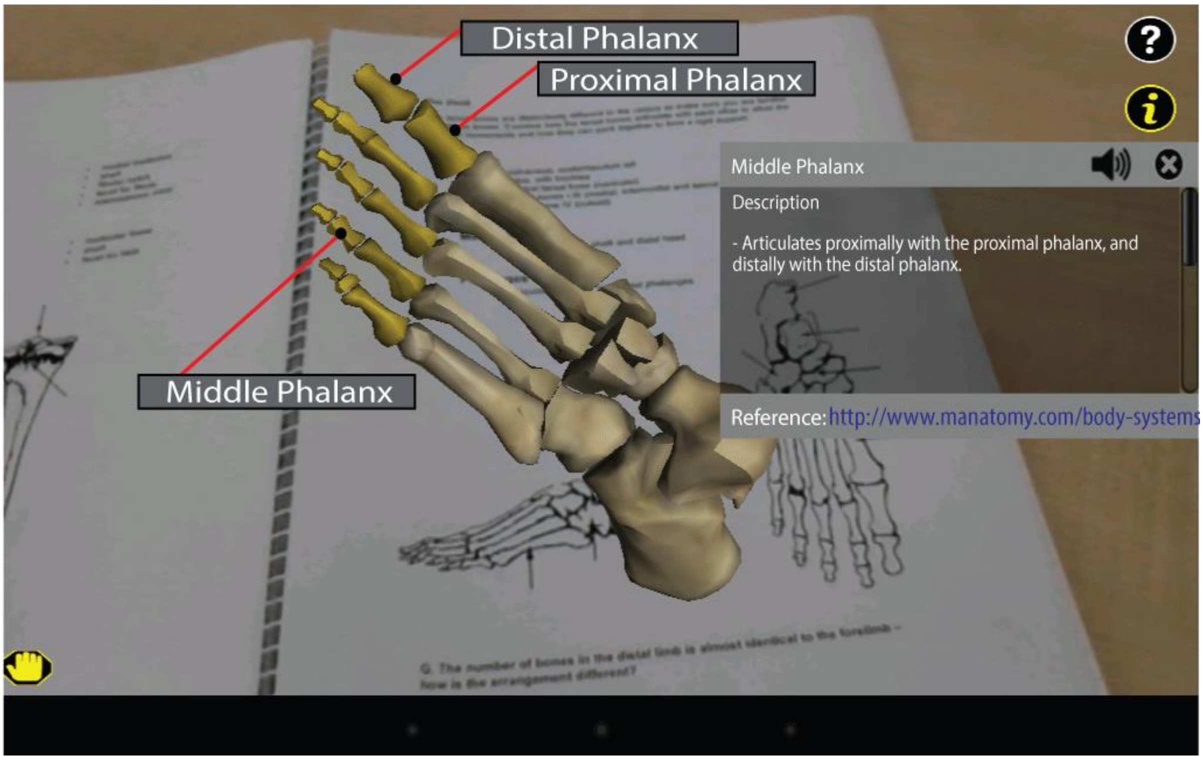
Screenshot of *Info-Pubic* page of HumAR



Screenshot of *Info-Femur* page of HumAR



Screenshot of *Info-Fibula* page of HumAR



Screenshot of *Info-Foot* page of HumAR

Appendix K: Academic Expert Review Questionnaire

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PROTOTYPE HUMAN ANATOMY IN MOBILE-AUGMENTED REALITY (HuMAR) APPLICATION VERIFICATION FORM

SECTION I. General Background Information

This section is aimed to gather expert's background information. Please fill in the blank and unless specified in the question, please select and tick (V) the appropriate answer for each of the following questions.

1. Expert's Name : INDANG ARIATI ARIFFIN

2. Teaching field/subject/unit : ANATOMY & PHYSIOLOGY

3. Teaching in : ☐ College : __________

   ☑ University : MANAGEMENT & SCIENCE UNIVERSITY

4. Teaching experience in the related field : 10 year(s)

5. I can be contacted via : ☐ Email : indang@msu.edu.my

   ☐ Mobile phone : __________

1

SECTION II. Content for Biology / Science Student

This section investigates the biology or science student towards the content and understanding with prototype HuMAR application for learning human anatomy. This section, you will need to respond, and please write or describe your opinion based on your expertise for each of the following questions.

No.	Question	Comment
6	I believe, student who enrol in human body anatomy subject can understand the material presented in prototype HuMAR application.	Yes, as the 3D model make it easy for student to apply with their knowledge
7	I am certain, student can understand the information taught in prototype HuMAR application based on the description given in the info panel.	Yes, the description is comprehensive
8	By using prototype HuMAR application, it enhances the student effectiveness towards understanding of the topic.	Yes, the application make it easy.
9	I believe, prototype HuMAR application can assist student-learner interaction in learning human body anatomy.	Yes, due to its interactive
10	Based on my ecperience, I believe, student can use prototype HuMAR application content to assist his/her learning in human's sekeletal system.	Yes, definitely

PROTOTYPE HUMAN ANATOMY IN MOBILE-AUGMENTED REALITY (HuMAR) APPLICATION VERIFICATION FORM

SECTION III. Content for non-Biology / non-Science Student

This section investigates the ***NON-BIOLOGY OR NON-SCIENCE STUDENT*** *towards the content and understanding with prototype HuMAR application for learning. This section, you will need to respond, and please write or describe your opinion based on your expertise for each of the following questions.*

No.	Question	Comment
11	I believe, a non-biology or non-science student can understand the human body anatomy subject, presented in prototype HuMAR application.	Yes, the application & 3D design make the non biology student understand well
12	I am certain, a non-biology or non-science student can understand the information taught in prototype HuMAR application based on the basic description given in the info panel.	Yes.
13	By using prototype HuMAR application, it enhances the non-biology or non-science student effectiveness towards understanding of the topic.	Yes, because it is interesting for them
14	I believe, prototype HuMAR application can assist non-biology or non-science student-learner interaction in learning human body anatomy.	Yes, the model & explanation clear
15	Based on my ecperience, I believe, non-biology or non-science student can use prototype HuMAR application content to assist his/her learning in human's sekeletal system.	Yes.

SECTION IV. Features of the Human Anatomy in mobile-Augmented Reality (HuMAR) Learning Environment

*This section investigates your perceptions about the features of prototype HuMAR application for learning. This section you will need to answer based on the following scale, please select and tick (√) **only ONE appropriate answer** that best describes your opinion for each of the following questions.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

No.	Statement	1	2	3	4	5
16	The realism of the three-dimensional (3-D) images in HuMAR motivates me to learn.	1	2	3	4 ✓	5
17	The smooth changes of images in HuMAR make learning more motivating and interesting.	1	2	3	4	5 ✓
18	The realism of the 3-D images HuMAR helps to enhance my understanding.	1	2	3	4 ✓	5
19	The ability to change the view position of the 3-D objects in HuMAR allows me to learn better.	1	2	3	4	5 ✓
20	The ability to change the view position of the 3-D objects HuMAR makes learning more motivating and interesting.	1	2	3	4	5 ✓
21	The ability to manipulate the objects (eg: rotate,scale,move) within the virtual environment makes learning more motivating and interesting.	1	2	3	4	5 ✓
22	The ability to manipulate the objects in real time helps to enhance my understanding.	1	2	3	4	5 ✓
23	The ability to see through the label of each object can improve my memory.	1	2	3	4	5 ✓

SECTION V. Suggestions and Comments

This section determines any improvements, recommendations or comments in terms of prototype HuMAR application and Human Body Anatomy subject to be considered in the future research. Please write in the space provided.

24. This prototype HuMAR application content can be learned by a non-biology or science student? *Yes / No, please state why.*

Yes, the diagram & explanation clear & easy to understand

25. Will a non-biology student can grasp at the content and have understanding of human anatomy if they want to learn? *Yes / No, please state why.*

Yes, the interactive approach. make it interesting

26. Any suggestion(s) / comment(s) regarding the focus of content prototype Human Anatomy in mobile-Augmented Reality (HuMAR).

Bigger font & more colourful to differentiate diff part.

~ Thank you for your time ~

Murdoch UNIVERSITY

PROTOTYPE HUMAN ANATOMY IN MOBILE-AUGMENTED REALITY (HuMAR)
APPLICATION VERIFICATION FORM

SECTION I. General Background Information

This section is aimed to gather expert's background information. Please fill in the blank and unless specified in the question, please select and tick (V) the appropriate answer for each of the following questions.

1. Expert's Name : SHAMSUL BAHRIN B. GULAM ALI

2. Teaching field/subject/unit : BIOLOGI (PARASITOLOGY, MICROBIOLOGY, HUMAN SYSTEM BIOLOGY)

3. Teaching in : ☐ College : ______
   ☑ University : UNIVERSITI TEKNOLOGI MARA

4. Teaching experience in the related field : 4 year(s)

5. I can be contacted via : ☑ Email : sbahrin@salam.uitm.edu.my
   ☐ Mobile phone : ______

SECTION II. Content for Biology / Science Student

This section investigates the biology or science student towards the content and understanding with prototype HuMAR application for learning human anatomy. This section, you will need to respond, and please write or describe your opinion based on your expertise for each of the following questions.

No.	Question	Comment
6	I believe, student who enrol in human body anatomy subject can understand the material presented in prototype HuMAR application.	Agree
7	I am certain, student can understand the information taught in prototype HuMAR application based on the description given in the info panel.	Agree
8	By using prototype HuMAR application, it enhances the student effectiveness towards understanding of the topic.	Agree. HuMAR application is a new learning approach for students.
9	I believe, prototype HuMAR application can assist student-learner interaction in learning human body anatomy.	Agree.
10	Based on my ecperience, I believe, student can use prototype HuMAR application content to assist his/her learning in human's sekeletal system.	Agree.

SECTION III. Content for non-Biology / non-Science Student

*This section investigates the **NON-BIOLOGY OR NON-SCIENCE STUDENT** towards the content and understanding with prototype HuMAR application for learning. This section, you will need to respond, and please write or describe your opinion based on your expertise for each of the following questions.*

No.	Question	Comment
11	I believe, a non-biology or non-science student can understand the human body anatomy subject, presented in prototype HuMAR application.	Agree, looks attractive for non-Science student.
12	I am certain, a non-biology or non-science student can understand the information taught in prototype HuMAR application based on the basic description given in the info panel.	Simple anatomical terminologies will be easier for them. How about more complex terminologies?.
13	By using prototype HuMAR application, it enhances the non-biology or non-science student effectiveness towards understanding of the topic.	more effective in Science student.
14	I believe, prototype HuMAR application can assist non-biology or non-science student-learner interaction in learning human body anatomy.	Agree for simple / introduction learning on human anatomy.
15	Based on my ecperience, I believe, non-biology or non-science student can use prototype HuMAR application content to assist his/her learning in human's sekeletal system.	Agree, but with guidance.

SECTION IV. Features of the Human Anatomy in mobile-Augmented Reality (HuMAR) Learning Environment
*This section investigates your perceptions about the features of prototype HuMAR application for learning. This section you will need to answer based on the following scale, please select and tick (√) **only ONE appropriate answer** that best describes your opinion for each of the following questions.*

.: (1-Strongly Disagree (SD), 2-Disagree (D), 3-Neither (N), 4-Agree (A), 5-Strongly Agree (SA)) :.

16	The realism of the three-dimensional (3-D) images in HuMAR motivates me to learn.	1	2	3	4 ✓	5
17	The smooth changes of images in HuMAR make learning more motivating and interesting.	1	2	3	4	5 ✓
18	The realism of the 3-D images HuMAR helps to enhance my understanding.	1	2	3	4	5 ✓
19	The ability to change the view position of the 3-D objects in HuMAR allows me to learn better.	1	2	3	4	5 ✓
20	The ability to change the view position of the 3-D objects HuMAR makes learning more motivating and interesting.	1	2	3	4	5 ✓
21	The ability to manipulate the objects (eg: rotate,scale,move) within the virtual environment makes learning more motivating and interesting.	1	2	3	4	5 ✓
22	The ability to manipulate the objects in real time helps to enhance my understanding.	1	2	3	4	5 ✓
23	The ability to see through the label of each object can improve my memory.	1	2	3	4 ✓	5

SECTION V. Suggestions and Comments

This section determines any improvements, recommendations or comments in terms of prototype HuMAR application and Human Body Anatomy subject to be considered in the future research. Please write in the space provided.

24. This prototype HuMAR application content can be learned by a non-biology or science student? *Yes / No, please state why.*

Yes, for simple/introduction on human anatomy.

25. Will a non-biology student can grasp at the content and have understanding of human anatomy if they want to learn? *Yes / No, please state why.*

Yes, I think because of the 3D images.

26. Any suggestion(s) / comment(s) regarding the focus of content prototype Human Anatomy in mobile-Augmented Reality (HuMAR).

(1) new way of learning human anatomy.
(2) We need new technology to gain interest among student in learning anatomy, as conventional text book way will be quite tough.
(3) Students in this era, prefer portable device, IT based learning.

~ Thank you for your time ~

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