INSTRUCTIONAL DESIGN MODEL OF MOBILE AUGMENTED REALITY FOR ENHANCING COMPREHENSION, LEARNING ENGAGEMENT, AND PERCEIVED MOTIVATION IN STUDENTS WITH DIVERSE SPATIAL VISUALIZATION ABILITIES

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Abstrak

Walaupun pelbagai model rekabentuk telah dicadang dan diadaptasi untuk pembangunan aplikasi Mudah Alih Realiti Terimbuh (MAR), tiada satu pun yang menangani integrasi elemen kefahaman, penglibatan pembelajaran, dan persepsi motivasi dalam pembelajaran Organisasi Sistem Komputer (CSO) di kalangan pelajar politeknik dengan Kebolehan Visualisasi Spatial (SVA) yang pelbagai. Ini mewujudkan jurang kritikal dalam pembangunan model rekabentuk untuk persekitaran pembelajaran berasaskan MAR. Kajian ini bertujuan membangun dan menilai Model Reka Bentuk Pengajaran Realiti Terimbuh Mudah Alih (MARID) untuk pelajar politeknik dengan SVA yang pelbagai. Berdasarkan model MARID tersebut, dua aplikasi MAR telah direka bentuk dan dibangun; Realiti Terimbuh Mudah Alih Realisme Fungsian (MARCO-FR) dan Realiti Terimbuh Mudah Alih Realisme Fizikal (MARCO-PR). Kedua-duanya direka bentuk untuk kursus CSO. Reka bentuk faktorial kuasi-eksperimen telah diguna untuk mengkaji kesan pemboleh ubah tidak bersandar mod MARCO, iaitu MARCO-FR dan MARCO-PR terhadap pemboleh ubah bersandar; kefahaman, penglibatan pembelajaran, dan persepsi motivasi, yang dimoderasi oleh SVA pelajar. Kajian ini melibatkan 200 pelajar politeknik diagih untuk menggunakan salah satu mod MARCO. Prosedur kajian melibatkan ujian pra, ujian pos, pengesahan pakar, dan ujian alfa-beta. Data dianalisis menggunakan statistik deskriptif dan statistik inferensi iaitu ANOVA. Dapatan menunjukkan bahawa pelajar yang menggunakan MARCO-FR memperoleh prestasi lebih tinggi dalam kefahaman, penglibatan pembelajaran, dan persepsi motivasi berbanding mereka yang menggunakan MARCO-PR, bagi kedua-dua tahap SVA tinggi dan rendah. Pelajar dengan SVA tinggi menunjukkan peningkatan luar biasa dalam kefahaman dan penglibatan pembelajaran dengan MARCO-FR, disebabkan realisme visual dan penekanan pada pengetahuan prosedur spatial. Pelajar SVA rendah juga mendapat manfaat daripada kedua-dua mod MACRO, namun peningkatan prestasi mereka lebih ketara dengan MARCO-FR. Kajian ini mengenengahkan MARID sebagai model reka bentuk pengajaran yang berkesan untuk MAR bagi memenuhi keperluan pembelajaran pelbagai. MARCO-FR disyorkan untuk semua tahap SVA, manakala MARCO-PR berpotensi untuk aplikasi lebih luas. Penyelidikan ini menyumbang kepada integrasi MAR dalam reka bentuk pengajaran untuk pendidikan teknikal dan memajukan teknologi pendidikan.

Kata Kunci: Model rekabentuk instruksi, realiti terimbuh, daya visualisasi spatial, penglibatan pembelajaran, persepsi motivasi

Abstract

Despite various design models that have been proposed and adapted for mobile augmented reality (MAR) applications development, none has addressed the integration of comprehension, learning engagement, and perceived motivation elements in learning Computer System Organization (CSO) among polytechnic students' students with diverse Spatial Visualization Abilities (SVA). This leaves a critical gap in the development of design models in educational technology for MAR-based learning environments. This study aimed to develop and evaluate the Mobile Augmented Reality Instructional Design Model (MARID) for polytechnic students with diverse SVA. Based on the MARID model, two MAR applications were designed and developed; Mobile Augmented Reality Functional Realism (MARCO-FR) and Mobile Augmented Reality Physical Realism (MARCO-PR). Both were designed for the CSO course. A quasi-experimental factorial design was used to examine the effects of the independent variables of MARCO modes, which were the MARCO-FR and MARCO-PR on the dependent variables: comprehension, learning engagement, and perceived motivation, moderated by the students' SVA. This study involved 200 polytechnic students who were assigned to use one of the MARCO modes. Research procedures included pre-tests, post-tests, expert validation, and alpha-beta testing. The data was analysed using descriptive and inferential statistics which is ANOVA. Findings revealed that students using MARCO-FR demonstrated significantly higher performance in comprehension, learning engagement, and perceived motivation compared to those using MARCO-PR, across both high and low SVA levels. High SVA students showed exceptional improvements in comprehension and learning engagement with MARCO-FR, attributed to its visual realism and emphasis on spatial procedural knowledge. Low SVA students also benefited from both MARCO modes, although their performance gains were more pronounced with MARCO-FR. This study highlights MARID as an effective instructional design model for MAR to address diverse learning needs. MARCO-FR is recommended for students across SVA levels, while MARCO-PR offers potential for broader applications. This research contributes to integrating MAR into instructional design for technical education and advancing educational technology.

Keywords: Instructional design model, augmented reality, spatial visualization ability, learning engagement, perceived motivation

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List of Abbreviation

ATID	Alessi and Trollip Instructional Design
AR	Augmented Reality
AE	Aesthetic Appeal
ARCS	Attention Relevance Confident Satisfaction
AST	Assessment Specification Table
CSO	Computer System Organization
CSOT	Computer System Organization Test
CLO	Course Learning Outcomes
DDT	Diploma Digital Technology
DPS	Drill and Practice Software
ICS	Introduction to Computer System
IG	Instructional Games
ID	Instructional Design
SA	Spatial Ability
SVA	Spatial Visualization Ability
SS	Simulation Software
SVATI	Spatial Visualization Ability Test Instrument
HSVA	High Spatial Visualization Ability
LSVA	Low Spatial Visualization Ability
UES	User Engagement Scale
TVET	Technical and Vocational Education Training
TS	Tutorial Software
IOT	Internet of Thing
MAR	Mobile Augmented Reality
MoHE	Ministry of Higher Education
MAR	Mobile Augmented Reality
MARCO	Mobile Augmented Reality Computer Organization
MARID	Mobile Augmented Reality Instructional Design
MAT	Motherboard Assembly Tutor
FR	Functional Realism
FA	Focus Attention
PSS	Problem Solving Software
PR	Physical Realism
PU	Perceived Usability
RASE	Resources Activity Support Evaluation
RW	Reward Factor
PLO	Program Learning Outcomes
PEO	Program Educational Objective

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Technology has been an integral part of our daily lives for the past three decades. In the context of education, technology plays a crucial role in teaching and learning processes. Educators today often perceive educational technology as devices or tools, such as smartphones, computers, smart glasses, and tablets, used as mediums for learning. However, the use of instructional technology in education is not a new concept. It refers to the application and integration of digital devices (Nasution, 2021). Emerging technologies provide alternative methods for accessing, analyzing, and processing knowledge, which are essential for teaching and learning.

The Framing of Malaysia Higher Education 4.0 Future Proof Talents (Ministry of Higher Education, 2018), based on the Malaysian Education Blueprint 2015–2025 (Ministry of Higher Education, 2018), emphasizes that learning and teaching will increasingly rely on technology, innovation, and personalized learning models. As the Fourth Industrial Revolution (IR 4.0) progresses, it is imperative to position technology at the forefront and at the core of education. This shift aims to enhance students' skills, drive the digitalization of knowledge, and foster better learning outcomes in classrooms. The new IR 4.0 era has a more profound implication on the education landscape and purpose. With instructional technology as an enabler, the methods of learning have been entirely transformed. Educators now act as facilitators, leveraging instructional technology to empower students to access more information and improve their learning outcomes. (Helen & Carolyn, 2021). To ensure a better understanding of a specific field or course, students need to meet industry demands (Helen & Carolyn, 2021). This aligns with the goal of producing high-quality TVET graduates outlined in the Higher Education Blueprint 2015-2025.

The Malaysia Education Blueprint 2015-2025 for Higher Education (Ministry of Higher Education, 2015) emphasizes that higher education institutions in Malaysia (universities, technical colleges, matriculation centers) should extend the use of advanced technologies such as big data, robotics, augmented reality, and automation to improve the quality of learning. The blueprint identifies twelve operational shifts required to achieve its vision. One significant shift, the 7th, highlights the importance of ICT management to boost Malaysia's educational standards by implementing modern educational technology. According to the Ministry of Higher Education (MOHE, 2015), mobile applications should serve as primary instructional tools. By leveraging mobile learning, educators can promote active, effective, and meaningful learning. This approach enhances students' knowledge, skills, attitudes, and motivation (Lucas, Paul, Adachi, John, Vigdis & Edward, 2018).

The Malaysian Polytechnic Standards (Department of Polytechnic and Community College, 2015) further support this by emphasizing the need for adequate learning facilities and infrastructure that integrate modern instructional technology. Such advancements enhance students' competencies while boosting their motivation, skills, and interests. Instructional technology has become an integral part of modern education systems, offering learners a variety of tools and resources to support them. (Kamal, Hasan & Kamal, 2020).

Visualization technology is one of the common tools used as instructional technology in education (Tasnem, Kevin & Jacques, 2019; Wei, Zhang, Yang & Li, 2019). It refers to the process of representing and interacting with information graphically to gain insights into the information (Padilla, 2009). Visualization technology plays a crucial role in helping learners acquire knowledge and develop critical thinking skills. Moreover, it aids in enhancing students' understanding of the information provided (Vermirovsky, 2013). According to Veide, Strozeva, and Dobelis (2014), 3D visualization simplifies abstract concepts, making them easier for students to grasp. It also promotes positive acceptance and creates engaging learning environments. Kozhevnikov and Thornton (2007) demonstrated that visualization skills can be improved by offering a variety of abstract visual images and encouraging students to process, store, interpret, and analyse these graphics or images. Enhanced engagement significantly improves the learning experience when using visualization technology in educational environments (Alqathani, Daghestani & Ibrahim, 2017Additionally, Fahri (2017) emphasized that visual learning methods motivate students to engage collaboratively. Creating visually appealing representations of information not only enhances its appeal but also makes it more informative (Bayu, Arshad & Ali, 2013). One such method of interactive visualization is employing Augmented Reality (AR) technology on mobile platforms (Cella & Jimenez, 2021). AR and mobile application ~~are~~ technologies that have the potential to revolutionize education by offering new possibilities for visualization and interaction. AR enables the superimposition of virtual objects onto the real world, while mobile apps provide a platform for delivering educational content and engaging students in learning activities (Cella & Jimenez, 2021). The combination of mobile application platform and AR technology is capable of creating an application that can provide an enjoyable and engaging visual learning environment for learners.

Thus, based on Malaysian Education Blueprint 2015-2025 (Higher Education) and Malaysian Polytechnic Standards (Polytechnic and Community College Institute, 2015), the study aims to design and develop an instructional design model that can be integrated into Mobile Augmented Reality (MAR) application to enhance students ' comprehension, learning engagement and motivation. This MAR application is dedicated for learning Computer System Organization (CSO), specifically for Polytechnic Diploma in Information Technology (Digital Technology) (DDT) students with different spatial visualization ability. This study also seeks to investigate student’s comprehension, learning engagement and motivation for the use of MAR application in learning CSO course.

1.2 Background of the Study

Computer System Organization (CSO) is one of the core courses in Diploma in Information Technology (Digital Technology) (DDT) programs in polytechnics. The CSO course introduces students to computer systems, with a focus on hardware and software concepts. This includes topics about assembly and upgrading computer components, installing software, and connecting peripherals. The curriculum for the Polytechnic DFC1033 Introduction to Computer System course was developed in 2018. This course serves as a fundamental introduction to essential knowledge and abilities in Information Technology. It is a prerequisite for ICT workers and is a key component in the Body of Knowledge (BoK) for computer studies in polytechnics.

Students will gain a comprehensive understanding of the essential and effective practices in computing studies, as well as the utilization of technology and the administration of IT environments. The significance of this subject was stated in Stallings (2013) research, which claims that students need to understand computer system's functional components, characteristics, efficiency and the relationship between the components. Fahri (2017) stated that learning CSO can provide a fundamental knowledge and skills that are required in the current industrial demand for students after graduation. Hence, learning CSO can enthuse students to develop skills relevant to the current trend of modern computing, considering the continuous trend in technology evolution (Stallings, 2018).

However, one common issue with the *Computer System Organization (CSO)* course is that it tends to be highly technical, plain, and theoretical, which can demotivate students (Raven, Qalawee, & Atroshi, 2016). Another challenge faced by students learning CSO is the lack of physical computer components for practical activities. While the course provides theoretical knowledge on how to operate and assemble computer systems, it does not offer sufficient opportunities for students to gain hands-on experience (Veni, 2014). Mustapha and Hashim (2018) found that students' underperformance in the CSO course is attributed to the inadequate availability of computer equipment, which forces students to share resources during practical sessions. Similarly, Wei et al. (2019) identified two key issues in CSO learning practices: the failure to implement individualized learning strategies and an inadequate integration of theoretical knowledge with technology skills. The lack of sufficient learning materials and practical exercises can lead to a decrease in students' spatial visualization abilities, significantly impacting their ability to learn CSO effectively. Previous studies have highlighted that traditional tool, such as textbooks, notes, and photos, are insufficient for enhancing students' spatial visualization abilities, ultimately causing demotivation (Alqathani et al., 2017; Feng, Lin & Yu, 2023).

Therefore, the existing teaching material used in CSO learning is very technical and hard to visualize, it is difficult to provide a learning environment which allows students to learn CSO continuously (Nazatul, 2015). While a number of learning tools have been developed, teaching materials that connect between theories, concepts and real computer components is still less emphasized. Previous studies proved that using AR can improve students to learn CSO effectively. One study tested the efficacy of augmented reality in the assembly of computer motherboards. The findings showed that users were able to finish the assembly tasks with minimal time when using AR instruction compared to conventional lab manual or ordinary display (Wang, Ong & Nee, 2016). Meanwhile, Giles (2015) developed an AR application of Motherboard Assembly Tutor (MAT) for training on how to assemble computer components and found that the use of AR improved task performance on the assembly of computer component and significantly improved the learning outcome over traditional learning. Other studies stated that using AR in computer hardware assembly will provide exciting and fun effects (Veni, 2014). According to Bal and Bicen (2016), using AR stimulates students to perceive and understand easily in a short period by increasing visibility. It is also claimed that AR can potentially enhance and increase spatial skills among students with different spatial visualization ability (Sorby, 2009). Martin et al., (2015) has conducted research that has shown AR is an efficient material to develop student's spatial visualization ability during learning visual materials. Furthermore, Martin et al., (2015) also stated that student spatial visualization ability has significantly improved after performing training with AR environment.

Nevertheless, AR helps students to develop and improve their spatial visualization ability in learning subject that is difficult to visualize without any actual environment or device (Jorge, Contero & Alcaniz, 2015). Jorge, Contero and Alcaniz (2015) also state that AR materials are useful to improve student spatial visualization skill and capabilities. Students with low-spatial visualization ability specifically benefit from AR technology because visualization helps reduce the unimportant cognitive load of learning materials and objectives (Lee, Elinda & Wong, 2014). This is also supported with research done by Petros (2016), which stated that student with low spatial visualization ability would improve through AR training system. Research by Cheng and Tsai (2013) found that AR encourages spatial knowledge, practical skills and conceptual understanding in education. However, some of the exploratory studies proposed that AR could improve stimulation and motivation into teaching and learning activities, deliver positive attitudes and better student engagement to the contents (Azuma, 1997; Klopfer & Squire, 2008; Jerry & Aaron 2010; Yuen, Yaoyuneyong & Johnson, 2011; Guo, Xu, Yang & Wang, 2023; Lin et al., 2023; Akçayır & Keskin, 2023). Hence, to provide appropriate AR learning materials, the techniques used during teaching and learning session need to be comprehensible to the students with different spatial visualization ability level (Feng, Lin & Yu, 2023).

In addition, collaboration and engagement among students can be promoted in such an efficient way offers by the AR to visualize abstract concepts (Smith, Johnson &

Lee, (2022). From the literature review, numerous AR advantages in educational settings have shown remarkable potential to integrate AR as teaching and learning tools (Alkhattabi, 2017). According to Sumadio and Rambli (2010), the integration of AR in education has the potential to enhance traditional learning approaches. AR technology can enhance students' motivation to learn and enhance their practical education methods (Medicherla, Chang & Morreal, 2010). As suggested by Diaz, Hincapié, and Moreno (2015), AR application is useful for teaching abstract concepts by combining dynamic and static content embedded with some multimedia features (i.e. text, graphics, video and illustration). El Sayed, Zayed and Sharawy (2010) mentioned utilizing AR technology can improve student's visualization capabilities. According to Bal et al., (2016) AR offers a fun learning experience when communicating with things, people and information as in the real situation or scenarios. In turn, AR also provides enhanced incentives for learning inspiration and allows learning processes to be immersive and efficient. AR can be useful in the lack of real computer components by providing supplementary and contextual information that can resemble a practical component (Bal et.al, 2016). Research done by Pantelic & Vukovac (2017), also showed that using AR technology will offer new experiences to students when they learn computers components by combining virtual object to the real-world. Sirakaya, (2018a) stated in his research, that using AR based application called HardwareAR, encourages students to learn with less help as it can be useful in increasing achievement and reducing the duration of motherboard assembly. Another research done by David Kaber (2021) showed that AR significantly improved assembly accuracy and spatial ability compared to a video-based training condition.

1.3 Problem Statement

This study arises from the concern over polytechnic students' underperformance in the Computer System Organization (CSO) course, necessitating an in-depth review of existing challenges. According to the Polytechnic Diploma in Information Technology (Digital Technology) (DDT) program's 2018 review report for the DFC1033 Introduction to Computer System (ICS) course, CLO 2 which focuses on applying knowledge of computer technology, hardware, maintenance, and troubleshooting showed average achievement levels, highlighting the need for improved instructional methods. (Balik Pulau Polytechnic Examination Department, 2018). As stated by Mustapha et al., (2018) CSO course is among the challenging courses for students to achieve excellent results and students' outcomes were less encouraging. In research done by Safiani, Danakorn, Nurul, Rustam, Najua & Taufik (2020), polytechnic students were found to have lack of hands-on skills, problem-solving abilities and facing hard time to applying theoretical knowledge to practical scenarios, such as system configuration and assembly process of computer components due to inefficient learning aids and tools.

Hence, this result will affect student's opportunities to get employed as the Information and Communication Technology (ICT) skills are considered an essential skills prospective employers look for and fundamental in today's digital age and are necessary for effective collaboration in the workplace (Bee & Hie, 2012; Ministry of Higher Education, 2012; Rasheed, Amin & Yusoff, 2016; Nguyen & Nguyen, 2018; Hochmair & Zielstra, 2020). In research done by Zafir, Ishak and Abd (2015), ICT skills are one of the most important criteria needed by the industry that can give added value to employee nowadays. Thus, this problem is due to several factors. According to the literature reviews and preliminary investigation on one of the CSO course, students facing difficulty in visualizing technical and abstract materials. According to Mustapha et al., (2018), the main reason why Polytechnic DDT program students do not score in CSO course is because of the poor teaching technique and aids. Nazatul et al., (2014) found that less motivation and interest among student in understanding theoretical materials in CSO course was due to the lack of interactive teaching material and instructional technology. Tseng and Lee, (2020) stated that a particular issue with CSO course is due to its contents tends to be slightly dry and theoretical as well as it becomes more intricate and compact over time, making it challenging to visually comprehend their intricate connections and arrangements.

In research done by Prasad, Alsadoon, Beg and Chan, (2015) they agreed that there is an issue in teaching CSO course which is combining the theoretical concepts with the practical experience. Pantelic et al. (2017) supported this view who mention that computer component is hard to visualize and hardly tangible in the real environment. In the same vein, Wei et al., (2019) stated that there is no particular learning strategy and training orientation that combines theoretical concept and technology capability in learning CSO course. Besides, CSO is a course that requires students to gain both fundamental knowledge and skills, but student tends to face difficulties while assembling computer hardware due to the hardware complexity structure (Sirakaya, 2018). Moreover, Zhan, Huang, Li & Huang (2017) found that the integration of self-learning computer assembly using augmented reality are still few in current literature and limited hands-on experience and practical exposure to computer hardware assembly can impede the ability to visualize and understand the assembly process. Similarly, Maria (2023) identifies a gap in research focusing on self-directed learning using AR for complex assembly tasks like computer assembly, while studies show AR's potential, more work is needed in this specific area.

Therefore, to improve student motivation, comprehension and learning engagement, new technology and learning strategies should be applied in polytechnic to comply with conventional learning methods (Sarizun & Zuraidah, 2017). This is in line with the Malaysian Polytechnic Standards (Department of Polytechnic and Community College, 2015), which stated that a well-equipped learning facility with newest instructional technology complemented the academics' competency and enhanced student's quality. More innovative and efficient technological tools are being developed, and inclusion of these materials in pedagogical process allows the advanced use of information and technology (Bal et al., 2016).

Evidence provided by pass researchers, mention that, due to low spatial visualization ability, students cannot imagine and visualise the actual environment (Mayer, 2009: Langlois, 2020). AR is a technology that allows users to interact with entities, object and knowledge as in real-world that can increase interaction, improving spatial visualization ability, allows fun learning, increase motivation and bringing learning processes more effective (Alsumait & Al-Musawi, 2013). Bakar (2018), in his survey on augmented reality acceptance among polytechnics students, find out that the result has shown a positive level of recognition. In the same context, research was done by Bal et. al., (2016), revealed how students view towards the course and academic achievement can have a positive effect in learning computer hardware course through the augmented reality integration. Jang & Chen (2017), supported this view in stating that AR provides learners with a realistic and interactive visualization of computer hardware components, allowing them to understand the spatial relationships and connections more easily. Learners can view virtual representations of components overlaid onto the physical environment, enabling a better understanding of how they fit together (Jeng et al., 2017). Also, learners feel excited and intrigue about the new style of learning and feel motivate and engaging in-class session. For example, one demonstration has been conducted by Pantelic et al., (2017), on assembling computer hardware components on a computer motherboard by using AR and an evaluation found that augmented reality can improve test scores, speed of task performance and significantly improve the learning outcomes. According to Chang and Lee (2020), AR based learning systems can provide real-time guidance and feedback to learners during the assembly process. Virtual instructions and visual cues can be overlaid onto the physical components, guiding learners step-by-step and offering immediate feedback on their actions (Chang & Lee, 2020).

AR is one way to enhance spatial visualization ability and realism of a three-dimensional object compared to the conventional method that uses text-based and static images (Saidin, Halim & Yahya, 2015). The primary objective of AR is to create highly realistic 3D simulations which is so convincing that users can hardly differentiate them from reality (Lampropoulos, 2020). As stated by InterDigital in 2017, the augmented reality realism, despite having close relation with computer graphics, it needs to be considered in a broader viewpoint. Beside pertains to the level of visual appearance, fidelity and representing virtual objects in relation to their physical counterparts which consider as physical realism, AR also should be expended as a part of the actual physical environment, enables virtual objects to be contextually integrated into the real-world environment, aligning with the physical surroundings, coexisting with real objects and interacts with in meaningful ways, such as manipulating, examining or controlling the virtual objects which consider as functional realism (InterDigital, 2017). AR is a current technology that is extensively used in education. It enables users to actively engage with virtual objects that exist alongside real-world objects in real time. The main goals of AR are to improve users' spatial visualization skills, enhance their interaction with the physical world, and make their tasks more efficient by providing realistic visual and virtual information (Lampropoulos, 2020).

The actual problem lies in the absence of an instructional design model that effectively integrates augmented reality (AR) with the Computer System Organization (CSO) syllabus to enhance students' comprehension, learning engagement, and perceived motivation. Despite the growing use of AR in education, there remains a gap in tailored instructional design frameworks that address the unique requirements of CSO content, limiting the potential impact of AR-based learning tools on student outcomes. This study seeks to bridge this gap by developing a conceptual instructional design model specifically for mobile augmented reality applications.

The summaries problem statement and solution provided are explained in graphical flow in Figure 1.1.

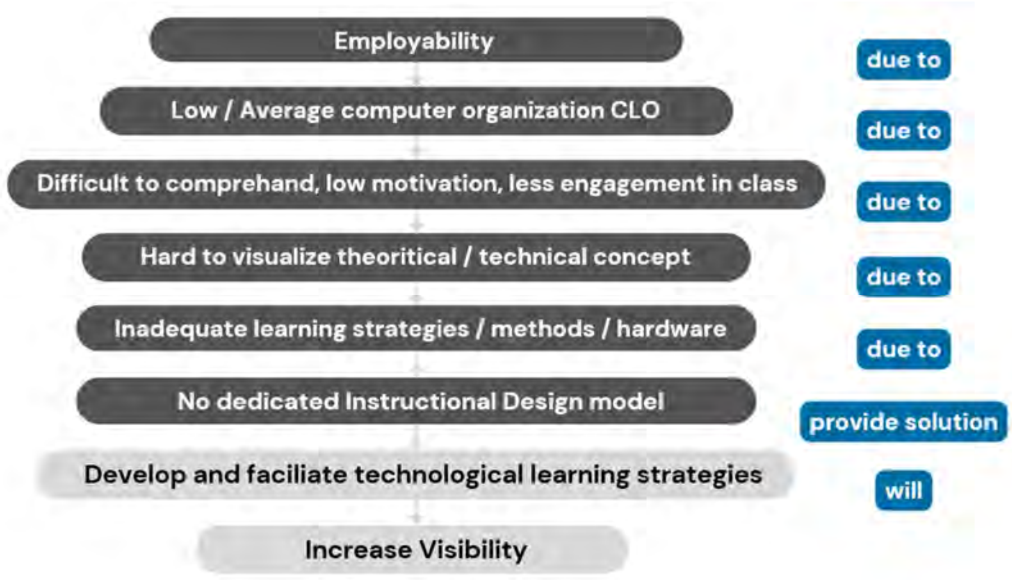

Figure 1.1 : Problem statement

Besides, although there are numerous studies on AR in education, unfortunately a few studies had been conducted to discover the effectiveness of AR based application on learning CSO among Malaysian polytechnic students. In addition, although a range of AR technologies have been developed to visualize and facilitate assembly processes in CSO learning, none of these MAR based application has contextualized the implementation of functional and physical realism in augmented reality to assist learners with specific spatial visualization ability in CSO learning. Moreover, although various design models have been proposed and adapted for mobile augmented reality (MAR) applications development (Cassidy & Joseph, 2023: Yuh, Kuo, Cheng & Arthur, 2019), none specifically address the simultaneous integration of engagement, motivation, and comprehension elements, leaving a critical gap in the development of design models in educational technology for MAR-based learning environments. Yet, there is still a gap in the learning CSO using augmented reality as a learning aid.

Therefore, this research intends to propose a conceptual instructional design model of Mobile Augmented Reality (MAR) application with integration of engagement, motivation, and comprehension elements, as well as to design and develop a MAR application to investigate the effectiveness of MAR to students' comprehension, learning engagement and motivation in learning CSO among polytechnic student with different spatial visualization ability.

1.4 Research Objectives

Objectives of the study are as following:

1. To design a conceptual instructional design model, MARID (Mobile Augmented Reality Instructional Design), that integrates functional and physical realism to guide the development of mobile augmented reality (MAR) applications for enhancing student comprehension, learning engagement, and motivation.
2. To design and develop two modes of Mobile Augmented Reality (MAR) application in learning Computer System Organization (CSO) course:
    a) Mobile Augmented Reality Computer Organization – Physical Realism (MARCO-PR)
    b) Mobile Augmented Reality Computer Organization – Functional Realism (MARCO-FR)
3. To investigate the effect of the MARCO modes in CSO course on students' comprehension, learning engagement and perceived motivation.
4. To investigate the effect of the MARCO modes on student Spatial Visualization Ability (SVA); High Spatial Visualization Ability (HSVA) or Low Spatial

Visualization Ability (LSVA) in CSO course on students' comprehension, learning engagement and perceived motivation.

5. To find the interaction effects between the MARCO modes and student SVA (HSVA or LSVA) in CSO course on students' comprehension, learning engagement and perceived motivations.

1.5 Research Questions

Following are the research questions for this study

1. a) What are the essential components required to design a conceptual instructional design model for a Mobile Augmented Reality (MAR) application?

   b) How are these components integrated into the two modes of Mobile Augmented Reality (MAR), specifically Functional Realism (MARCO-FR) and Physical Realism (MARCO-PR)?

2. a) How does these two modes of Mobile Augmented Reality (MAR) application designed to support different SVA in learning CSO course?

   b) What are the functionalities required in a Mobile Augmented Reality (MAR) application to support learning in the Computer System Organization (CSO) course?

3. a) Is there any significant effect of MARCO modes on students' comprehension?

b) Is there any significant effect of student SVA (HSVA or LSVA) in CSO course on students' comprehension regardless of MARCO modes?

c) Is there any interaction effect between MARCO modes with student SVA (HSVA or LSVA) in CSO course on students' comprehension?

4. a) Is there any significant effect of MARCO modes on students' learning engagement?

b) Is there any significant effect of student SVA (HSVA or LSVA) on students' learning engagement regardless of MARCO modes?

c) Is there any interaction effect between MARCO modes and SVA (HSVA or LSVA) on students' learning engagement.

5. a) Is there any significant effect of MARCO modes on students' perceived motivation?

b) Is there any significant effect of student SVA (HSVA or LSVA) on students' perceived motivation regardless of MAR modes?

c) Is there any interaction effect between MARCO modes and students SVA (HSVA or LSVA) on students' perceived motivation.

1.6 Research Hypotheses

The research hypotheses are formulated as null hypotheses. Level of significance, 0.05 ($p<0.05$) is used to determine the hypothesis decision (i.e., rejected or accepted). Nine theories were derived from those research questions.

H1a: There is no significant difference between MARCO modes on student’s comprehension.

H1b: There is no significant difference between students’ SVA on student’s comprehension regardless of MARCO modes.

H1c: There is no significant relationship effect between the MARCO modes and students’ SVA on students’ comprehension.

H2a: There is no significant difference between MARCO modes on students’ learning engagement.

H2b: There is no significant difference between students’ SVA on the students’ learning engagement regardless of MARCO modes.

H2c: There is no significant relationship effect between MARCO modes with students’ SVA on students’ learning engagement.

H3a: There is no significant difference between MARCO modes on students’ perceived motivation.

H3b: There is no significant difference between students’ SVA on the students’ perceived motivation regardless of MARCO modes.

H3c: There is no significant relationship effect between MARCO modes with students’ SVA on students’ perceived motivation.

1.7 Research Components Mapping

This section presents a systematic mapping of the research design's core elements, namely the Research Problem (RP), Research Objectives (RO), Research Questions (RQ), and (RH) Research Hypotheses. The alignment of these components is critical for ensuring logical consistency and coherence in the research framework. By establishing obvious relationships between these elements, this mapping allows for a more comprehensive understanding of how the study's objectives address the problem, how the questions drive the research, and how the hypotheses are produced and empirically evaluated. This systematic strategy assures methodological inflexibility and strengthens the overall integrity of the research design. However, RO1 and RO2 are not applicable in this context for RH, as they pertain to the design process of the conceptual instructional design model as well as the design and development proses of augmented reality application, which fall outside the scope of analytical focus. The main objective of developing the conceptual design model and augmented reality application is to perform as a tool for RQ3 to RQ5. The relationships among these elements are detailed in Table 1.1**,** providing a clear and concise representation of their alignment.

Table 1.1

Mapping table for research design elements

Research Problems	Research Objectives (RO)	Research Questions (RQ)	Research Hypothesis (RH)
MAR and Visualization	RO1	RQ1	NA
	RO2	RQ2	NA
	RO3	RQ3	RH1
	RO4	RQ4	RH2
	RO5	RQ5	RH3

NA: Not Applicable

1.8 Research Framework

The aim of this study is to discover MARCO application's effect in student comprehension, student motivation and learning engagement in CSO learning. The independent variable referred to the alternative way of instruction with two treatment modes, namely (i) Mobile Augmented Reality Computer Organization with Functional Realism (MARCO-FR) and (ii) Mobile Augmented Reality Computer Organization with Physical-Realism (MARCO-PR). The dependent variables of this study are consisted of (i) student's comprehension, (ii) student's learning engagement and (iii) student's perceived motivation. Students' visualization ability level is used as the moderating variables in this study. The general idea of MARCO application is based on O'Brien's Model of Engagement (2018) which highlight on learning engagement element. Churchill, King & Fox RASE Pedagogical Model for Integrating Technology (2013) emphasizes on the comprehension of the Computer System Organization course instructional content. Alessi & Trollip's Instructional Design System (2001) with Spatial Cognition Theory (1993) guided the MARCO application modes development process; Keller's ARCS Model of Motivational Design (1987) supports MARCO's motivational aspects. The research framework of a study is illustrated as in Figure 1.2.

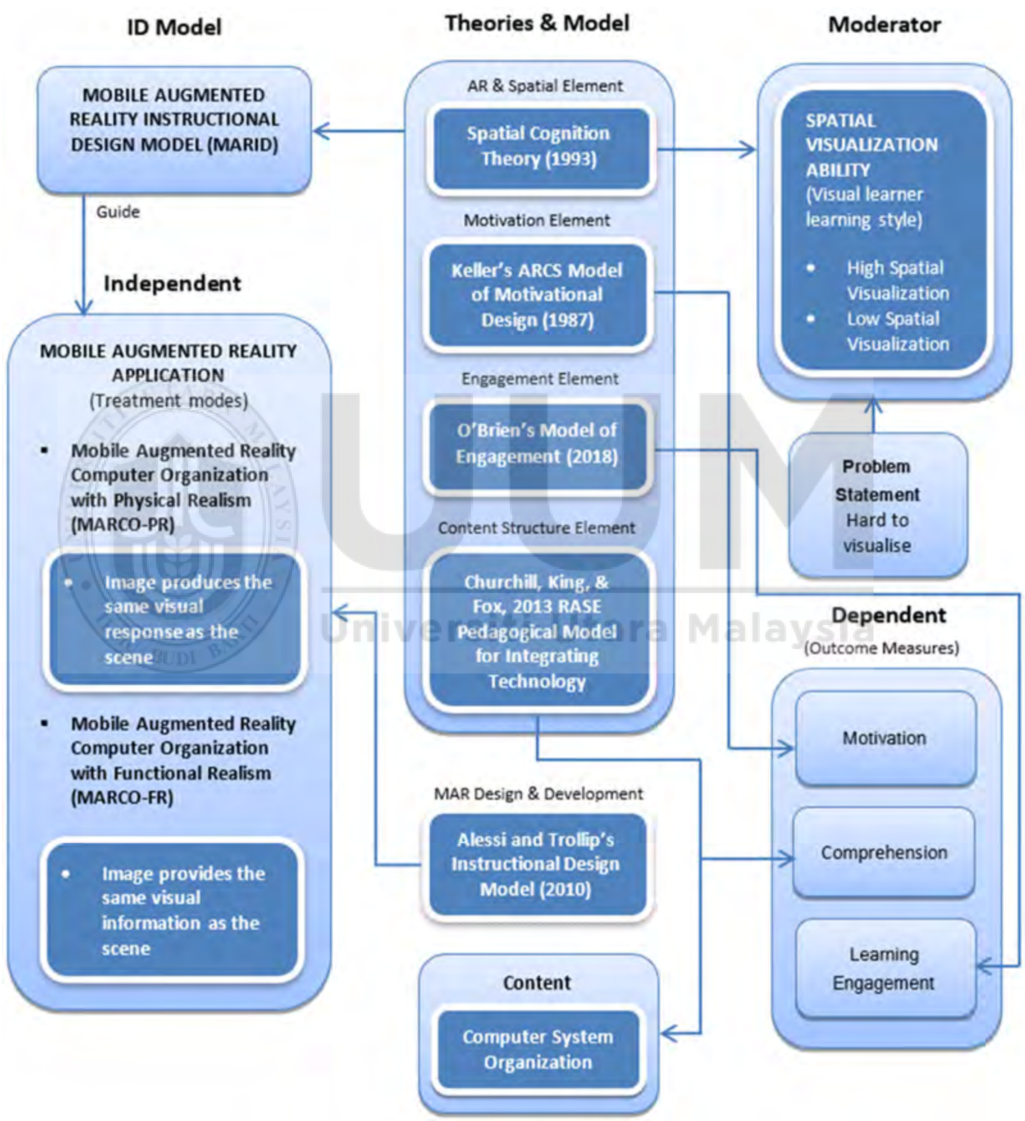

Figure 1.2 : Research framework of the study

1.9 Theoretical Framework

A theoretical framework provides the foundation for a research study by outlining the key theories and models that lead the research by connecting existing knowledge and explain the relationships between variables. Theoretical fundamental for this study is adopted from Alessi and Trollip's Instructional Design Model (2010), Spatial Cognition Theory (2013) and Churchill, King & Fox RASE Pedagogical Model for Integrating Technology (2013). Alessi and Trollip's Instructional Design Model (2010) with Spatial Cognition Theory (1993) are use as development model and theory that provide frameworks for organizing and structuring instruction as well as emphasized on the development of the MARCO modes based on mobile augmented reality environment and principles specifically addressing spatial visualization, whereas Churchill, King & Fox RASE Pedagogical Model for Integrating Technology (2013) is used as macro model and guided for comprehension of the course and course content structure and student learning outcomes aspect of the MARCO modes as well as focuses on broader learning strategies that used to facilitate course content comprehension.

Besides, this study also used the guidelines of two learning theories: O'Brien's Model of Engagement (2018) with ARCS Model of Motivational Design (Keller, 1987). O'Brien's Engagement Model (2018) emphasized the element of MAR engagement whereas ARCS Model of Motivational Design (1987) provides guidelines to develop MARCO's motivational aspect.

The dotted boxes in the diagram represent sub-categories or specific aspects within a broader category. It enables to refine and specify the theoretical underpinnings of the study, ensuring that the MARCO application is grounded in relevant and well-established theories. By breaking down the broader categories into more specific sub-categories, the researchers can more precisely target their interventions and measure their impact on learner outcomes.

Arrows in this research framework indicate a direct influence or relationship between two components. The arrow direction from spatial visualization to design & development of MARCO indicated that the understanding of spatial visualization theory drives the design and development of the MARCO application to ensure that the application effectively enhances learners' spatial visualization abilities. While arrows from macro strategies and micro strategies to design and development of MARCO indicates that the development of the MARCO application integrated by both micro and macro learning strategies which is implementing engagement and motivation elements to optimize its effectiveness in facilitating learning.

Figure 1.3 illustrates the theoretical framework for this study and detailed explanations are described in Chapter 2.

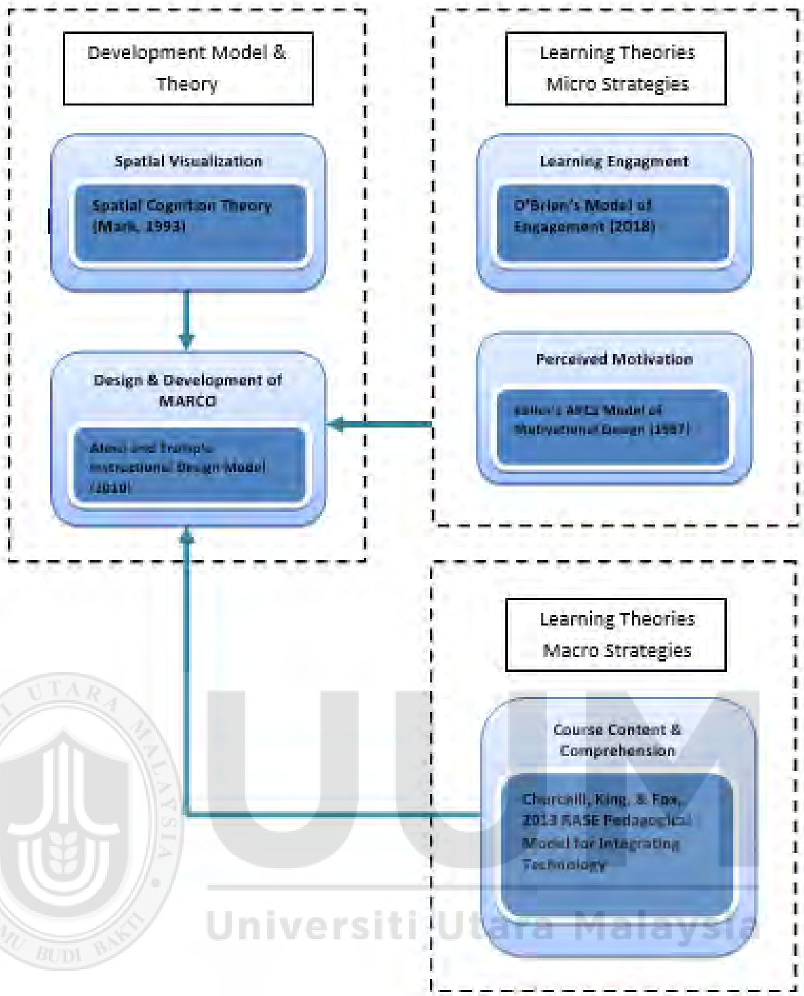

Figure 1.3 : The theoretical framework of the study

1.10 Significance of the Study

Malaysian Polytechnics plays a major role in TVET development as Malaysia's leading institution for technical and vocational education and training. New emerging technologies such the Internet of Things (IoT), big data analytics and augmented reality are likely to transform the current world's environment. Augmented reality is one of the new technologies highlighted under industrial 4.0. Based on the literature review, there is no an instructional design model that effectively integrates augmented reality (AR) with the Computer System Organization (CSO) syllabus to enhance students' comprehension, learning engagement, and perceived motivation. One of the significant findings in this study was bridging this gap by developing an instructional design model specifically for mobile augmented reality applications. Few studies also have performed to discover the effectiveness of MAR based application on learning CSO among Malaysian Polytechnic students. Another significant finding showed that MARCO application serves as a teaching aid and contributes to facilitating students in learning CSO course. The developed MARCO application would assist the students in retaining, sustaining the knowledge in CSO courses. This MARCO application was designed and developed with great concern to attract the attention of the target group and to promote their learning.

The expected result in this study is to provide useful information to different parties and offer potential solutions for polytechnic instructional strategies, including the implementation of MAR technology. Besides, it can assist Polytechnic DDT students and lecturers in the learning of CSO courses. In fact, this research reflects yet another boost to MARCO's application learning awareness. The findings of this study can oblige as a valuable resource for the Polytechnics Curriculum Division, Polytechnics and College Community Education Department (PolyCC), Ministry of Higher Education (MoHE) in developing course modules that utilize augmented reality technology-based materials. As this method of teaching is being implemented, PolyCC and MoHE, in line with its National Industrial Revolution 4.0 Policy, will also revolutionize the national education system by applying the latest technology to which students nowadays are constantly exposed, thus ensuring the integration of technology in education and keeping up with the evolving needs of the digital era. The implementation and application of various theories and concept in the development and implementation of MARCO application enables valuable information. Besides, The MARID Model provided valuable information for instructional designers by integrating, adopting, and guiding the use of this model in the future, while this study contributed as a reference for other instructional designers in the design and development of effective learning applications to facilitate active learning for students. As for future research, this study will contribute to the knowledge of MAR learning environment concepts and will also discuss the advantages (and/or disadvantages) of using MAR for students with different spatial-visualization abilities.

1.11 Scope and Limitation of Study

This study scope focuses on the effects of MAR on student comprehension, learning engagement and motivation. The data collection conducted to Semester 1 students in 12 national Polytechnics in Malaysia who enrolled in DFC1033 Introduction to Computer System (ICS) course during June 2020 session (Polytechnics Student Recruitment Division, 2020) who will represent the sample population. Learning content of this study is only focus on CLO 2 in ICS course. This study is not cover other variables that are not consider as course comprehension, learning engagement and motivation. The other students which do not fall as part of Semester 1 who enrolled in DFC1033 Introduction to Computer System (ICS) course during June 2020 session are not within the scope of this research.

Several limitations must be acknowledged when doing the research. The main limitation of the project is the lack of resources and time allocated for the creation of 3D animated content using Unity 3D for the development of the MARCO application. Preparing the necessary materials is a laborious task. Computer System Organization (CSO) requires a comprehensive understanding as it encompasses multiple computer components and the development and design of the MAR. Thus, the researcher chose for a Mobile Augmented Reality (MAR) in this study due to its cost-effectiveness, accessibility, convenience, and portability, while still offering a satisfactory immersive experience in the MAR environment. A further constraint of the project was that the research only included semester 1 students in Malaysian Polytechnics as the accessible population. Hence, the findings of this study can only be generalized to Malaysian Polytechnics.

1.12 Definition of Operational Terms

In order to ensure the correct terms are used, a list of operational definitions needs to be clearly defined.

Augmented Reality (AR)

Augmented Reality refer to the superimposing techniques in digital images that give a sense of perception or virtual reality. The AR system provides a composite view of the user that overlaid the view of the user from a real situation with a computer-generated virtual scene that provides additional information to the stage. The computer-generated virtual scene enhances the sensory perspective of virtual world.

Mobile Augmented Reality (MAR)

An augmented reality system which overlays digital information in the real world, through a mobile phone application. It expands a smartphone user's physical world interactively in real time, with virtual content generated by computer.

Mobile Augmented Reality Instructional Design (MARID)

Mobile Augmented Reality Instructional Design Mobile Augmented Reality Instructional Design (MARID) model is a instructional design model tailored specifically for Mobile Augmented Reality (MAR) applications, emphasizing the aspects of implementation, comprehension, engagement, and motivation.

Mobile Augmented Reality Computer Organization (MARCO)

MARCO is a Mobile Augmented Reality (MAR) based application for learning Computer System Organization (CSO), specifically designed and developed for Polytechnic Diploma in Information Technology (Digital Technology) (DDT) students with different spatial visualization ability. Its instructional content is based on Polytechnic DFC1033 Introduction to Computer System Course Syllabus.

Mobile Augmented Reality Computer Organization with Physical Realism (MARCO-PR)

Mobile Augmented Reality Computer Organization with Physical Realism (MARCO-PR) provides an image similar to visual response as the real scene. It contains additional information (i.e.: 3D model, animation, text) for particular visible objects. Augmented Reality marker will trigger by a real object. Physical realism in augmented reality pertains to the ability of the technology to accurately represent the physical properties of virtual objects in relation to the physical world. It emphasizes the accuracy and fidelity of the virtual objects, ensuring they behave and interact realistically.

Mobile Augmented Reality Computer Organization with Functional Realism (MARCO-FR)

Mobile Augmented Reality Computer Organization with Functional Realism (MARCO-PR) provides virtual images that same with visual information as a scene. Augmented Reality marker will trigger by image assign. Functional realism refers to the extent to which augmented reality technology can provide users with a realistic and functional experience by overlaying virtual objects or information onto the physical world. It focuses on the usability and practicality of the augmented reality system in achieving specific tasks and goals effectively.

Computer System Organization (CSO)

Computer System Organization course is a core subject in Department of Information and Communication Technology (Digital Technology) (DDT) in Malaysian Polytechnics. Designed to introduce the fundamental concepts of a computer system. These include the physical units of a computer component hardware and assembly.

Topics Comprehension

Refers to the ability to process information that students have read and understand its meaning. This involves levels of understanding in a particular topic (Computer System Organization) to measure the degree of any changes in this knowledge or understanding.

Learning Engagement

Refers to the degree of focus attention, usability, user satisfaction, inspiration and reward factor that students respond during learning sessions. It also refers to the level of inspiration student's experiences. Learning Engagement can be measure using User Engagement Scale (UES).

Perceived Motivation

Related to sustaining behavior, engaging students and inspiring them to keep going and guide them in a particular direction. The perceived motivation may be assessed using the Instructional Materials Motivation Survey (IMMS).

Spatial Visualization Ability

Refers to the ability of students to experience and interpret visual information. The processing of visual information is the visual perception ability that show the pupil on how to interpret and understand the significance of the visual knowledge obtained by their eyesight. It is also called visual learning. Visual learning is a system of maps, tables, illustrations, and symbols used by the learner. Spatial Visualization Test Instrument (SVATI) can be used to test simulation level.

Students High Spatial Visualization (HSVA)

Students who scored above 50% in PSVT mean to have a high visual learning style. These students prefer to learn by using methods that are primarily visual and have a strong sense of color, shape and pattern.

Students Low Spatial Visualization (LSVA)

Students who scored lower than 50% in PSVT mean to have a low visual learning style. These students prefer to learn by using other methods of learning style such as aural, verbal and psychical.

1.13 Summary

In this chapter discussed on the research background, research issues in the problem statement, aim of the study, a list of objectives, and followed by research questions. The theoretical and research framework were also listed, in order to complete the thesis. In this study, the theories implemented were discussed briefly. Finally, the chapter concluded with the operational terms' definition used in this study. In the next chapter, a review of relevant prior research and its analysis are presented.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter discusses the notable publications from various disciplines that are related to the research field. It also includes published data that provide evidence for the validity of the theories and models used in this study. Furthermore, this study aims to identify the research gap in Mobile Augmented Reality (MAR) technology as it relates to studying the Computer System Organization (CSO) course. The background details and literature review connected to MAR, CSO and studies linked to the research variables are also discussed. The subsequent chapter then continues with an overview of all pertinent learning theories, frameworks and models. In addition, this chapter examines all interconnected resources and previous research including other relevant variables in this research.

2.2 Computer System Organization (CSO)

Computer system organization (CSO) is one of the core courses in the Malaysian Polytechnic Digital Technology Diploma (DDT) programs. CSO course is designed to introduce computer system course that emphasized on hardware, software including assembly and upgrading computer components, installing software and connecting peripherals (Polytechnic DFC1033 Introduction to Computer System Curriculum, 2017). This course is a foundation for basic Information and Communication Technology (ICT) knowledge and skills, which is necessary for ICT professionals and the component in the Body of Knowledge (BoK) in Computing Studies. Students will be introduced to the values and best practices of environmentally sustainable computing and the use of innovations and ICT environment management methodologies. Also, all computing students must develop an understanding of the characteristics, efficiency and interaction of the functional components of the computer system (Stalling, 2013). Fahri (2017) stated, in CSO course learning, it is vital for students to be equipped with sufficiency skills and fundamental understanding in using advance computer technology that will be useful in their future undertaking after graduate. Sirakaya (2018a) clarified in their research that learning CSO is mostly related to understanding technical concept and visualization of computer functionality and component. According to Andrews & Dark (2019), proficiency in CSO course opens career opportunities in computer maintenance, technical support, system administration, and IT consulting. It serves as a foundational skill for individuals pursuing careers in the field of computer technology and system maintenance. Hence, in this continuous technology development, CSO course learning can inspire students to acquire skills relevant to the current trend of modern computing (Stallings, 2018).

Learning CSO is crucial for students, as it provides a solid foundation for comprehending the inner workings of computer systems. However, many students encounter challenges in grasping the complex concepts and practical applications of this course (Dewan, Mamun & Rahman, 2020). Research carried out by Mustapha (2018) on CSO course in Malaysian Polytechnics indicates the factor that affects student performance in CSO course is because of inadequate learning material and practical exercise which is consistent with the finding from literature reviews that discovered the common problem in CSO course is it tends to be somewhat technical, dry and theoretical and also lack of physical computer component for practical session, which can lead to demotivation and decrease of spatial visualization ability among students (Veni, 2014; Raven et al., 2016; Alqathani et al., 2017). According to Ali et al., (2018), the most common problems that student faced while learning computer components without having a hands-on session is their lack of visualization tools and skills (Wei, 2019; Akçayır, 2023).

To deal with these challenges, experts have proposed various approaches to solve this technical and abstract visualization issue in CSO course. One of the approaches is to combine learning strategies in the classroom with technology as learning aids (Liarokapis & Anderson, 2010; Hou, 2013; Shirazi 2014; Rizov & Rizova, 2015; Patel, 2017; Pantelic, 2017; Wei, 2019; Dewan et al., 2020). Furthermore, students would discover that incorporating technology into the learning process by implementing an affective learning aid would increase their motivation and learning engagement (Sirakaya 2018b; Liarokapis et al. ,2010; Henrie, 2016; Lin et al., 2023).

One effective approach to enhance learning in CSO is to employ visualization strategies as effective learning aids. Visualization techniques, such as interactive AR simulations, facilitate the understanding of complex concepts by providing visual representations of abstract ideas and making the learning process more engaging, motivating and effective (Xie, Liu & Sun, 2021). Shabiralyani, Hasan, Hamad & Iqbal, (2015) stated that visual learning strategies stimulate learners ' interest, foster the learning process, gain motivation and help lecturers to explain effectively. Good visual learning strategies can guide to solve spatial-visual problem as they provide an accurate visual image of an object (Shabiralyani et al., 2015). Similarly, Heinrich, Bornemann, Lawonn and Hansen (2019) notes that visualization technique with additional contextual information have become a powerful tool for investigating real-world processes. A range of visual learning strategies is required to improve students' motivation, engagement and comprehend in CSO course. Visual learning strategies are vital to assist learners in developing visual thinking and providing them with an enhanced learning tool (Raiyn, 2016). The next section will provide details explanation of visual learning approach potential and its benefits toward improving learning process.

2.3 Visualization Learning Strategies

Previous literature on CSO emphasized visualization has significant affective on student performance, motivation and learning engagement. (Ke et al., 2005; Seok & Kim, 2008; Rizal 2009; Chen et al, 2013; Fahri, 2017; Alqahtani 2017; Sirakaya, 2018a). Moreover, the utilization of digital technology for visualization purposes holds significant potential across various domains, since it may intelligently address the constraints associated with conventional teaching approaches. (Gargish, Mantri, Kaur, 2020). Visual learning is from the process of acquiring knowledge through visual presentations. It involves mixing ideas and concepts with graphic representations to enhance understanding and retention of information (Raiyn, 2016). Visual information is commonly displayed through various multimedia tools (i.e. images, diagrams, simulations, graphs, 2D and 3D graphics (Felder, 1993; Rodger et al. 2009; Lu, 2018). Furthermore, visual learners are more attentive to learn and remember learning contents with graphics such as via images and illustrations (Gappi, 2013).

Consistently, numerous researchers have been well alert of the importance of visualization learning in improving comprehension, engagement and motivation among students (Ke, Kang,Chen & Li, 2005; Seok & Kim, 2008; Rizal 2009; Chen & Teh, 2013; Fahri, 2017; Alqahtani 2017; Sirakaya, 2018a;). As they mention, visualization skills are a crucial factor that can lead to student's improvement in learning and understanding visual object and mental images of the computer functions and components along with improving learning engagement and motivation. Visualization skills are the process of eliciting the memory to mentally produce images and are also known as the ability to mentally picture 3D images or shape (Ali et al., 2018).

Visualization learning tools are among the most crucial learning process technologies at all levels. Because of the vital role of perceiving, interpreting and manipulating 3D spatial relationships for learning and problem-solving in many areas educational researchers have made significant efforts to develop and incorporate visualization learning tools (Stieff, Bateman & Uttal 2005). Although such tools exist for most areas, CSO is one of the areas required for visualization tools, because their disciplines require multiple, three-dimensional spatial relationships to facilitate the assembly of computer hardware (Hou, 2013; Veni 2013). According to recent research conducted by Zhao, Li & Ma (2022), visualization strategies significantly improve students' comprehension, engagement, and retention of course material. Similarly, the study by Chen, Liu & Xu (2021), highlights that incorporating visualizations in computer education promotes active learning and facilitates the development of problem-solving skills. Hence, by providing appropriate visualization learning tools (e.g., 3D visual environments), it can support students to develop their visual thinking, perceive information effectively and sustain attention and interest to the course (Rizov et al., 2015; Raiyn, 2016).

By integrating visualization with augmented reality (AR), users may engage in interactive and captivating depictions of information (Li, 2022). AR improves the visualization process by combining visual elements and digital overlays with the real-world environment. This integration creates dynamic and captivating experiences that encourage a better understanding and longer retention of knowledge (Kim, 2021). AR technologies have the potential to be used in educational applications and can have a significant influence on learning and education (Nincarean, Ali, Halim & Rahman, 2013). AR is a technology that combines virtual images, 3D objects, and multimedia components with the real-world environment that the user sees. It also includes computer-generated virtual scenarios (Hibberd, Johnson, To & Swati, 2013; Kesim & Ozarslan, 2012). According to Saidin, Halim, and Yahaya (2014), the use of AR has been proven to enhance student's ability to visualize abstract and technical ideas.

The concept of the visualization learning strategy in AR is to allow students to comprehend knowledge that may not be immediately relevant through conventional or traditional methods. Enhancing students' ability to visualize would facilitate their performance of every practical task and activity, such as the installation of a computer system (Rizov et al., 2015). In this instructional approach, students are requiring to choose a lesson inside the AR learning environment and pick appropriate learning tools to display the visual content. The student must adhere to the instruction and complete the assignment given as depicted in Figure 2.1.

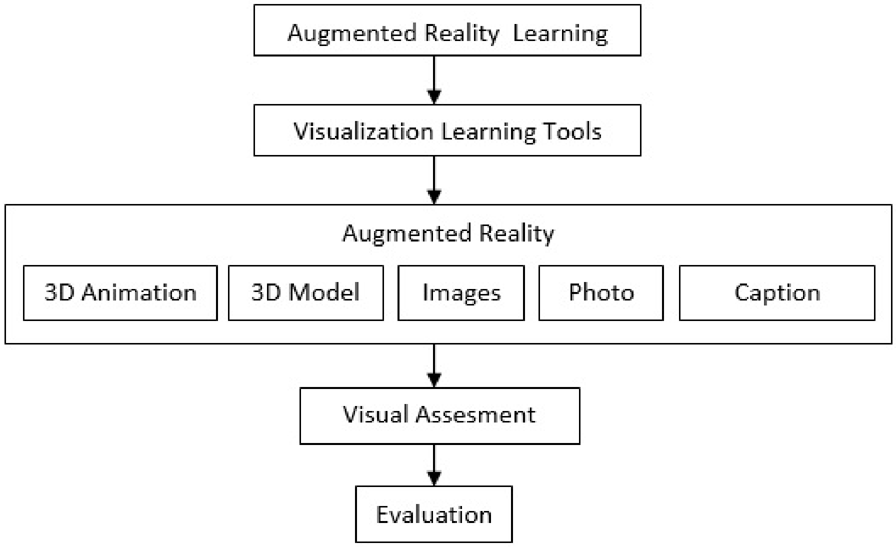

Figure 2.1 : Visualization learning strategy using AR.

According to Chen et al. (2021), utilizing visualization learning strategies in combination with AR technology can significantly enhance individuals' spatial visualization abilities. By providing immersive and interactive experiences, AR enables learners to visualize and manipulate virtual objects in three-dimensional space, fostering a deeper understanding of spatial relationships (Zhang, 2021). The next section will provide details explanation of AR technology and its advantages toward improving visualization.

2.4 Augmented Reality

Research have shown that the use of Augmented Reality (AR) will triggers the visualization enhancements as it allows users to overlay digital information onto their real-world environment, enhancing their perception and understanding of the surroundings (Marques, 2021). General description of the term AR is a digital display that overlays virtual graphics with physical reality (Vyas, 2015). To further understands this technology, it is essential to take into consideration the early definitions of previous research on the development of AR technology. Several studies have explored several definitions of AR. Tom Caudell and David Mizell first used the term AR in their work for Boeing in the early 1990s, where they created the head-mounted display (HMD) displaying basic wireframes, schematic diagrams, models and text shown throughout the physical world (Caudell, & Mizell, 1992). Dunser and Billinghurst (2012) propose the notion of AR, which involves the merging of real-world elements within the present context. Also, a simulated interface model often aligns itself internally with real-world orientation. According to El Sayed, Zayed & Sharawy (2011), AR allows the unknown or incomplete real-life details to be applied to the real scenarios which make up a complete scenario. Similarly, Chen & Tsai (2013) pointed out that AR helps interact with 2D or 3D virtual objects located in a real-world situation. In the same way, Cuendet, Bonnard, Do-Lenh, & Dillenbourg, (2013) reported that AR refers to techniques imposing abstract materials on real world objects.

Besides, a study outlined that AR technologies that enable users to view the real world but add them to virtual 3D objects and appear to coexist with the real world (Ko, 2013). Craig (2013) defined that AR is not just a specific technology but as a medium utilizing a multitude of technologies. AR technology is a world experience that can be improved by incorporating digital information to improve a person's understanding of reality (Bayu et al. 2013). AR allows users to be active in the environment and enhances users' awareness by providing users with contextually relevant knowledge beyond the user's actual perceived presence (Qiao, Dustdar & Junliang, 2019). Wei (2019) points out that AR technology produces virtual digital worlds in real time, thereby effortlessly combining them with the physical world to create more realistic and practical results.

Milgram and Kitshino (1994) did a conceptual study on mixed reality, which incorporates both the real physical environment and the virtual environment. Figure 2.2 displays a visual depiction of the mixed reality continuum. Mixed reality is the space that lies between a completely virtual environment, where all inputs are digitally created, and the physical world, which does not entail any digital simulation of information. AR is categorized as a type of mixed reality, where users experience a blend of actual physical elements and computer-generated simulations (Azuma, 1997; Milgram & Kitshino, 1994).

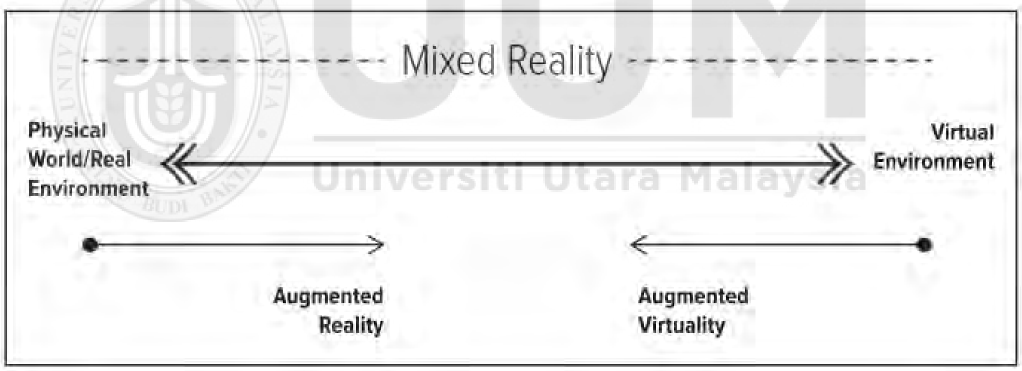

Figure 2.2 : Milgram and Kishino's Reality-Virtuality continuum graphic (Milgram & Kitshino, 1994)

On the other hand, Azuma (2020) have published a comprehensive paper examining the existing varied uses for AR inline with research done by Milgram and Kitshino (1994). Azuma (2020) identifies and characterized AR technology by three main features: real-time interaction, virtual object integration, and spatial mapping. These features enable users to interact with virtual content overlaid on the real world, seamlessly integrating digital elements into their physical environment. Research conducted by Azuma, R., et al. (2020) and Wang, Z., et al. (2021) validates the significance of these features in augmenting user experiences, providing valuable insights into the current capabilities and potential applications of AR technology.

AR technology has evolved over the last decade to improve AR effectiveness and reliability, while the central architecture of AR is not altered (Nazatul, 2015). AR is composed of four main components as follows:

i. Camera - A device camera for capturing and tracking target information which is the marker for AR. Accuracy of the tracking depends on camera quality.
ii. Marker - Marker is the target information to trigger digital content into the device.
iii. Device - Device to store, process information and display digital content through device screen when device camera detecting specific AR marker. AR's developments are currently proliferating on the mobile device (mobile phones / tablet), evidenced by the rise in handheld devices, leading to the creation of an AR subset: Mobile AR (MAR).
iv. Digital content - A digital content will appear on the display screen when the camera is capable of detecting the AR marker.

The interactive relationship between different AR components is illustrated below in Figure 2.3.

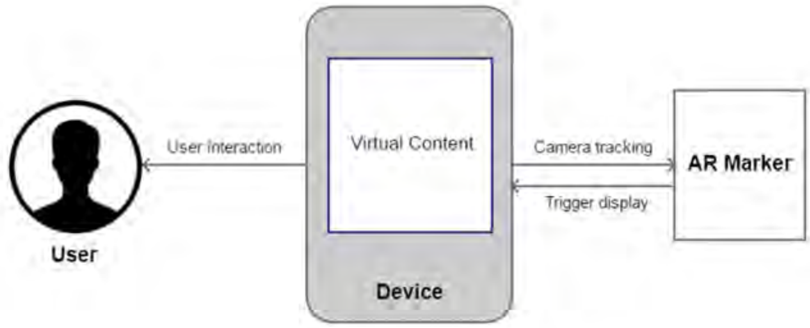

Figure 2.3 : AR architecture comprised by four elements. (Nazatul, 2015)

With the rapid technology development, educators are constantly looking to add new technologies to enhance their learning and teaching experience. The AR is one of the fast-growing innovations with great educational promise that educational researchers are gradually noticing. The ability to combine virtual and real worlds has given rise to new opportunities to improve the quality of teaching and learning activities. AR effectiveness can be further improved by integration with other forms of emerging technology. Mobile AR (MAR) has to do with innovative technology, such as smartphones or handheld devices. The next section will provide details explanation of MAR potential and its benefits toward education.

2.4.1 Mobile Augmented Reality (MAR)

The progress of AR on mobile devices has been rapidly expanding, as seen by the rising popularity of portable computer worldwide in recent years. In order to enhance the interactivity, entertainment, and educational value of the applications, MAR applications were developed (Baker, Bakar & Zulkifli, 2018). The progress of MAR has been enhanced by advancements in three key technologies: (a) the creation of specialized AR applications for handheld and desktop devices (such as iPad, Mobile

Phones, Google Glass, Apple Vision and Microsoft HoloLens) and availability of versatile development kits (such as ARCore and ARKit); (b) improvements in handheld device performance and sensor integration; (c) progress in computer vision (CV) technologies (Qiao et al., 2019). MAR systems require the utilization of portable mobile interfaces to enable users to interact with digital information that overlays actual items or actual items or surfaces in a conventional and socially acceptable manner. Implementing AR on mobile phones is highly convenient because most mobile devices are now equipped with cameras.

Modern mobile devices are now equipped with powerful processors, large memory capacities, high-resolution cameras, advanced multimedia features and a range of sensors. In addition, the enhanced connection provided by 5G technology can fulfill the basic hardware needs for AR on mobile phones (Arulanand, Ramesh Babu & Rajesh, 2020). The MAR technology enables the seamless integration of virtual information into a person's actual surroundings, without confining the user to a specific equipped space. Users should ideally be able to operate in any location and have all the necessary information readily available for any given situations. Thus, the method of transforming the way knowledge is conveyed to individuals is assured (Höllerer & Feiner, 2004). Mobility is a fundamental characteristic of MAR technology, which allows transmission of information in many situations, beyond the constraint of conventional location-based systems (Cao, Lam, Lee, Liu, Hui & Su, 2023).

In addition, the ownership of mobile devices has resulted in a heightened desire to integrate the benefits of intelligent computing and AR technology throughout educational sessions. The integration of AR technology on mobile devices has become viable due to advancements in mobile technology such as built-in cameras, virtual cloud computing, big data, crowd sourcing (Chatzopoulos, Bermejo, Huang & Hui, 2017). Due to its portability, several MAR applications are designed to operate on mobile or wearable devices such as laptops, smart glasses, smartphones, tablets and TVs. If a mobile application has the following features, a MAR application can be defined as:

i. Input - This includes the device's various sensors (camera, gyroscope, microphone, GPS), as well as any system that surrounds this. Smartphones usually come with digital sensors.
ii. Processing - This specifies the type of information that will be made in the mobile device screen. The processing process required a remote database and local access in the device.
iii. Output - The screen presentation of the current view of the users and the mobile device.

The best option for universal mobile AR is the smartphones. This is due to its higher computing power, portability, camera quality and allows user to just point and hold smartphones camera for activation of AR utility. However, it also depends on the generality of smartphones, the storage and rendering capabilities of the device and the quality of the camera.

Smartphone’s memory and storage size is also an important parameter that needs to be considered. Presently, the advancements of smartphones technology are now growing rapidly. Smartphones are now equipped with robust hardware capabilities, powerful processor and extensive mobile operating systems, which facilitate wider software compatibility, and multimedia functionality (including camera and video), alongside with high resolutions smartphones screen. For MAR application to run in smartphones, it requires a good amount of graphics memory. Nowadays, with technological advancement in smartphones visual processing allows MAR to be implemented effectively through smartphones. A key aspect of the MAR application is its capability to track and record information in real-world connection with digital content with a physical object. Two predominant forms of tracking and recognition are generally used are vision-based or marker-based AR markers and position based or markerless AR marker (Dunleavy & Dede, 2014; Yuen, Yaoyuneyong & Johnson, 2011). Therefore, the next section will be introducing and discussing MAR with tracking marker technology.

2.4.2 Augmented Reality Marker Tracking Technology

A marker is an essential element for applying the AR. Markers are physical objects or locations where the real and virtual realities combine (Kipper & Rambolla, 2013). It is what the computer defines on which digital data (text, photographs or 3D models) is to be overlaid with real objects of the physical environment, while at the same time producing new experiences for learners in real time (Pombo & Marques, 2017).

Similarly, Bacca, Baldiris, Fabregat and Graf (2014) defined AR markers as images or objects identified with an application which are used as trigger in user application. When a computer's camera senses these markers in real-world when operating an AR program, it allows the visual material to be projected in camera view over the actual position of the marker (Pathania, Mantri, Kaur, Singh & Sharma, 2023).

Regarding AR styles, in particular for an educational setting, Dunleavy and Dede (2014) and Yuen et al. (2011) established two primary modes in AR systems to gather information that are commonly used by educators. Both types are vision-based or marker-based AR and position-based or markerless AR.

AR Marker or vision-based tracking systems comprise of visual elements positioned in the area and automatically identified in live video camera using an associated recognition algorithm. The virtual characters move and appears to the real object, simultaneously when the user moves the marker (Billinghurst et al., 2001). Marker-based AR uses a variety of elements such as actual 3D objects or printed image targets as markers to simulate by scanning cameras or smartphones. Therefore, these visual codes would be interpreted by software or mobile applications that respond to the information (Kaenchan, 2018).

They are various number of different marker type used as marker-based tracking such as physical 3D object, QR codes, 2D tags and image targets. The most popular type of AR marker for an educational setting is a physical 3D object recognition and image target (Dunleavy & Dede, 2014). In terms of tracking technology, marker-based solutions are generally favored because of better accuracy and flexibility in implementation than markerless solutions (Bottani & Vignali, 2019).

Image target is one of the types of markers used for Marker based tracking. These are images which register with the application manually and function as triggers that show virtual content. The use of images for image targets consists of various types with complex outlines. This facilitates the detection of image recognition and tracking algorithms (Unity Documentation, 2019).

Physical 3D object recognition is a specific type of marker used in Marker-based tracking that recognize 3D physical object as a marker. 3D physical object is scanned, and the object data files will be register as an object target in the application. This physical 3D object will function as triggers that display virtual content (Vuforia Developer Library, 2017). It gives superior experiences an improved interaction with the 3D objects (Suriya, 2016).

The second forms of the marker are markerless AR. Markerless tracking refers to a type of AR that relies on the location or position of objects, rather than using markers. This tracking methodology relies on cutting-edge technologies such as GPS, accelerometers, gyroscopes, and sophisticated algorithms for rendering virtual objects or enhancing features in the environment. AR technology and software would manipulate these things as if they were physically connected or associated with real-world locations or objects. Markerless AR, on the other hand, utilizes location-based data from mobile devices, specifically the Global Positioning System (GPS), to analyze AR data. Markerless AR technology utilizes the actual environmental location to generate a reaction, whereas marker-based AR involves placing codes or images in a real environment that trigger a predetermined response.

Nevertheless, both types of AR marker tracking technology (marker-based AR and markerless AR) demand specific AR tools or programs to work. However, the preeminent AR visualization technique to present digital input are depending on the purpose of the MAR application. AR marker-based technology is particularly well-suited for visualizing the assembly of components, identifying individual components, and facilitating simulations, as it enables precise tracking and recognition of specific markers, enhancing the accuracy and efficiency of the visualization process (Kumar et al., 2022). In the development of MARCO application, the introducing of marker-based AR brings multiple advantages and wide potential consequences for the growth of educational and learning environments (Ozerbas, 2019; Billinghurst, 2002; Klopfer & Squire, 2008; Cooperstock, 2001; Shelton & Hedley, 2002). Marker-based AR are preferred for simulation, task assembly and academic studies (Imbert, Vignat, Kaewrat & Boonbrahm, 2013). In particular, the usefulness of marker-based AR technology was shown when computer motherboards were installed (Safiani et al., 2020). This is demonstrated as users can complete task assembly using AR instructions in a shorter time compared to common displays or manuals (Nazatul et al. 2014; Pantelic et al. 2017).

The efficiency of the AR visualization process is closely tied to the degree of realism, as higher levels of realism in AR systems result in the production of high-quality visual outputs that accurately represent the real world (Lee et al., 2020). Through the improving technology in smartphones graphics processing memory, allows virtual scene can be rendered in a very high-quality visual realism output (Haller, 2004). In the next section, will be discuss on type of realism in AR for enhancing visual realism in MAR application.

2.4.3 Augmented Reality with Realism

Various approaches have been proposed to enhance the precision of AR experiences in literature. Engaging with virtual items in AR sometimes lacked realism compared to doing experiments with tangible materials, as the virtual models lacked physical qualities. The virtual analysis will replicate the actual experiment by projecting the presence of virtual and real objects in the same place (Montero, Zarraonandia, Diaz & Aedo, 2019; Imbert et al., 2013). Haller (2004) discovered that realistic experiences enable users to actively participate and feel immersed in them, while higher abstraction stimulates users' senses and enhances their thoughtful of being there in any location.

The goal of AR is to provide realistic representations of a simulated environment that effectively transmit the same immersive experience as a real-life scenario and captivate the interest of consumers (Haller, 2004). For effective student engagement, diverse MAR applications in education require practical interactions with real-world objects or interactions between users and virtual things. Sugara and Mustika (2017) suggested that learners can enhance their desire to learn and improve their education practices based on realism. According to Khan, Johnston and Ophoff (2019), AR offers immersive experiences and can create interaction, interactivity and a greater degree of realism for actual learners. The use of enhancement graphics in actual environment is preferred for providing instructions. These enhancements are designed to draw attention and enable users to focus more on efficient visualization of the information presented (Westerfield, Mitrovic & Billihurst, 2015). From the perspective of the learner, AR provides useful guidance in the actual world and enables the efficient gathering and input of vital information to assist with user assembly tasks (Yuan, Ong & Nee 2008). Sirakaya et al. (2018) introduced the MAR application for computer hardware assembly of computer hardware. With respect to graphical realism, the findings from this application suggested that AR-assisted conditions were ideal for assembly tasks rather than paper-based manuals (Yuan et al. 2008). According to researchers, integrating AR can enhance learners' willingmess to study and improve their practical class practices (Chang, Morreale and Medicherla, 2010).

Ferwerda (2003) states that there are three levels of graphic realism differ in the extent to which visual coding is used to establish reality:

i. Physical Realism - the process of creating a visual representation that closely resembles a real-life scenario. The image must have precise depictions of the scene's shapes, textures, and illumination characteristics.
ii. Photorealism - The ability of a picture to evoke the same emotional response as a genuine situation, making it indistinguishable from reality. Image recognition systems are limited by the mechanical aspects and can only accurately replicate pictures to the extent that display technology can accurately present them or as they are understood by human visual perception.
iii. Functional realism – the ability of non-photographic pictures to convey the same visual information as an actual situation. Knowledge in this context refers to the understanding of the many characteristics of things at a certain

location, including their forms, heights, locations, motions, and materials. This understanding enables an observer to make accurate judgements and visual observations.

Similarly, a significant portion of these levels of graphical realism are utilised in the visual content of the MARCO programme. The objective of this study is to enhance the realism of the augmented reality (AR) experience for learners through the use of MARCO application's visual content. The MARCO application effectively uses two distinct forms of realism: physical realism and functional realism. According to Azuma (2020), physical realism, focuses on achieving visual coherence and seamless integration of virtual objects with the real-world environment. This involves aligning virtual objects with real-world spatial features, lighting, and textures to create a convincing and believable AR experience. According to Haller (2004), physical realism has the ability to engage learners, enhance visual perception, and provide a sense of presence in the virtual world. Moreover, as noted by Siltanen (2012), physical realism is used to emphasis augmentation and preferable in which AR is used to give instruction where it enables better visualization as the learners can concentrate on the visual content to be conveyed. On the other hand, according to Diegman (2015) and Liarokapis (2010), functional realism allows learner to receive immediate visual feedback on how a given object would look in a different setting and interaction between objects as well as the related properties of objects. Functional realism is also referring to the ability of AR systems to simulate the functionalities and behaviors of virtual objects realistically. This includes their interactions, movements, and responses to user input (Billinghurst, 2015).

Moreover, both physical and functional realism supports the understanding of 3D shapes. Integrating realistic and interactive AR information with the actual environment provides learners with a truly enjoyable experience (Montero et al., 2019). The literature review further supports the idea of how spatial visualization ability interacts with the way in which visual information is interpreted and processed regarding visual realism (Arzu Rebecca, Kai-Florian, John & Sara. 2017). Tarampi (2016) observed that learners for high spatial visualization abilities tend to prefer practical displays when utilizing AR technology, whereas those with low spatial visualization abilities may benefit from more visually guided or explicit displays with additional visual cues, annotations, or step-by-step instructions to support comprehension and task completion.

Previous research has demonstrated that spatial visualisation skills are crucial for activities involving assembly and for comprehending visual material that is enhanced by visual reality. MAR technology offers significant potential and a wide range of educational applications. AR features can inspire and include learners with varying spatial visualisation abilities, facilitating their learning process and aiding in the development of their visualisation skills (Saidin, Halim & Yahya, 2015). Kerdjoudj (2018), demonstrate the positive impact of AR based learning on knowledge retention and comprehension by enhances understanding, engagement and knowledge retention by providing visual and interactive representations in immersive way (Li, 2021). In the next section, will provide details explanation on theory underpinned for MAR based learning.

2.4.4 Theoretical Underpinned for Augmented Reality Learning

This section sets out the relevant theories used to justify the suggested benefits of using AR visualization in learning CSO course. Taking these multi-perspective theoretical foundations into consideration leads to an interpretation of how AR visualization could operate as an interface for assembly guidance such as computer component assembly. Moreover, AR has characteristics which can be presumed by incorporating the following theory.

2.4.4.1 Spatial Cognition Theory

Considering that the visual-spatial aspect is crucial in AR technologies, it should be based on the traditional theory of spatial cognition (Mark 1993). Even though spatial cognition theories are relatively old, they continue to be relevant in understanding how AR technology can augment spatial cognition and enhance learning experiences as well as provide valuable insights into the benefits of AR technology for enhancing spatial cognition (Ware, 2019). There are four key point that underpinned relationship between AR and spatial cognition in various domains:

i. Embodied cognition: AR enhances embodied cognition by integrating virtual elements into the physical environment, allowing users to interact with and manipulate virtual objects within their spatial surroundings. This aligns with the concept that cognition is influenced by bodily experiences.

ii. Mental mapping and spatial representation - AR overlays virtual content onto real-world settings, facilitating the creation of mental maps and spatial representations. Users can visually perceive and navigate spatial information, aiding in the development of mental models and cognitive maps of physical spaces.

iii. Spatial awareness and navigation skills - AR provides visual cues and markers that assist users in understanding their spatial orientation, position, and relationships within a given environment. This supports the enhancement of spatial awareness and navigation skills, especially in training or real-world navigation scenarios.

iv. Spatial problem-solving and reasoning - By manipulating virtual objects and exploring their spatial relationships in AR environments, users can engage in spatial problem-solving and develop spatial reasoning skills. AR allows for hands-on interaction with spatial data, leading to improved spatial problem-solving abilities. (Ware, 2019; Hecht & Savio-Ramos, 2019).

The application of AR technology allows for a direct connection between spatial cognition and spatial topology, enabling users to interact with and perceive spatial information in a more immersive and engaging manner (Kwon, Park & Lee, 2021). There are two topology categories that endorse the notion of spatial cognition (Mark, 1993): Visual-spatial knowledge and Visual-spatial space topology.

Visual-spatial knowledge topology:

i. Procedural knowledge - This helps learners to navigate in a geographical area and provides the basis for navigation.

ii. Declarative knowledge – Allows students to determine the substantial facts about and objects within geographical space.

iii. Configurational knowledge – Refers to geographical spatial knowledge, commonly found to be map-based with information about distances and relationships between spatial objects or entities and relative positions, orientation. (Golledge, 1991; Mark & Freundschuh, 1995).

Visual-spatial space topology:

i. Haptic space - The visual –spatial knowledge that is related to the motion of the objects or body.
ii. Pictorial space - The understanding of space which is based on the visual context.
iii. Trans perceptual space - The visual-spatial knowledge that consists of several sources of information or experience at the certain time. (Mark, 1993).

AR visualization is considered to be the incorporation of procedural or configuration of information into the visual-spatial knowledge topology (Shelton & Hedley 2002; Kwon, Park & Lee, 2021). AR can also be procedural, as it provides a 3D perspective and lets users to experience it in a virtual setting. This is made possible by the ability to rotate, zoom, or animation the 3D objects. It might also be configurational due to the interactive modalities, where a user physically holds an object and perceives the complete geographical environment from their own perspective. Enhancing the cognitive process via which individuals understand, verify, calculate, and execute spatial awareness would enhance the overall perception of three-dimensional material for users of augmented reality.

AR visualisation can encompass both haptic and pictorial spaces allowing for the integration of physical action and visual input to acquire visual-spatial knowledge based on the visual-spatial space topology. The traditional theory of spatial cognition demonstrates that physical action involves not only the management of specific conditions, but also has a strong connection to procedural knowledge, which is the initial form of visual-spatial knowledge topology (Mark 1993). Additionally, the integration of procedural knowledge and manipulation of situation could significantly improve the visual perception and spatial information. Therefore, AR visualisation demonstrates its benefits of accurate understanding and perception by utilising haptic visual-spatial spaces and intense imagery obtained via active engagement and stimulation (Hou, 2013). This theory of spatial cognition provides essential insight through the development of Mobile Augmented Reality for Computer Organization (MARCO). The in-depth explanation of each topology applied in MARCO application modes are discussed in chapter 4.3.

The incorporation of visual, spatial and sensorimotor feedback might also enable AR visualization to utilize its full potential. As a result, AR visualization has been recommended as an effective spatial visualization tool for users to provide manipulation inputs associated with spatial and visual indication due to sensorimotor feedback while also essential to guide tasks assembling due to the spatial and visual indication set in daily user environments (Hou, 2013). The efficiency of AR visualization plays a vital role in leveraging the benefits and advantages of AR technology in the field of education, enabling interactive and immersive learning experiences that enhance student engagement, motivation, knowledge retention, and comprehension. (Akçayır & Akçayır, 2017). In the next section, will provide details discussion on AR in education.

2.4.5 Augmented Reality in Education

The utilization of MAR applications has significantly benefited the field of education. Research in the field of education has traditionally centered around identifying effective instructional strategies that promote active learning, enhance student engagement, motivation and develop students' competence in the digital era (Gargish et al., 2020). While various educational approaches can be helpful, there is a growing interest among educators and academics in creating more efficient strategies to improve teaching and learning settings and foster innovation among students (Elmqaddem, 2019). In recent years, the rapid growth of technology has greatly influenced the way teaching and learning are conducted at all levels of the education system. The teaching process and methods should be built for both students and teachers and tailored to the new technologies. This improved learning method would benefit students because they are tech-savvy natives who have used all types of mobile devices and have access to information on multiple digital channels (Chrirstina, Jorge, Melcho & Carment, 2017).

AR is a possible pedagogical approach to the ever-changing challenges in teaching and learning. Sumadio and Rambli (2010) stated that there was a high possibility that traditional learning methods could be improved when AR used in education. This fact is supported by a finding that shows the excellent potential of AR in education specifically in visualizing abstract concepts (Saidin et al., 2015). AR can be applied to computers by improving the perception and real-world experience of a user by overlaying virtual 3D content with the real environment The efficiency of AR visualization lies in its ability to provide seamless access to virtual content, enabling users to effortlessly access and utilize information in the real world to carry out tasks effectively and efficiently (Billinghurst, Clark & Lee, 2015).

Moreover, AR can enhance interactions by integrating virtual and actual worlds, hence promoting seamless collaboration and fostering captivating teamwork, as opposed to relying solely on screen-based communication (Kerawalla, Scanlon, Jones, Littleton, Mulholland, Collins, & Conole, 2020). Additional research has demonstrated the prominent role of mobile devices in modern education, highlighting their influence and benefits (Chen, Kao, & Sheu, 2003; Denk, Weber, & Belfin, 2007; FitzGerald et al, 2012). Remarkably, the use of MAR apps has been feasible and is currently seeing significant growth due to the widespread adoption and increasing usage of mobile phones (Azuma et al., 2001; Papagiannakis, Singh & Thalmann, 2008).

Dunleavy, Dede, and Mitchell (2009) examine the impact of AR on student experiences and interactions. According to Klopfer and Yoon (2004), AR has the ability to integrate digital resources directly into our physical environment. AR in education has numerous advantages, including its alignment with the fundamental principles of constructivist learning, the changing preferences of users, and its ability to enhance comprehension of 3D animation (Green, Lea, & McNair, 2014). Mobile devices enable students to access AR experiences from any location where they have access to a platform that supports the use of the MAR application. Undoubtedly, AR has garnered significant attention in the field of education and has been found to be utilized for educational purposes in recent years (Wu, Lee, Chang, & Liang, 2013).

AR offers a number of educational advantages, and one of it is the opportunity to interact in a concrete way while also encourages learners to participate actively in the growth of their knowledge base (Ibili, 2013). Table 2.1 presents a list of AR advantages offered for education.

Table 2.1

Advantages of AR use in education

No	Pedagogic Benefits	Researcher
1	It attracts student attention to classes	Delello (2014), Tomi and Rambli (2013)
2	It increases motivation towards classes	Kerawalla, Scanlon, Jones, Littleton, Mulholland, Collins and Conole, (2020), Perez-Lopez and Contero (2013)
3	It concretizes abstract concepts	Lin et al. (2023), Cai, Chiang & Wang (2013)
4	It allows easy comprehension of complex topics	Núñez et al. (2008), Yen, Tsai and Wu (2013)
5	Allows the impossible teaching cases to be implemented.	Kerawalla et al., (2020), Yuen, Yaoyuneyong and Johnson (2011)
6	It ensures the safe application of dangerous	Wojciechowski and Cellary (2013)
7	It promotes imagination and creativity amongst students	Klopfer and Yoon (2004)
8	This fosters credible thinking	Wu et al. (2013), Yuen et al. (2011)
9	It provides enriched learning experiences	Sin and Zaman (2010)

10	It supports learning by doing	Dunleavy, Dede and Mitchell (2019), Guo et al. (2023)
11	It ensures student-centred learning	Delello (2014)
12	This gives learners the ability to use their own learning styles	Akçayır & Keskin (2023)
13	It provides situational learning opportunities	Wu et al. (2013)
14	It supports constructive learning	Delello (2014)
15	It increases learning engagement	Yip (2019), Guo et al. (2023)

Furthermore, AR technology in learning has proven to enhance visualization capabilities, enabling learners to interact with and manipulate virtual objects in real-world contexts, leading to improved comprehension, engagement, and knowledge acquisition (Zhang, Zhou & Wang, 2022). Table 2.2 presented the potential visualization benefits from enhancing the learning process that can be obtained by students using AR technology. Visualization of information with AR technology environments is an efficient method for expanding information process visually (Bayu, 2013).

Table 2.2

AR visualization benefits

No	Author	AR Visualization benefits
1	Shelton & Hedley, (2002); Shelton & Stevens, (2004)	Students will find opportunities to explore objects from different angles and perspectives with the aid of 3D teaching materials created by AR.
2	Singhal, Bagga, Goyal, & Saxena (2012)	Supports smooth integration in real and virtual worlds and allows for object manipulation using a concrete Graphic User Interface (GUI) metaphor.
3	Coffin, Bostandjiev, Ford & Hollerer (2010)	Provide lecturers with a way of improving students ' understanding of the workplace by embedding simulated notes and diagrams into the actual tools.
4	Saidin, Halim, & Yahaya (2015)	As AR allows detailed visualization and object animation, misconceptions arising from the students ' inability to visualize concepts such as chemical components can be minimized
5	Cerqueira & Kirner (2012)	AR allowing objects and principles that cannot be observed by the human eye to be macro or micro-visualized. AR shows concepts and thoughts in various ways and from different viewpoints that allow students to better understand the subjects
6	Giles, Mitrovic & Billinghurst (2015)	AR allows training in a complex situation (i.e., require manipulation of object) by combining concept and 3D spatial information.
17	Shuhada & Kamir (2019)	Provide assist to improve skills in understanding technical or mechanism of a system

Moreover, AR offers benefits without disconnecting students from the reality of classrooms and allows students to establish realistic experiences with virtual objects and surrounding physical environments (Matcha & Rambli, 2013; Wu, Huang, Cheng, Lee & Chang, 2020). AR technology engages students by bridging the gap between the reality of the classroom and virtual environments, offering immersive and interactive experiences that captivate learners and enhance their engagement and motivation (Wu et al., 2020).

AR technology has been utilized in several field in education such as Computer System Organization (CSO), programming, networking and project analysis (Sugara, 2017; Sirakaya, 2018a; Veni, 2013; Kesim, 2012). One of the studies implementing AR in the education field as is CSO (Mustika, et al., 2015). The focus of this study was to identify the effect of Mobile AR (MAR) on student comprehension in learning CSO, motivation and learning engagement. MAR is more widely used as a learning platform compared to other forms of AR, as it leverages the ubiquity of mobile devices to provide accessible and versatile learning experiences that can be easily integrated into various educational settings (Dunleavy, Dede & Mitchell, 2019).

Despite the wide-ranging application of Mobile Augmented Reality (MAR) in education, there is a notable absence of an Instructional Design (ID) model specifically tailored for MAR development that integrates elements of motivation, engagement, and comprehension. While studies have explored the impact of AR on intrinsic motivation and learning outcomes (Josef & Joerg, 2018), and other researcher have examined the integration of AR with instructional design frameworks like ADDIE

(Sorte & Kim, 2023) a comprehensive ID model that comprehensively incorporates these elements remains undeveloped. This gap underscores the need for a structured approach to designing MAR experiences that effectively enhance learner motivation, engagement, and comprehension. Thus, in the next section, previous studies on MAR in CSO is presented and discussed.

2.5 MAR Learning in CSO Course

One of the objectives of this study is to determine the effect of MAR on student comprehension in learning CSO. Gargish et al., (2020) stated that MAR based applications used in education can enhance student's academic achievements. According to Sugara (2017), research carried out by Shaaban, Mat and Mahayudin (2015), has shown MAR can improve user's comprehension in assisting computer maintenance process. In education, AR technologies aim to achieve better learning outcomes than using conventional teaching and learning methods (Pantelić et al., 2017). The use of AR had a positive impact on student achievement in the motherboard assembly and helped less supportive learners finish the assembly process in a relatively short time (Sirakaya, 2018).

Similarly, Veni (2014), found that using MAR technologies in learning computer assembling process can bring an exciting new learning environment. However, other researchers who have looked at MAR technologies have found two significant factor that affect attitude toward intention to use MAR in learning computer hardware which is the simplicity of use and enjoyment (Prasetya 2016). Meanwhile according to Giles et al., (2015) AR will boost the learning output substantially over traditional computer motherboard assembly process manual. In contrast, Nazatul et al. (2015) found in their study that the majority of students were motivated to utilise AR for learning purposes and to actively participate in the learning environment (Huisinga, 2017). Moreover, the ability to observe virtual entities like 3D models and abstract ideas by merging them with the actual environment establishes AR as a crucial method for instructing, constructing, and maintaining jobs that involve the manipulation of tangible items. The findings reported in this section together suggests that increasing motivation and confidence in understanding were the primary elements that drove engagement and led to improved comprehension (Huisinga, 2017).

On the other hand, it is crucial to identify the factor that affect student when learning CSO using MARCO application as learning tools, as well as prior studies that aim to identify trends in findings across these studies. Table 2.3 summarizes the literature review of prior AR research in CSO study. The study provides descriptions of how in the relevant fields the AR system has been applied.

Table 2.3

Summary of past research on AR applications in CSO learning

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
1999	Evaluating the Effectiveness of Augmented Reality Displays for a Manual Assembly Task (Baird et al. 1999	AR Computer Component Assembly Cybernaut P133 AR Wearable Device	15 students from graduate & undergraduate university. Age range of 20-37 years.	Research Method: • Quantitative. • Experimental. Instrument: • Questionnaire	Dependent Variables: • Time Completion • Type of Error, • Questionnaire Responses Independent Variable: • Paper Instruction • Computer-Aided Instruction, • Opaque AR Instruction • See-Through Instruction.	AR Instruction better instructional aid. Faster computer assembly time. Less error using AR instruction and fastest questionnaire response	Studies didn't access user/learning engagement and motivation of MAR. Studies Cybenaut P133 AR Wearable Device needs high-performance desktop requirement. Low-resolution graphics. Assembly task only focus on component installed on the motherboard

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
2011	An Augmented Reality Learning Space: PC DIY (Chiang et al. 2011)	AR PC DIY Learning Space (AR-PCLS) Desktop-Based AR System.	26 students from a university	Research Method: • Quantitative. • Experiment Instrument: • Questionnaire	Dependent Variables: • Pleasure • Learnability • Interaction • Satisfaction Independent Variables: • AR-PCLS Software	All variables score above 3.5, and among all variables, satisfaction construct gets the highest score. Learners adopt AR based learning very well.	The study uses only the questionnaire as assessment tool. Empirical experiments need to be conducted to understand the potential of AR as an educational tool. Participants consist of a small group of students; the findings of this study cannot be generalized.

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
2014	Students' perception of mobile augmented reality applications in learning Computer Organization. (Nazatul et al. 2014)	AR for learning Computer Organization Android-Bases Mobile Augmented Reality	24-second-year student from university who enrolled in Computer Organization course.	Research Method: • Quantitative • Experiment Instrument: • Questionnaire	Dependent Variables: • Satisfaction Level Independent Variable: • AR for learning Computer Organization .	The student's satisfaction level is high when using the MAR application. The result shows that MAR could assist a student in learning complex material. MAR was useful and attractive as well as motivated students to learn by themselves.	Studies didn't access user/learning engagement of MAR. No suitable device to run AR mobile apps. Assembly task only focus on component installed on motherboard
2015	The Development of Mobile Augmented Reality for Laptop Maintenance (Shaaban et al. 2015)	Mobile Augmented Reality for Laptop Maintenance (MAR4LM). Android-Bases Mobile	50 students from the university	Research Method: • Quantitative • Survey	Dependent Variables: • User Acceptance Independent Variable: • MAR4LM	The good platform using MAR application since user, have access to mobile devices	MAR4LM app currently only work with a single laptop model. The research did not state the result of user evaluation. Need further study on the

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
		Augmented Reality					effectiveness of the application.
2015	Intelligent Augmented Reality Training for Motherboard Assembly. (Westerfield et al. 2015)	Motherboard Assembly Tutor. MAT Android-Bases Mobile Augmented Reality	16 Participant	Research Method: • Quantitative • Quasi-Experiment Instrument: • Written Pre-Test • Physical Post Test	Dependent Variables: • Task Completion Time • Error Counts Independent Variable: • Intelligent AR tutor • Traditional AR tutor Moderator Variable: • Computer Experience	AR has been repeatedly shown to improve education and training through visualization and interactivity. Intelligent AR system was improved test scores by 25 %, task performance was 30 % faster compared to the same AR training system without smart support.	Small set of participants Studies didn't access user/learning engagement and motivation of MAR Studies didn't measure participant level of spatial visualization.

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
2016	Student Acceptance in Augmented Reality Computer Hardware Learning Media (Prasetya et al. 2016)	ARCH. AR in computer hardware	132 students from polytechnic	Research Method: • Quantitative • Survey Instrument: • Written Pre-Test • Physical Post Test	Dependent Variables: • Perceived Usefulness (PU) • Perceived Ease of Use (PEU) • Perceived Enjoyment (PE) • Attitude Toward Using (ATU) • Intention to Use (ITU) Independent Variable: • ARCH	PE was the essential factor that influences the willingness of students to use the ARCH system in the learning process.	The research model developed originally from (Technology Acceptance Model) TAM model, with perceived enjoyment

Year	Research Title (Researcher)	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
2017	The Development of Educational Augmented Reality Application: A Practical Approach (Pantelic et.al 2017)	AURASMA AR for computer component	Secondary & Primary School Student.	Research Method: • ADDIE Development	Not applicable	Guidelines using ADDIE as an instructional model for creating MAR application mode.	Focus on the development process of AR instructional content only.
2018	Effects Of Augmented Reality on Student Achievement and Self-Efficacy In Vocational Education And Training (Sirakaya et al. 2018)	HardwareAR	46 students from the university	Research Method: • Quantitative • Quasi-Experiment Instrument: • Pre-Post Test • Course Achievement Test • Self-Efficacy Questionnaire • Observation Form	Dependent Variables: • Course Achievement • Self-Efficacy Independent Variable: • HardwareAR • Printed Textbook • Traditional AR tutor	AR application can be effective in increasing learner achievement. AR technology draws student interest and attention into courses and increases student motivation. AR does not change the students' computer self-	Studies didn't measure participant level of spatial visualization. No instructional design model refers to this study.

Year	Research Title (Researcher)	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
					Moderator Variable: • Computer Experience	efficacy or their attitudes towards computers	
2019	Research on the Design and Effect of Computer Hardware Courses in the Smart Learning Environment (Wei et al., 2019)	ARA Intelligent Learning Software	20 students from college	Research Method • Quantitative • Quasi-Experiment Instrument: • Pre-Post Test • Hardware learning test • Learning Content Test • Course Evaluation Test	Dependent Variables: • Level of immersive • Participation & Communication • Learning speed • Degree of approval Independent Variable: i. ARA Intelligent Learning Software	AR application can be useful in improving learner understanding in basic concept and characteristic of computer hardware and also improve students' learning quality. AR improving sense of immersion through self-learning, improving learning speed and engagement in class	Small set of participants Studies didn't access motivation of MAR Studies didn't measure participant level of spatial visualization. No instructional design model refers to this study.

Year	Research Title	AR Application	Sample	Research Method & Instrument	Variables	Findings	Comments/ Knowledge Gap
2020	Using Augmented Reality Application to Reduce Time Completion and Error Rate in PC Assembly (Safiani, Danakorn, Nurul, Rostam, Najua, Taufik, 2020)	AR PC Application	20 students from ICT students	Research Method: i. Quantitative i. Quasi-Experimental	Dependent Variables: • Time of completion • Error Rate	This study has found that generally the time to complete the task were shortening and fewer error or mistake made during the assembly process in AR assisted system group than manual instruction.	Small set of participants did not allow for more generalization of the findings. No instructional design model refers to this study. Studies didn't measure participant level of spatial visualization.
2021	Augmented Reality Application for Laptop Assembly with Assembly Complexity Study (Chew & Aun, 2021)	AR Guide Assembly	Lecturers from university	Research Method: • Application Development	Dependent Variables: v. Handling Difficulty v. Insertion Difficulty	AR Application for the laptop assembly with product assembly complexity has been successfully developed	No instructional design model refers to this study. Focusing on development of AR

				AR object tracking technology has been introduced which can track 3D objects with detailed features	application, studies didn’t access other variable related to learning field.

Nonetheless, the previous literature reviews and research conducted by Nincarean et al. (2013) suggest that although a lot of research has been done on MAR, comparatively few studies have been conducted on MAR specifically in the field of CSO learning among Malaysian Polytechnic students. Nevertheless, while some research has been carried out on MAR in learning CSO, only a few studies have attempted to determine the effects of learning engagement and motivation toward MAR learning environment. In addition, although a range of AR systems and MAR application have been developed to visualize and facilitate assembly processes in CSO learning, none of these have contextualized the implementation of functional and physical realism in AR systems and MAR applications to assist learners with specific Spatial Visualization Ability (SVA) in CSO learning. Considering MAR has demonstrated a positive impact on CSO learning (Wu, Hwang, & Liaw, 2020), in the next section will provide details discussion on learning engagement and MAR learning.

2.6 Learning Engagement and MAR Learning

Recent literature suggests that educators are utilizing MAR technology as a powerful tool in teaching CSO (Patni, Jena & Tripathy, 2021). While the utility of MAR is significant, the user experience is crucial for the success of the MAR application (Liaw, 2010). User experience refers to the interaction between a user's perception and reality when using a specific application. This interaction is influenced by the user's evaluation of the quality, service, and usage of the app (Pérez-Sanagustín, 2016). Engagement pertains to the user's deep understanding and emotional connection with an application, contingent upon whether the application fulfils their requirements, values, capabilities, and expectations, as well as their satisfaction with the design and efficiency of the application (Baker et al., 2018).

Engagement in student learning is crucial for fostering a constructive learning experience. Learning engagement refers to the active involvement of students in learning activities inside their classrooms (Skinner, Kinderman, & Furrer, 2009). The level of student engagement in learning is considered a crucial factor in predicting their comprehension (Handelsman, Briggs, Sullivan, & Towler, 2005). MAR has shown its advantages in growing the contribution to learning and understanding specific topics, in particular with regard to spatial visualization skills (Radu & Schneider, 2019). According to Radu et al., (2019), learning engagement in MAR environment affecting educational representations was significantly higher, as students felt a greater sense of aesthetics and engagement. According to Wang, Bergin, and Bergin (2014), a lack of learning engagement can negatively impact both course outcomes and the learning process. Simultaneously, research has shown that incorporating MAR technology into educational courses can enhance student engagement (Abdusselam & Karal, 2012; Dunleavy et al., 2009). Researchers have done studies on approaches and tools that can boost the level of engagement in the course, as MAR is widely recognized as an excellent tool for facilitating the learning process and student engagement. While there are existing studies in the literature that discuss the relationship between MAR technology and learning engagement (Cai, 2013; Delello, 2014; Yusoff & Dahlan, 2013), there is a lack of research specifically examining the impact of MAR on learning engagement in CSO learning among Malaysian students in Polytechnics. This area of study warrants further investigation. The concern of learning engagement is essential for any MAR application since it is also related to user motivation (Baker et al., 2018).

According to Baker et al., (2018), there are 16 notable engagement elements to consider when creating a MAR framework that will triggers engagement, captivate the interest and participation of the customer. This 16-engagement element are aligned with O'Brien's Model of Engagement (2008). O'Brien's Model of Engagement (2008) is a user engagement process model that aims to identify and understand the key components that contribute to user engagement in various contexts. Integrating and enhancing engagement elements of MAR application with O'Brien's Model of Engagement (2008) can be achieved through designing user-centered experiences within the MAR learning environment (O'Brien, 2020). MAR applications are prominent for their ability to incorporate various engagement elements into the learning process (Wu, Lee, Chang & Liang, 2019). The implementation process of these MAR application involves designing user-friendly interfaces, integrating interactive features, and leveraging real-world context to create engaging learning experiences (Wu et al., 2019). Summary of MAR engagement elements are outlined in Table 2.4.

Table 2.4

Summary of MAR engagement elements

No	Elements	Description	Reference
1	Aesthetics	This is the element of mixing the nature of beauty, art, and taste and with the creation and appreciation of MAR.	Huang & Lioa (2015); O'Brien & Toms (2010)
2	Novelty	The element of using MAR to teach new behaviour and knowledge.	Lee & Crompton (1992); Assaker, Vinci & Connor (2011); Patzer, Smith & Keebler (2010)
3	Motivation	This is the ability to be willing and desires to accompany a task	Alqathani & Mohammad (2008); Serio, Ibanez & Kloos (2013)
4	Attention	Act of gaining awareness and making something interesting.	O'Brien & Toms (2010); Terregrosa, Torralba, Jimenez, Garcia & Barcia (2015); Serio et.al (2013); Wojciechowski & Cellary (2013)
5	Interest	It should gain involvement to act by the users.	Permadi et.al (2015); Serio et.al (2013); Nachairit et al. (2015); Pendit et.al (2015)
6	Feedback	Positive information that will enhance passionate reactions which will promote positive performance.	Mouratidis, Vansteenkiste, Lens & Sideridis (2008); Hector et.al (2014)
7	Usability	The element of flexibility, ease of use and learnability of MAR	Shafi, Selvakumar &Shakeel (2018); O'Brien et.al (2010); Huang & Lioa (2015); Hector & Payel (2014); Pribeanu (2014); Nilsson & Johansson (2007); Haugstvedt (2012)

8	Interaction	Ability to connects between users and app	Nachairit et al. (2015); Haugstvedt (2012)
9	Challenge	The app should be able to provoke users to action	Permadi et.al (2015); Nachairit et. al (2015); Chou & Chanlin (2014)
10	Perceived Control	Making users feel in control of the event or situation	Shakeel (2014); Hector et al. (2014)
11	Perceived Time	Estimated time spent on a mission; may also mean ample or insufficient time to complete a task	O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)
12	Interruptions	The participant describes him/herself as vulnerable to distraction.	O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)
13	Positive Effect	Affect is the emotional investment that the consumer creates to immerse himself in the experience and to retain his presence in the background; this variable describes a positive response.	O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)
14	Negative Effect	Affect is the emotional investment that the user makes to be immersed in the environment and to sustain their involvement in the environment; this variable describes a negative response.	O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)
15	Goal	A target that is sometimes well defined, often psychological, and sometimes with experience in mind when initiating a computer program connection.	Kevin & Gavin, (2018); O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)

16	Awareness	Realization of physical environment and roles by the individual (e.g., hunger, thirst)	O'Brien (2020); Billinghurst, & Denser, (2012); Green et al. (2014)

(Source: Baker et al., 2018 & O'Brien, 2020)

In order to determine which MAR applications have met the user engaging quality, it has to be assessed with the right measurements. MAR application, designed based on engagement elements and O'Brien's Model of Engagement (2008), can be evaluated using User Engagement Scale (UES) (O'Brien & Toms, 2010) as an assessment instrument to measure the quality of user engagement (Kim, Biocca, & Han 2020). The UES provides a reliable and validated method for evaluating the levels of attention, affect, and agency experienced by users in mobile AR applications (Kim et al., 2020). The UES is an instrument designed to assess user engagement and has been used in several digital environments and O'Brien, Cairns & Hall (2018) has identified four significant parameters for user engagement measurements:

i. Focus Attention (FA) - Refers to getting distracted and losing track of time in the relationship.

ii. Perceived Usability (PU) - Refers to understanding arising from the relationship and the degree of control and energy that has been exerted.

iii. Aesthetic Appeal (AE) - Remarks the interface's usability and visual appeal.

iv. Reward Factor (RW) – Refers to durability, overall activity success, commitment, creativity, excitement, participation in the interactive task and feeling involvement, the sense of being "drawn in" and having fun.

The assessment of UES involves the administration of a questionnaire to gather self-reported data from users. The scale consists of a set of items or statements that capture different aspects of user engagement (O'Brien & Toms, 2010). Studies using the subscales or the entire UES have also shown that the questionnaire has shown good reliability and validity in general (O ’Brien & Lebow, 2013; Wiebe et al., 2014). Moreover, these studies are supported by Baker et al (2018) who mention that dimensions of UES are the characteristic that represents the engagement elements to the MAR application. The details explanation of the engagement elements and O’Brien’s Model of Engagement (2008) applied in MARCO application design and development are discussed in subsection 2.10.3 and 4.2.5, while details explanation on UES are discussed in subsection 3.6.2. Apart from this, research has demonstrated that MAR experiences not only enhance user engagement but also positively influence perceived motivation, indicating that higher levels of user engagement in MAR experiences are associated with increased perceived motivation. (Khan, Lye & Chuah, 2020; Lee, Kim & Ham, 2019). In the section will present a comprehensive discussion on the concept of perceived motivation and its relation to MAR learning.

2.7 Perceived Motivation and MAR Learning

Motivation is a learner’s desire to engage in the learning environment (Di Serio, Ibanez & Kloos, (2013). MAR in education research has documented increases in motivation and engagement (Green et al., 2014; Lee, Kim & Ham, 2019; Khan, Lye

& Chuah, 2020). MAR has been found to significantly influence and enhance users' perceived motivation, as the interactive and immersive nature of MAR experiences stimulates curiosity, engagement, and a sense of enjoyment, ultimately fostering intrinsic motivation (Lee et a.l, 2019). Technological advancements and the introduction of new teaching techniques have rendered certain methodologies obsolete due to their inadequate response to contemporary trends. These outdated approaches might result in monotony and a lack of motivation during instructional activities (Chin, 2017).

Furthermore, contemporary students are considered digital natives due to their familiarity with a wide range of electronic devices and their ability to navigate and process information across several digital platforms. Thus, adaptation of the new emerging technologies in learning process seemingly will benefit to the students (Chin, 2017). In their research, Coimbra, Cardoso and Mateus (2015) highlighted MAR technologies will promote inspiration, comprehension and a greater understanding of learning material. Integrating MAR application technology into the learning process has proven to be highly advantageous for students who face difficulties in visualising concepts. MAR application technology serves as a means to connect the gap between traditional static paper materials and digital content. (Billinghurst & Denser, 2012). Visual struggling learners showed a self-perceived motivational increase in willingness to learn and explore if MAR support was available during their study (Billinghurst & Denser, 2012). As Fahri (2017) has reported, MAR technology's versatility can transform the way learners learn by incorporating MAR learning applications into structured classroom activities (Mohamad, Lakulu & Samsudin 2016; Johnson, Adams, Estrada & Freeman, 2014) in which students' learning performance and motivation have improved significantly (Hafizul, 2012).

According to Hung, Chen & Huang (2016), in their research, 3D model of animated AR graphics will enhance learning efficiency of students and increase their motivation. Meanwhile, Sampaio and Almeida (2016) argued that by adding more MAR application technology into the learning process, it has a slight negative impact on the concentration of students but a big impact on the motivation. Participants utilising the MAR tools had significantly higher levels of enthusiasm at the start of each session compared to those who did not get MAR supports (Dunser et al., 2012). This opinion is confirmed by Radu et al., (2019) who argues that MAR applications show improvements in motivation and self-confidence to engage with course content and peers compared to non-MAR application, Moreover, the immersion and interaction characteristics offered by MAR applications can encourage students to participate in learning and motivate students to learn (Khan et al., 2019). In a greater context of immersive virtual learning environment, MAR can turn empty space into an amusing educational experience that can lead to improving student's motivation and learning experience (Shuhada et al., 2019).

Almost every research that has been conducted on MAR includes a section on the motivational aspect that has shown positive impact on improving learner's motivation towards learning process (Cai, 2019; Fotaris, Pellas, Kazanidis & Smith, 2017; Tobar-Muñoz, 2017; Diegmann, Schmidt-Kraepelin, Van, Eynden & Basten, 2015; Iwata, Yamabe & Nakajima, 2011).

Keller (1983, 1984, 1987) designed the ARCS model to stimulate and sustain the perceived motivation of the students in learning environments. The ARCS motivation design model presents a systematic approach to the development of instructional motivational approaches (Song & Keller, 2001). Keller (1987, 2000) defined four important dimensions of motivation (ARCS) which would be tailored to the nature of the instructional material:

i. Attention (A) - Motivation to learn is encouraged when the curiosity of a learner is awakened because of a perceived gap in current knowledge.
ii. Relevance (R) - Once the information to be acquired is understood to be meaningfully linked to the needs and goals of a learner, desire to learn is encouraged.
iii. Confidence (C) - Learning motivation is encouraged when learners think they can master the learning task.
iv. Satisfaction (S) - Learning motivation is encouraged when learners anticipate a learning task and experience satisfactory results.

Together these studies provide valuable insights into the implementation of motivation aspect in MARCO application design and development. Details implementation of motivation aspects that are applied in MARCO application are discussed in subsection 2.10.4.

2.8 Spatial Visualization Ability

Respective scholars that have studied this ability have contributed to several definitions of spatial ability. In 1993, Gardner provided a definition of spatial ability as the capacity to accurately perceive the visual surroundings, manipulate and modify one's original observations, and replicate the qualities of one's visual encounter, even without any physical stimuli present. Gardner (1993) defines spatial ability as the cognitive capacity that involves visual perception, mental imagery, acute insight, and knowledge of the natural environment. According to Thurstone (1938), spatial ability is considered to be one of the most robust cognitive capacities.

It is commonly characterized as the capacity to cognitively manipulate shapes, weights, and distances. Halpern (2000) defines spatial ability as the capacity to mentally visualize the appearance of an atypical shape when it is rotated in space, or the ability to perceive the connection between different shapes and objects. According to Maizam (2000), spatial ability refers to the capacity to create accurate and dependable mental representations of spatial information that may be applied in three-dimensional (3D) contexts. Spatial ability, as defined by McGee (1979), is a test used to assess learners' capacity to cognitively rearrange or manipulate the elements of a visual stimuli. This requires detecting, retaining, and recovering configurations when the figure or portion of the character has changed position.

To relate to this study, the definition reflects the types of spatial skills needed in solving visualization problems in CSO learning. One of the spatial ability components is Spatial Visualization Ability (SVA) (Linn & Petersen, 1985). SVA is the ability to manipulate complex spatial information by many steps. It is commonly linked to complex, multi-step spatial manipulations (Chin, 2017). Linn and Petersen (1985) summarized the effectiveness of SVA involving review of task criteria and rapid implementation of solution procedures. According to Contero, Naya, Company, Saorín & Conesa (2006), SVA has a learning effect described as being able to picture 3D shapes in the mind's eye. According to Norman (1994), spatial skills of learners are the most important and significant predictor of success in object manipulation and computer-aided design interaction.

Research has shown that 3D spatial representations are the most commonly utilised method of describing physical components in problems that require mental transformations, such as rotation, reflection, folding, unfolding, and visual synthesis of figures (Maizam, 2000). The term 3D spatial representation refers to a visual depiction of space that exhibits combination of dimensions, namely height, width and depth inside a figure. In addition, as stated by Kwiatek (2019), SVA plays a crucial role in spatial cognition for the job of assembly. It relies on the ability to mentally manipulate 3D objects and analyse design information in order to visualise the necessary constructs. SVA may be classified into two levels: high SVA (HSVA) and low SVA (LSVA). Table 2.5 outlines the differences in the characteristics between

HSVA and LSVA learners based on the research done by Hindal (2014), Hou (2013) and Madar (2009).

Table 2.5

High and low SVA learners' characteristics

High Spatial Visualization Ability (HSVA)	**Low Spatial Visualization Ability (LSVA)**
Non-Sequential learner.	Sequential learner. Step-by-step learner.
See the big picture first before they learn the details	See segment by segment first before they learn the details
Able to compose significant amounts of information from different domains, but they often miss the details.	Impossible to compose large amounts of information from different domains, but meticulous with the details.
Organizationally impaired learner	Structured learners
Unconscious about time. Perform better in untimed situations	Conscious about time.

(Source: Hindal, 2014)

The level of SVA, whether high or low, has been found to have a significant impact on learning outcomes particularly in fields that require spatial reasoning and visualization skills (Uttal, Meadow, Tipton, Hand, Alden, Warren & Newcombe, 2013). SVA are essential for the success in solving many tasks and also important for success in many fields of study (Domínguez, Martín-Gutiérrez, González & Corredeaguas, 2012). Despite their importance in different fields, students with varying degrees of SVA would have different approaches and attitudes towards understanding multimedia instruction and 3D visualization (Alqahtani, 2017). Learners with high SVA tend to demonstrate better performance in spatially oriented tasks and have a deeper understanding of complex spatial information while learners with low SVA tend to promote alternative visualization strategies by emphasizing the importance of non-spatial cues, leading to enhanced attention to detail and critical thinking skills (Uttal et al., 2013).

Studies also have shown that SVA is related to task comprehension. Examples of these studies include Shaaban (2015) in laptop maintenance, Pantelić (2017) and Sirakaya (2017) in computer hardware, Westerfield et al., (2015) in motherboard assembly, Fahri (2017) and Sampaio et al. (2016) in Information, Communication Technology (ICT) course and Mesia, Sanz and Gorga (2016) in computer programming. SVA skills demonstrate an advantage in task comprehension, such as the assembly process, as their ability to mentally manipulate and visualize spatial information allows for a better understanding of the relationships between components and facilitates problem-solving (Hegarty, Chase, Waller & Levin, 2019). Research in the field of literature demonstrates that SVA may be enhanced by educational methods that involve clear instruction, repeated practice, and personalised feedback aimed at cultivating spatial reasoning and visualisation skills (Majid and Husain, 2014; Ali et al., 2018; Vasavada, 2016; Sommerauer & Müller, 2018).

Essentially, there are variations in the precise definition and measures used for SVA. However, when it comes to learning that involves physical components, assembly processes, and practical tasks, the definition of spatial ability given by McGee (1979) is the most commonly used. This is likely because spatial problem-solving in this context often requires mental transformation processes, such as mental rotation (manipulate, rotate, twist, zooming or invert) (Madar, 2009; Maizam, 2000). In fact, MAR based application accommodates as a platform for executing mental transformation processes by providing 3D overlay and virtual information, thereby facilitating the enhancement of SVA skills (Chen, Lin, Chiang & Chen, 2020). In the section will present a comprehensive discussion on SVA implementation on MAR.

2.8.1 Spatial Visualization Ability and MAR

A strong correlation has been seen between the method of learning and the individual's SVA. The research conducted by Martín-Gutiérrez, Contero, and Alcañiz (2015) shown that learning using MAR has a considerable positive impact on the development of SVA. In the same view, Radu et al., (2019) reported that implementation of MAR educational application compared to conventional pedagogical approaches such as textbooks, instructional video and PC-based instruction showed that MAR could increase students ' understanding of structures that are either spatially complex or invisible to the naked eye. Further study reveals that MAR is an effective and useful resource for creating spatial visualization capabilities (Christina, Jorge, Melchor & Madel, 2017). Studies have shown that HSVA learner benefits more from MAR visualization-based training (Duenser, Steinbügl, Kaufmann & Gluck, (2005). Nonetheless, Chin (2017) concluded that LSVA learners are more positively affected by MAR visualization-based training but with specific assistance as they have troubles in mentally visualizing them.

Bal et al., (2016) Diegmann et al., (2015) and Liarokapis et al., (2010) explored how MAR affects the learners understanding of SVA. Bal et al. (2016) found that MAR helps students to easily understand and learn through improved visual in a short time. Diegmann (2015) and Liarokapis (2010) reported that MAR emphasis the following distinctive advantages for enhancing SVA:

i. Provided with information related to a real-world place while simultaneously considering the object of interest;
ii. Enable complex procedures transparent and effective ways to show relationships to the learners;
iii. Object modelling application that allows students to receive immediate visual feedback on how a given object would look in a different setting and interaction between objects; and
iv. Individual skill training in specific tasks, for example assembly task used in computer build, operations and maintenance.

MAR offers as a capable technology to improve students' spatial ability due to its media attributes (visual rotating, zooming into details, animations, highlighting aspects, etc.) and immersive learning environment (Tuker, 2018). Moreover, MAR is an effective platform for enhancing and conceivably improving the SVA by administering proper treatment sessions and reliable instructional application (Tuker, 2018).

SVA can be improved and trained by MAR application with systematic treatment and instructional (Duenser et al., 2006). Several studies have shown the usefulness of MAR in training spatial visualization ability (Tuker, 2018; Rafael, Maria, Antonio & Higinio, 2018). According to Tuker (2018), in order to carry out practical training in the field of SVA, every instructional application must adhere to a methodical strategy that is determined by the specific skills and information that need to be acquired. MAR based applications which specifically target the instruction of SVA can be categorised as instructional applications. Roblyer and Doering (2010) categorize instructional applications into five distinct groups:

i. Drill & Practice Software is designed to enhance skill development by providing students with the opportunity to solve a diverse variety of issues or answer questions. It also offers feedback on the accuracy of their responses;
ii. Tutorial software is designed to facilitate self-directed learning without the need for a teacher. These are the primary instructional resources that the student must acquire knowledge from. These software programmes are autonomous and allow the user to modify the pace at which instructions are delivered;
iii. Simulation software refers to the use of computer programmes that create models of machines or environments to accurately depict how a system

operates. Students can acquire practical experience by utilising simulations. This programme emphasises the study of the system itself by providing students with scenarios generated by the software or manually created by a teacher who observes the student during the simulation process, rather than focusing on general problem-solving methods;

iv. Instructional games enhance learners' motivation by integrating gamification, game aspects, rules, competition, and entertainment considerations into learning and simulation exercises; and

v. Problem-solving software is designed to enhance the learner's analytical thinking abilities by providing the essential knowledge and skills to solve specific problems.

The consideration of the SVA factor is crucial in the process of learning CSO. The design and development of the MARCO application were primarily influenced by the tutorial software and simulation software approaches, with a strong emphasis on incorporating 3D models, animated images, and simulations. The implementation of tutorial software aims to provide learners with autonomy to explore the application independently (Safie, Wahid & Idris, 2017; Hou, 2013). On the other hand, simulation software is designed to guide and support learners in comprehending the concept of CSO and to provide realistic simulations of assembling computer hardware and components (Saforrudin, 2016).

2.9 Relationship between MAR, Course Comprehension, Learning Engagement, Perceived Motivation and Spatial Visualization Ability

In this study, Mobile Augmented Reality for Computer Organization (MARCO). MARCO application utilized Mobile Augmented Reality (MAR) technology features and multimedia element as a visualization support tools (digital information, graphics, image overlay, 3D animation and model). This provides advantages to high SVA students who are exceptional at visualizing abilities and offers advantages for students with low SVA who would learn more easily if visualization resources are available. Therefore, MARCO application is designed and developed to support students from both high and low SVA.

MARCO application provides interactive learner control to cater to both high and low SVA. Previous research has shown that high SVA learners are non-sequential learners which means that students do not learn in a step-by-step procedures as most traditional classroom learning session still using textbooks, classroom management techniques, verbal teaching and symbolic (Hindal, 2014). They are self-oriented learners and prefer unrestricted navigation and enjoy themselves exploring new information (Silverman, 2003). Whereas low SVA learners are more sequential learners and they prefer a linear format in a step-by-step manner or guided navigation (Silverman 2003). Thus, the impact on learner's motivation and in learning engagement can be achieved through MARCO application, which support both high and low SVA. Once students engage in the activities, they will be able to understand the learning material that will result in a successful learning outcome.

The key aspect of this study is to show that the MARCO application was designed using established visualization supports to cater both high and low SVA students of the Diploma in Information Technology (Digital Technology) (DDT) program as it contributes to influence and improving SVA learners and yield a positive impact through the following factors:

i. Enhanced Spatial Visualization: MARCO application facilitates the visualization and manipulation of virtual objects, promoting the development of spatial visualization abilities among learners (Chen et al., 2021).
ii. Immersive and Interactive Learning: MARCO application provides immersive and interactive learning experiences, which enhance learning engagement and comprehension by allowing learners to actively explore and interact with virtual content (Wu et al., 2020).
iii. Real-World Contextualization: MARCO application contextualizes learning materials within real-world settings, enabling learners to make meaningful connections between abstract concepts and their practical applications, leading to increased comprehension and motivation (Lee et al., 2019).
iv. Personalized and Adaptive Learning: MARCO application platforms can be tailored to individual learners (self-oriented learners, non-sequential learners and sequential learners) offering personalized learning experiences that align with their unique needs and preferences, thereby fostering motivation and supporting learning comprehension (Zhang, Lundeberg, Koehler & Eberhardt., 2020).

As a final point, it lays out what the research aims to investigate which is to determine how does MARCO application affects student perceived motivation, learning engagement and comprehension of the course. The relationship between MARCO application, Motivation, Learning Engagement, Course Comprehension and SVA is illustrated in Figure 2.4.

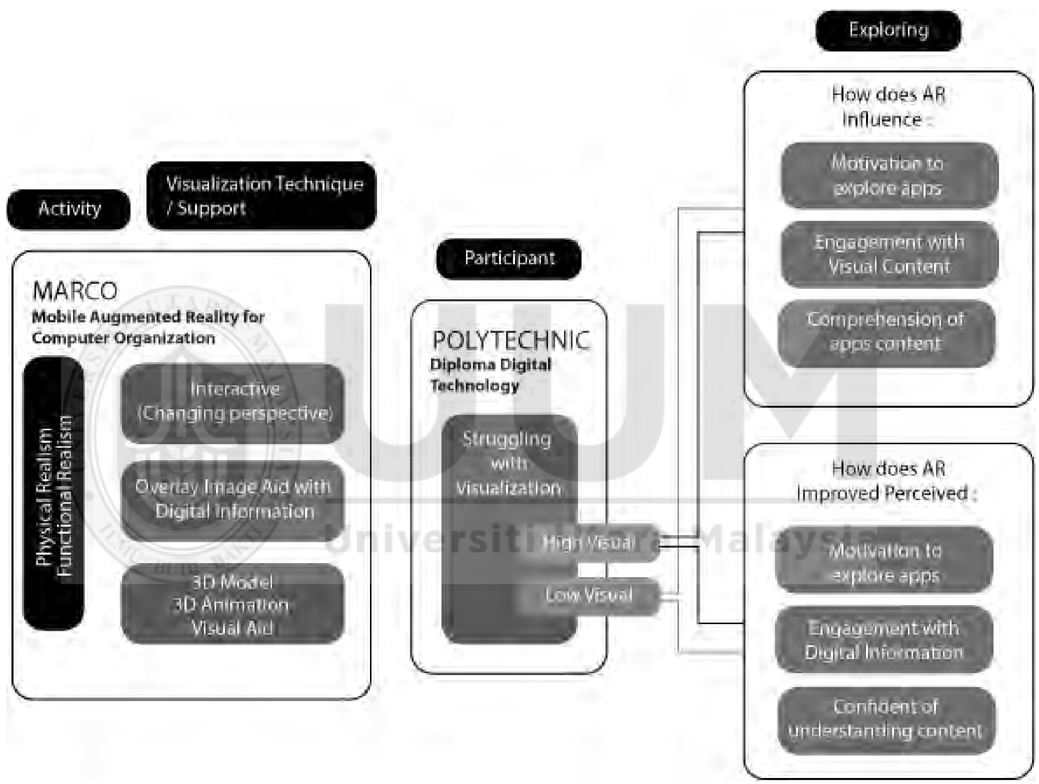

Figure 2.4 : Relationship between MARCO, motivation, engagement comprehension and SVA.

2.10 Incorporated Instructional Design Model and Learning Theories

To provide a meaningful learning, the design and development of the instructional materials must be logically focused and discussed pedagogically. Instructional materials that are based on the theoretical framework of instructional design, model and learning theories are more likely to be effective. While research has investigated the influence of AR on intrinsic motivation and learning outcomes (Josef & Joerg, 2018), and others have explored the alignment of AR with established instructional design frameworks such as ADDIE (Sorte & Kim, 2023), a holistic ID model that systematically incorporates these critical elements is still lacking. For instance, studies by Akçayır and Akçayır (2017) have highlighted the potential of AR to enhance learning experiences, yet they emphasize the need for structured design frameworks to optimize its educational benefits. Chen (2018) introduced Virtual Reality Instructional Design (VRID) model, which provides a guidance for designing VR-based learning materials. However, despite this progression in VRID, a comparable and comprehensive Instructional Design (ID) model specifically for Augmented Reality (AR) remains absent. Similarly, Radu (2014) underscores the importance of integrating motivational and engagement strategies within AR-based instructional designs to improve comprehension and retention. Despite these advancements, the development of a comprehensive ID model tailored specifically for MAR, which integrated of comprehension, engagement and motivation elements, remains an unmet need in the field. However, several general ID models can be adapted to suit the unique characteristics of MAR technology.

This study is grounded in four main instructional design models and theories as an outline to design and develop MARCO application. The structure of the instructional materials is guided using Churchill, King, & Fox, 2013 RASE Pedagogical Model

(2013) as a macro model to support content structure, whereas O'Brien's Model of Engagement (2008) and Keller's ARCS Model of Motivational Design (1987) as a micro model to support AR engagement elements and motivational aspects of MARCO application. Furthermore, the design and development process of MARCO application modes was driven by Alessi and Trollip's Instructional Design Model (2001) and Spatial Cognition Theory (1993). By leveraging these models, instructional designers can create effective and engaging MAR-based learning experiences. The following subsection provides detailed explanations for each model and theory.

2.10.1 Alessi and Trollip's Instructional Design Model

The Instructional Design Model (ATID) developed by Alessi and Trollip (2001) provides a versatile approach to instructional development process. The approach is essentially grounded on a three-phase framework consisting of planning, design and development phases. Every phase of this approach may be divided and adjusted to suit the development process. The planning phase ensures that the entire project is fully understood and measures all the limitations. Next, the design phase focuses on assembly processes and how to treat material from both an instructive and an interactive point of view, while the development phase involves implementing the prototype design of a multimedia learning application (Khan 2013).

In addition, the ATID model includes three attributes: (a) Standards (b) Continuous Assessment, and (c) Project Management. These principles form a good foundation for the entire process of design and development. The development of the specification is controlled within the framework by explicitly identifying the specifications. In addition, a continuous iterative strategy is employed to conduct continual evaluation at each level in order to accomplish all features. The development process is adaptable at each step, depending on the outcome of the preceding step. Another crucial characteristic of this approach is the implementation of project management techniques to guarantee the timely completion of the application within the assigned budget. Effective project management can be accomplished while maintaining the necessary expectations (Por & Fong, 2011). Alessi and Trollip (2001) presented a comprehensive framework for the development of interactive materials.

ATID model is a flexible model of instructional development that can accommodate the use of various emerging technologies. Previous research found that the ATID concept was used as a basis for the design and development of applications based on AR. Table 2.7 show summaries of relevant research and development on AR application using ATID model as a development model.

Table 2.6

Summary of AR application using ATID as a development model.

No	Researcher / Year	Augmented Reality Application	Level	Peripherals
1	Nurhidayah, Tahmir & Karim (2017)	Biomagazine Integrated with Augmented Reality in Genetics Concept	Secondary School	Mobile Augmented Reality (Marker Based)
2	Suwancharas (2016)	Augmented Reality for English Listening Skills	Undergraduate Students	Mobile Augmented Reality (Marker Based)
3	Gopalan, Zulkifli, Mohamed, Alwi, Mat, Bakar, & Saidin (2014)	Augmented Reality Science Textbook	Elementary School	Mobile Augmented Reality Book (Marker Based)
4	Bakar, Zulkifli, Mohamad (2011)	Augmented Reality for Children's Road Safety	Elementary School	Mobile Augmented Reality (Marker Based)

Nonetheless, ATID model is adapted in the development of MARCO due to its thorough and systematic implementation roadmap from the planning program to the actual end product. Instructional design developers gravitate towards utilizing Alessi and Trollip's Instructional Design Model (2001) due to its comprehensive framework that guides developers through all stages of the instructional design process, ensuring a systematic and organized approach (Gagne, Wager, Golas & Keller 2016) and offers practical guidelines and strategies for instructional design, making it highly applicable for developers to translate theoretical principles into actionable steps (Morrison, Ross, & Kemp, 2020). Figure 2.5 shows the three-phases model of Alessi and Trollip's Instructional Design Model (2001). Details design and development stages that are carried out in MARCO are discussed in Subsection 4.3.

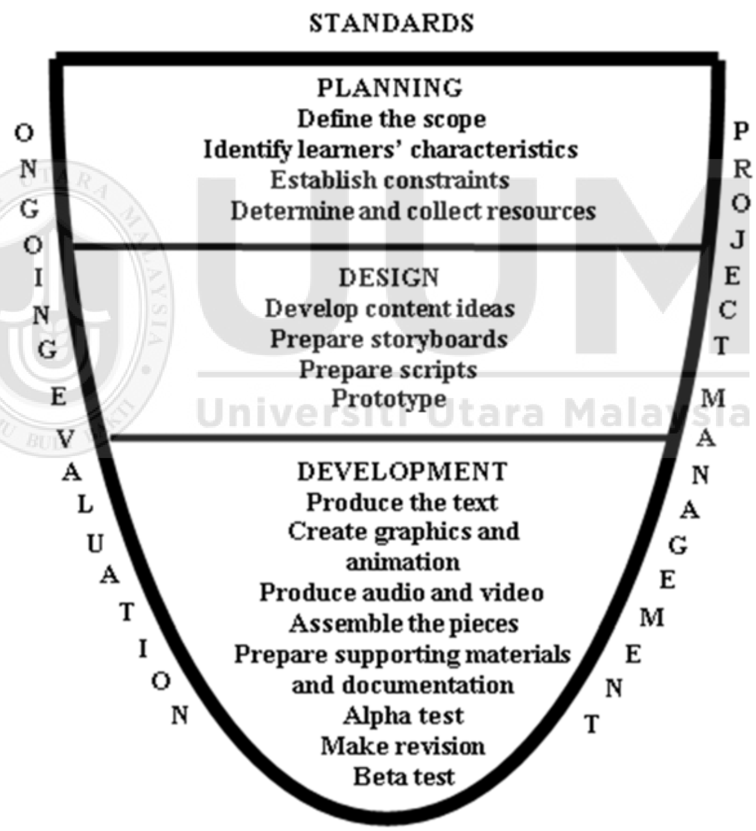

Figure 2.5 : Alessi and Trollip's Instructional Design Model (2001)

2.10.2 Churchill, King, & Fox RASE Pedagogical Model

In 2013, King and Fox developed the RASE model, which incorporates theoretical notions such as constructivist learning environments. The following terms and concepts are mentioned: problem-solving (Jonassen, 1999), engaged learning (Dwyer, Ringstaff & Sandholtz, 1985-1998), problem-based learning (Savery & Duffy, 1995), productive environments for active learning (Grabinger, 1996), technology-based learning environments (Vosniadou, 1995), interactive learning environments (Harper & Hedberg, 1997; Oliver 1999), collaborative knowledge building (Bereiter & Scardamalia, 2003), micro lessons (Dodge, 1995; Divaharan & Wong, 2003; Churchill, 2006). The RASE model is composed of four main elements: Resource, Activity, Support and Evaluation. This model is illustrated as shown in Figure 2.6.

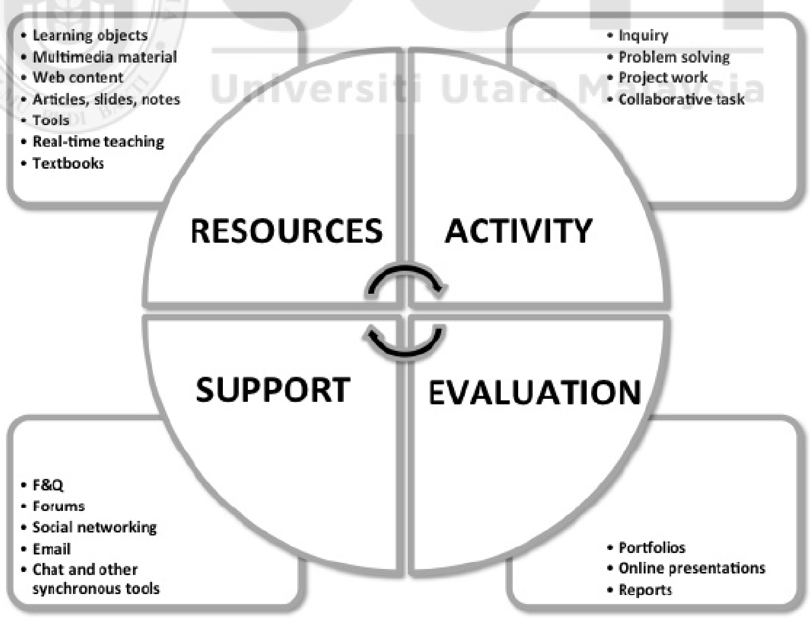

Figure 2.6 : RASE Pedagogical Model for Integrating Technology (Churchill, King, & Fox, 2013)

The RASE model is seen as an important component of teaching and learning quality assurance. The model can also be used in almost any course and program. RASE emphasizes that four items must be well premeditated in order to achieve the intended learning outcomes:

i. Resource: Tools include (a) materials, such as seminars, textbooks, journal articles, digital media, handouts, and (b) resources used by students when working on their operation, such as courseware, smartphone apps and online applications. When integrating technological resources into teaching, it should be designed in a way that leads students to learn from these resources rather than simply learning from them.

ii. Activity: To engage students in resource use and work with activities such as experimentation and problem solving to obtain learning outcomes through experience.

iii. Support: Students receive assistance in which tools to address emerging issues independently or in cooperation with other students (i.e., peers, courser mentors and supporting technology team).

iv. Evaluation: Assessment that provide structured information to guide the progress of students and to help them understand what else we must do to achieve learning outcomes.

Instructional design developers find the RASE Model to be a valuable resource for designing instructional content, as it offers a systematic approach that encompasses content organization, instructional strategies, and learner engagement, ensuring a comprehensive and effective design (Churchill, King & Fox 2019; Merrill, 2017). In this study, the RASE model was used as a guide to design the instructional content of MARCO to provide an effective, engaging and motivating application. The details explanation of RASE model incorporation in MARCO content development is discussed in Chapter 3.

2.10.3 O'Brien's Model of Engagement

O'Brien's Model of Engagement (2008) is a process model that aims to uncover the essential elements that constitute user engagement. This is a depiction of the method by which users interact and the characteristic that is improved to enhance comprehension. O'Brien (2008) introduced the Model of Engagement, which defines engagement as a process in which user applications establish and sustain commitment, disengage from the use or task, and potentially re-engage several times during a single contact with the application. The process is characterised by four clearly defined stages: (a) point of engagement, (b) sustained engagement, (c) disengagement, and (d) re-engagement. These stages are associated with various aspects of engagement and correspond to the most significant stages of the model proposed by O'Brien and Toms (2010; 2008). The intensity of the characteristics may differ based on the integration of the user and system attributes that occur during the interaction.

This model is based on four engagement phases:

i. Point of Engagement: Motivated by the esthetic appeal or a creative interface design, users ' motives and desires, and users ' willingness and desire to be part of the experience and to feel that there is enough time to use the application

ii. Engagement: These are maintained when consumers can remain interested in the application and are characterized by positive emotions.

iii. Disengagement: Depending on the outcome, the accessibility of the devices and the obstacles of their surroundings contributed either to positive or negative emotions.

iv. Re-Engagement: Upon disengagement it affected consumer choices. Users returned to the application because they had been fantastic feedback before or because it presented them with something new that could not be purchased elsewhere and could provide adequate levels of control, challenge and comments to make individual users unaffected or frustrated.

Figure 2.7 shows the model with four engagement stages mapped with attributes of engagement. The prominent attributes are represented with a high point which indicates the level of attributes intensity.

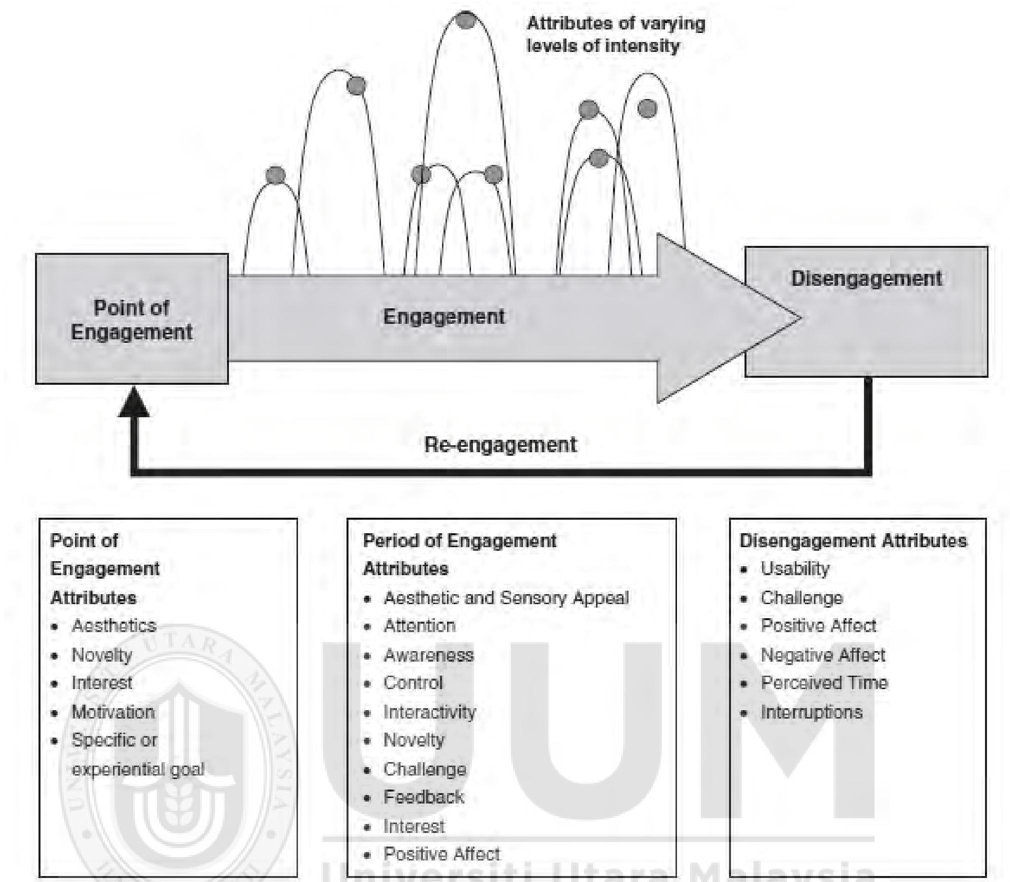

Figure 2.7 : O'Brien Model of Engagement (O'Brien's, 2008)

A significant amount of literature has been published on the engagement element for Mobile Augmented Reality (MAR). A systematic literature review on the trend of user engagement theoretical framework was conducted by Doherty and Doherty (2018) which reported that O'Brien's Model of Engagement (2008) are one of the most widely applied user engagement models in term of application context and have been extensively used in a field of virtual learning environments and classroom learning. O'Brien's Model of Engagement (2008) provides a solid theoretical foundation in designing MAR application with a component of engagement. According to Baker et al. 2018, MAR must be a focused, movable and engaged augmented environment which can raise users engaging quality and permit them to attain the preferred objectives. In 2013, Nincarean et al. published a paper describing users who felt motivated, enjoyed and had positive educational effects when experiencing AR, leading to higher levels of engagement to learning performance. In a study which set out to determine engagement on AR, Kaenchan (2018) found that the integration of AR into the learning process could add excitement and increase the motivation of the learner, positive attitudes and engagement to the task. This view is supported by Diegmann (2015) who lists four benefits of the integration of AR in the learning process, which increases motivation, attention, concentration and satisfaction. Nevertheless, developing MARCO required 16 engagement attributes that were tested, implemented and summarized in Table 2.6. The 16 engagement attributes that are carried out in MARCO application design and development are discussed in detail in subsection 4.5.2.

Table 2.7

Engagement element carried out in MARCO design and development

No	Engagement Elements	Definition
1	Aesthetic	This is the dimension integrating the essence of elegance, architecture, and taste with MAR formation and enjoyment.
2	Novel	The aspect of using MAR to teach new behaviour and knowledge.
3	Motivation	This is the ability to be willing and desires to accompany a task.

4	Attention	Act of gaining awareness and making something interesting.
5	Interest	It should gain involvement to act by the users.
6	Feedback	Positive information that will enhance passionate reactions which will promote positive performance.
7	Usability	The element of flexibility, ease of use and learning of MAR.
8	Interaction	Ability to connects between users and app.
9	Challenge	The app should be able to provoke users to action.
10	Perceived Control	How users feel in charge of their experience with the technology
11	Perceived Time	Estimated time spent on a mission; may also mean ample or insufficient time to complete a task
12	Interruptions	The participant describes him/herself as vulnerable to distraction.
13	Positive Effect	Affect is the emotional investment that the consumer creates to immerse himself in the experience and to retain his presence in the background; this variable describes a positive response.
14	Negative Effect	Affect is the emotional investment that the user makes to be immersed in the environment and to sustain their involvement in the environment; this variable describes a negative response.
15	Goal	A target that is sometimes well defined, often psychological, and sometimes with experience in mind when initiating a computer program connection.
16	Awareness	Realization of physical environment and roles by the individual (e.g., hunger, thirst)

(Source: Baker et al. 2018 & O'Brien, H. L. 2020)

2.10.4 Keller's ARCS Model of Motivational Model

The ARCS Motivational Development Model (1987) often utilises instructional content to deliver training resources that are both effective and motivating. The development of the ARCS model was motivated by a need to better comprehend the key aspects influencing learning motivation and to establish systematic approaches for identifying and resolving issues related to learning motivation (Keller, 1987). The ARCS model is founded on Keller's macro-theory of motivation and instructional design (1979, 1983, 1987a: Keller & Kopp, 1987). The model consists of four primary components: attention (A), relevance (R), confidence (C), and satisfaction (S). Figure 2.8 displays Keller's ARCS Model of Motivational Model.

Figure 2.8 : Keller's ARCS Model of Motivational Model (Keller, 1987)

Such four key criteria of the ARCS model include a number of concepts hypotheses, a collection of techniques, variables that define human motivation, formal design processes and motivational methods. The principles relating to the ARCS model conditions are described in Table 2.8 and ARCS model strategies are summarized in Table 2.9. The details explanation of ARCS model integration in MARCO design and development is discussed in Chapter 3.

Table 2.8

Details of ARCS Model (Keller, 2008)

Conditions	**Principles**
Attention	Learning motivation is stimulated when the interest of a learner is awakened because of a perceived gap in current knowledge.
Relevance	Learning motivation is stimulated when the acquired knowledge is perceived as being meaningfully related to the learner's needs and goals.
Confidence	Learning drive is increased as learners believe they can complete the learning activity effectively.
Satisfaction	When learners anticipate and experience successful learning outcomes, motivation to learn is stimulated.

Table 2.9

ARCS categories of strategies

Attention	**Relevance**	**Confidence**	**Satisfaction**
A1: Perceptual Arousal:	R1: Goal Orientation:	C1: Learning requirements:	S1: Intrinsic Reinforcement:
Capturing students' interest with	Refers to how new learning methods	Refer to providing standards and criteria	Refers to the natural enjoyment

surprises and uncertain	allows learners' use their existing skills to achieve learning objectives	to initialize positive anticipations to achieve a goal	of the learning experience
A2: Inquiry Arousal:	R2: Motive Matching:	C2: Success Opportunities:	S2: Extrinsic Rewards:
Stimulates curiosity and grabbing students' attention	Refers to learners' learning motives and needs.	Refer to gain achievement through various experiences	Refers to positive response and constructive feedback
A3: Variability:	R3: Familiarity:	C3: Personal Control:	S3: Equity:
Combines a variety of teaching methods to attract attention	Refer to learners' prior knowledge/skills	Refer to personal aptitude and expertise to increase confidence	Refers to consistence and sustaining success.

Moreover, instructional design developers employ Keller's ARCS Model as a motivational aspect in application design and development because it emphasizes capturing learners' attention through various strategies, such as using novel or surprising elements, stimulating curiosity, or presenting real-life scenarios, which enhances learners' engagement and motivation (Keller, 2010; Spector et al., 2016). This model also emphasizes the importance of demonstrating the relevance and practicality of the instructional content to learners' and goals, promoting intrinsic motivation (Keller, 2010; Chen, Liu & Lee, 2017). Furthermore, the Keller's ARCS Model focuses on building learners' confidence and self-efficacy through strategies like providing clear instructions, offering support, and incorporating achievable goals, leading to increased motivation and persistence (Keller, 2010; Hung, Zhang & Chen 2020) as well as providing opportunities for learners to experience a sense of satisfaction and accomplishment, such as through immediate feedback, recognition, or rewards, which enhances motivation and promotes continued learning (Keller, 2010; Chen et al., 2017).

2.11 Research Gap

While the field of instructional design has seen significant advancements, the specific application of Instructional Design (ID) models for Mobile Augmented Reality (MAR) learning remains relatively unexplored even though several general ID models can be adapted to suit the unique characteristics of MAR, a dedicated model tailored to the specific needs of MAR-based learning has yet to emerge (Johnson, Adams, & Willis, 2015). To further enhance the effectiveness of MAR in education, there is a need to develop a specialized ID model that specifically addresses the unique characteristics of MAR and incorporates elements such as comprehension, engagement, motivation, and spatial visualization ability (SVA). This new model could integrate the strengths of existing models while addressing the specific challenges and opportunities presented by MAR technology.

The focus of this study was on implementation of MARCO application modes to explore whether this will increase student interest in comprehension, learning engagement and perceived motivation. Although a lot of research has been done in this area, there is no study that explores in depth how Malaysian Polytechnic students enhanced their spatial visualization ability by implementing of MAR technology with integration of functional and physical realism. To resolve this gap, this research focuses on improving spatial visualization ability from the standpoints of MAR application. In addition, based on the knowledge of the researcher, no study was conducted to investigate the effects of MAR on course comprehension, learning performance and perceived motivation in CSO learning among students with specific spatial visualization skills.

2.12 Summary

This chapter provides an overview of CSO, AR technology, instructional principles, MAR application, spatial visualization ability and the outcome domains of this study. This chapter also presents a detailed review of the theoretical framework that framed the foundation of this study. This chapter provides a detailed review of the theoretical framework that formed the foundation of this study. This chapter concludes with a comprehensive overview of prior studies, which is crucial and valuable for researchers to comprehend the current challenges in CSO, spatial visualization learning, instructional methods, and the increasing acceptance of AR in education. Building upon the insights gained from the literature review, in the next chapter, a research methodology is presented.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Overview

The objective of this research is to examine the effects of Mobile Augmented Reality Computer Organization (MARCO) on dependent variables: student comprehension, learning engagement and student perceived motivation. In this research, two modes of MARCO: Mobile Augmented Reality Computer Organization with Physical Realism (MARCO-PR), and Mobile Augmented Reality Computer Organization with Function Realism (MARCO-FR) are developed. This chapter describes the design and methods of the research, the variables involved, techniques of data collection, methodology of data analysis, the sample of research and sampling. It also includes the design of teaching materials and the data collection and statistical analysis processes.

3.2 Research Design

A research design is a plan to answer the research question and a good research design ensures that the data obtained will help to answer research question effectively (Virginia Tech University Libraries, 2018). In this study, quantitative quasi-experimental design will be use as research design. This research design is selected because the study aims to identify the distinctive cause and effect of using different MARCO modes (MARCO-FR & MARCO-PR) in learning Computer System Organizations (CSO). The quasi-experimental design will be employed in this study.

The quasi-experimental research design is used when it is not feasible for the researcher to randomly assign subjects within the sample (Gribbons & Herman, 1997).

In this research, four sections of the same course are compared and thus, the random assignment of subjects to either group is not within the researcher's control. The researcher used the 2 X 2 factorial design to examine the main effect of MARCO treatment modes approach as an independent variable on the dependent variables: student perceived motivation, learning engagement and student comprehension. It also designs to investigate the effect of students' Spatial Visualization Ability (SVA); High Spatial Visualization Ability (HSVA) and Low Spatial Visualization Ability (LSVA) as a moderator variable on three dependent variables in both treatment modes. The X and O notations was employed to visually represent the temporal sequence of treatments (X) and measurement (O) for each combination of independent variables, enabling a clear depiction of the intervention's effects on the outcome measures over time (Smith & Johnson, 2022). Table 3.1 illustrates the research design.

Table 3.1

Factorial design of the study

Independent Variables (Treatment Modes)	**Moderator Variables**		**Dependent Variables**
MARCO-PR **(X_1)**	HSVA	LSVA	O_1 O_2 O_3
MARCO-FR **(X_2)**	HSVA	LSVA	O_1 O_2 O_3

HSVA	High Spatial Visualization Ability
LSVA	Low Spatial Visualization Ability
X1	Mobile Augmented Reality Computer Organization with Physical Realism
X2	Mobile Augmented Reality Computer Organization with Functional Realism
O_1	Student Comprehension
O_2	Learning Engagement
O_3	Perceived Motivation

The researcher used two experimental groups:

i. Experimental group (I) consisted of HSVA and LSVA students who were taught using MARCO-PR.

ii. Experimental group (II) consisted of HSVA and LSVA students who were taught using MARCO-FR.

The research design with the treatments and instruments involved are illustrated in Figure 3.1.

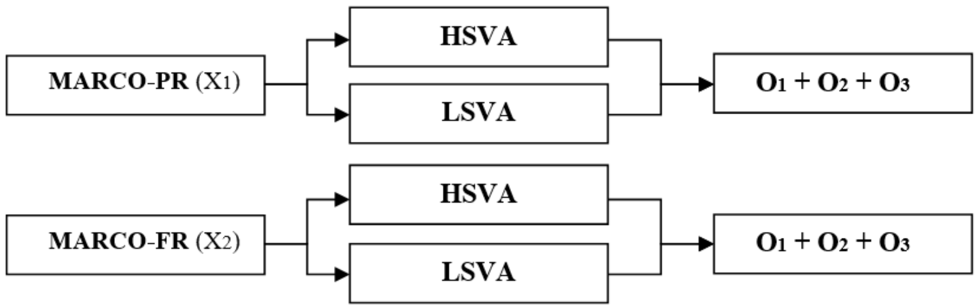

Figure 3.1 : Research quasi-experimental design

In addition, this quasi-experimental study will involve a pre-test and post-test, which will be conducted under the supervision of the researcher and lecturer with the pre-arranged selected classes. Pre-test and post-test questions are developed to measure the level of understanding of the students on one of the subjects in the CSO course. These pre-test questions will be given to the students from both experimental groups, MARCO-PR and MARCO-FR before the experiment. At the end of the experiment, the students will then be given the evaluation and post-test questions. The students' score will be analyzed to assess the efficacy of the modes of treatment. Table 3.2 describes the flow of the quasi-experimental pre-test and post-test design.

Table 3.2

Quasi-experimental pre-test and post-test design

O_{1a}	X_1	O_{1b}	O_2	O_3
O_{1a}	X_2	O_{1b}	O_2	O_3

X_1 Mobile Augmented Reality Computer Organization with Physical Realism

X_2 Mobile Augmented Reality Computer Organization with Functional Realism

O_{1a} Pre-Test Student Comprehension

O_{1b} Post-Test Student Comprehension

O_2 Learning Engagement

O_3 Student Motivation

3.3 Sample and Population

The research population refers to the overall subjects the researcher needs to collect and draw conclusions (Murphy, 2016). The purpose of population definition is to establish boundary conditions that specify who is included in or excluded from the population (Murphy, 2016). There are two types of populations used in this research: (i) target population and (ii) accessible population. Target population refers to the entire group of individuals that researchers used for generalizability. The target population typically varies in characteristics and is known as the theoretical population (Steinrucken, Paul & Song, 2013). Accessible population is the population in which researchers derive their conclusions. Each population is a subgroup of the target population and is referred as the study population. (Figure 3.2). Researchers draw their samples from an obtainable population (Steinrucken et al., 2013).

The accessible population for this research refers to the entire students that registered in the Polytechnic Diploma in Information Technology (Digital Technology) (DDT) program who enrolled the DFC1033 Introduction to Computer System (ICS) course during June 2020 session in National Polytechnics. The total number of students enrolled for that particular semester is 413 (Polytechnics Student Recruitment Division, 2020).

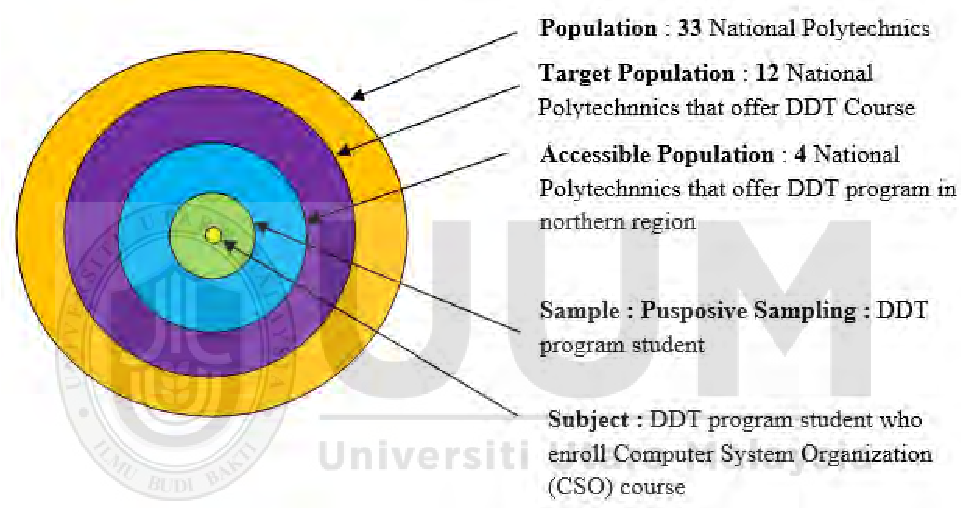

Figure 3.2 : Linking population, sample, and elements in a study

According to Steinrucken et al. (2013), a sample is the population representation that is being studied, and the researcher drawing conclusions based on the sample. The sampling process consists of selecting a sample from a predefined population that represents the population (Steinrucken et al. 2013). The sample size is the number of subjects involved in the research on which the experiment was conducted (Aron & Aron, 2009).

The overall population of Semester 1 students in 12 Malaysian Polytechnics in Malaysia who enrolled in DFC1033 Introduction to Computer System (ICS) course during June 2020 session is 413. A sample of 200 students from that population was randomly selected from four Malaysian Polytechnics. This samples consisted of polytechnic students across the country with homogenous background based on the established qualification (Polytechnics Student Recruitment Division, 2020). The sample size (n=200) was determined using the sample size table of Krejcie and Morgan (1970), stating an error margin of 5 per cent. Purposive sampling was used in this study and participants have been chosen from students of the DDT program who are required to complete an CSO course. According to Othman, (2013), purposive sampling is used to access a subset of population as all sample of a study are selected because they fit a specific profile. The distribution of the sample in the study is tabulated in Figure 3.3.

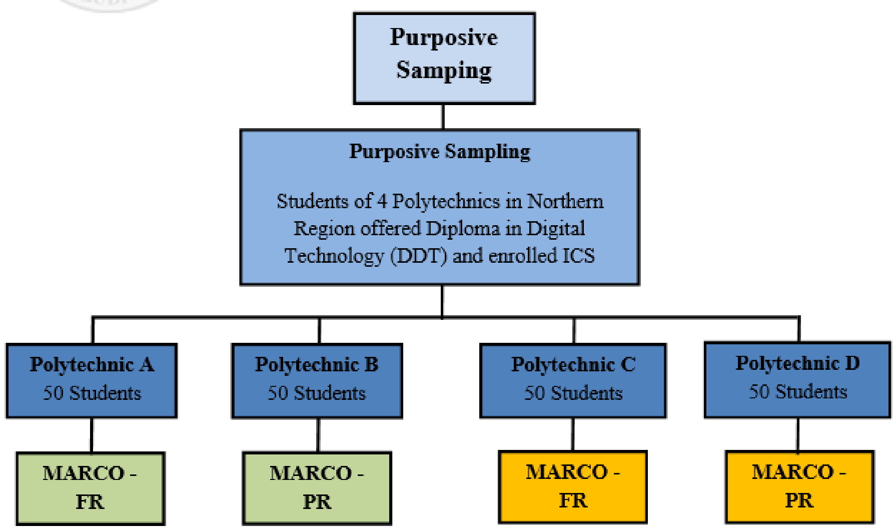

Figure 3.3 : Group distribution depending on MARCO modes

3.4 Research Variables

This study included three types of variables: (a) the independent variables; (b) the dependent variables; (c) the moderator variables. The summarized variables are shown in Figure 3.4.

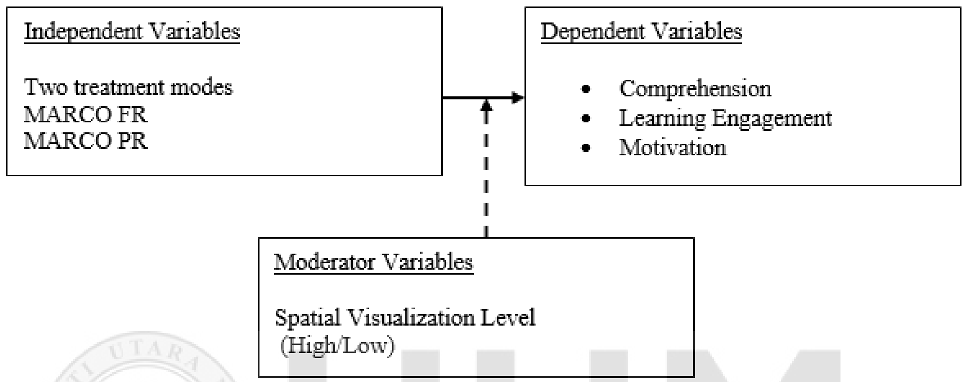

Figure 3.4 : The relationship between independent, dependent, and moderator variables

3.4.1 Independent Variables

Independent variables: MARCO treatment modes which have two modes, (i) Mobile Augmented Reality Computer Organization with Physical Realism (MARCO-PR) and (ii) Mobile Augmented Reality Computer Organization with Functional Realism (MARCO-FR):

i. MARCO-PR: Student learned computer hardware assembly & installation topic in CSO course by using Mobile Augmented Reality (MAR) application which integrates digital visual information (sound, 3D images, animation and text) with a real environment. It helps students to identify computer hardware and its function. MARCO-PR mode provided details visual simulation as the real hardware on every hardware component as well as seamless integration of virtual objects with the real-world environment.

ii. MARCO-FR: Student learned computer hardware assembly & installation topic in CSO course by using Mobile Augmented Reality (MAR) application which integrates digital visual information (sound, 3D images and text) with a real environment. It helps students to identify computer hardware and its function. MARCO-FR mode provided functional visual simulation (3D) on every hardware component as well as simulate the functionalities and behaviors of virtual objects realistically.

The details explanation of MARCO treatment materials modes in on subsection 3.5, offering a thorough understanding of its focus and content.

3.4.2 Moderator Variables

Moderator variables for this study is: Student Visualization Ability (SVA), which has two levels (i) High Spatial Visualization Ability (HSVA) and (ii) Low Spatial Visualization Ability (LSVA). SVA are assessed using Spatial Visualization Ability Test Instrument (SVATI) to classify student visualization level whether they HV or LV.

i. HSVA: Students can visualize an object in 2D or 3D dimension and able to visualize configuration change on the object when it manipulated. They are also able to visualize idea and imagination into real objects. Score above 50% in SVATI.

ii. LSVA: Students hard to visualize an object in 2D or 3D dimension and poor to visualize idea and imagination into realistic objects. Score low than 50% in SVATI.

The significance of SVA as a moderator variable in this research that involving visual learning environments lies in its essential role in influencing how learners interact with and comprehend visual information (Smith & Johnson, 2023). A comprehensive exploration of SVA's provides invaluable insights into how learners with varying levels of SVA skills navigate and make sense of visual stimuli, ultimately elevating understanding of the learning process in visual learning environment contexts.

3.4.3 Dependent Variables

Dependent variables comprising three variables:

i. Comprehension: Students' understanding in CSO course assessed and measure using a Computer System Organization Test (CSOT), which was applied twice: before and after the treatment. The actual scores of the students' comprehension test is the adjusted mean of the post-test score that was calculated based on the pre-test score. The details explanation of CSOT in on subsection 3.6.1.

ii. Learning Engagement: Students' learning engagement. The level of engagement evaluated using O'Brien's User Engagement Scale (UES) (O'Brien's, 2018). The details explanation of UES in on subsection 3.6.2.

iii. Perceived motivation. The perceived motivation scores evaluated using an Instructional Material Motivational Scale (IMMS) (Keller, 1993). The details explanation of IMMS in on subsection 3.6.3.

It is crucial for unraveling the intricate interaction between these variables as a profound understanding of how learners with varying levels of SVA engage with MAR instructional content and gain deeper insights motivational perceptions interact with their SVA skills, particularly in the virtual learning environment, providing a holistic understanding of effective learning strategies (Chen, Williams, Rodriguez & Patel, 2023).

3.5 Research Treatment Materials Modes

The treatment materials in this research are focused on the content of the CSO course, a key subject required for all students of the DDT programs at National Polytechnics. CSO course is based on DFC1033 Introduction to Computer System (ICS). It is a compulsory subject that needs to be passed by students. The syllabus of the course includes course synopsis, course learning outcomes (CLO), Program Learning Outcomes (PLO), course outline content, course activities, mode of delivery, Program Educational Objective (PEO), assessment specification table (AST), teaching-learning and assessment strategies. This course was selected because it is a fundamental course in computing studies offered in the DDT program. Also, this course emphasized on the hardware, software and foundation in basic Information Technology knowledge and skills necessary for ICT professionals.

The primary purpose of designing and developing the MARCO is to create better interactivity and engagement in a learning environment. Two modes of application are formed as a medium to instruct student with different visualization ability. The application content is developed based on ICS syllabus according to Polytechnic Curriculum Division (2018). The main focus on this application is on computer hardware function and assembly. Four groups of students will learn using equal application content but with different modes. The student will be guided to use the application, and they also will be taught based on learning instruction that will be provided by researchers and will be assisted by lecturers.

The specification of two treatment modes: Mobile Augmented Reality Computer Organization with Physical Realism (MARCO-PR) and Mobile Augmented Reality Computer Organization with Functional Realism (MARCO-FR) are listed in Table 3.3.

Table 3.3

MAR treatment modes specification

Characteristics		**MAR Treatment modes**	
Variables		**MARCO-PR**	**MARCO-FR**
Objectives		1. Provide a visual learning environment to improve comprehension, increase motivation and engage learners. 2. Explain part of subtopic contents of the syllabus	
Presentation Modes		Mobile Augmented Reality with Physical Realism	Mobile Augmented Reality with Functional Realism
Elements	Text / Caption	√	√
	Animations	√	√
	3D Models	-	√
	Actual Component	√	-
	Sound	√	√
Features	Details 3D	-	√
	Interactive computer assembly simulation.	√	√
	360 View	√	√

The difference between both modes is MARCO-PR focuses on achieving visual coherence and seamless integration of virtual objects with the real-world environment. This involves aligning virtual objects with real-world spatial features and textures to create a convincing and believable AR experience as well as emphasis augmentation to give instruction where it enables better visualization as the learners can concentrate on the visual content to be conveyed. Through this approach, learners are guided to interact with real computer parts, while AR overlays deliver immersive and detailed instructions on each component's functionality and significance, fostering a comprehensive understanding of computer systems. On the other hand, MARCO-FR allows learner to receive immediate visual feedback on how a given virtual object would look in a different setting, properties and interaction. Through this approach, learners engage with representations of computer parts in a virtual environment (3D models and animation) as well as the ability of AR systems to simulate the functionalities and behaviors of virtual objects realistically. This includes their interactions, movements, and responses to user input. Thus, in the next section, will provide details explanation on research instrument use to measure the dependent variables of this study.

3.6 Research Instrument

Research instruments that used in this study consist of, (i) Computer System Organization Test (CSOT) to measure students' comprehension, (ii) O'Brien's User Engagement Scale (UES) (O'Brien's, 2018) to measure students' learning engagement and (iii) Instructional Materials Motivation Scale (IMMS) (Keller, 1993) to measure students' perceived motivation. UES and IMMS were chosen for their proven effectiveness in measuring engagement and motivation in digital learning environments (O'Brien, 2018; Keller, 2010). These scales align closely with the study's focus on engagement and motivation, as demonstrated in prior augmented reality-based research. Additionally, the Spatial Visualization Ability Test Instrument (SVATI) (Maizam, 2002) are used to determine whether they are high visualization level or low visualization level. Summary of research instruments are listed in Table 3.4.

Table 3.4

Summary of the research instrument

Test	**Developer/ Year**	**Durations (Minutes)**	**Type**	**Items**	**Descriptions**
Computer System Organization Test (CSOT)	Adapted from DFC1033 Introduction to Computer System (ICS) final year examination	30 30	Pretest Posttest	30 30	The two sets of tests were identical except for the order of the questions.
Learning Engagement Scale (UES)	O'Brien's (2018)	30	Learning Engagement	30	• Focus Attention (FA) • Perceived Usability (PU) • Aesthetic Appeal (AE) • Reward Factor (RW)
Instructional Materials Motivation Scale (IMMS)	Keller (1987), translated by Toh (1998)	20	Perceived motivation	36	• Attention • Relevance • Confidence • Satisfaction
Spatial Visualization Ability Test Instrument (SVATI)	Maizam (2002)	30	Spatial Visualization Ability	28	• 3D Spatial information

3.6.1 Computer System Organization Test (CSOT)

Computer System Organization Test (CSOT) used to assess the comprehension of the students before and after use of treatment modes. These pre-test and post-test question items are based on the DFC1033 Introduction to Computer System (ICS) course. The topic chosen in this study is on ‘Chapter 1: Introduction to Computer System’ and ‘Chapter 2: Computer Assembly and Installation’. This topic was chosen because it is related to the understanding of each component in the computer system and also the assembly and installation method that requires a high level of spatial visualization to comprehend (Dewan, Mamun & Rahman, 2020). The designing and developing of the CSOT are being prepared using the following steps:

i. Researcher hold several meetings with two subject matter experts who are qualified and experienced lecturer who had been teaching the CSO course of at least 4 years to define the items of the test.
ii. Constructing and reviewing test items based on CSO course subtopic chosen. Items are also validated by other CSO course lecturers who are respectively experts in field.
iii. Piloting the pre-test and post-test item to test the coefficient of reliability using Alpha Cronbach.

The expert-formed questions items offer several advantages in term of novelty and specificity. The questions tailor specific to the research interests and hypotheses, accurately assess the relevant skill sets, delve deeper into specific areas that allows for uncovering new insights and contributing to the improvement of knowledge and higher level of engagement (Barroga & Matanguihan, 2022). In this research, the reliability coefficient is calculated on the basis of data obtained during the pilot study. The reliability coefficient is commonly used to indicate the consistency of an entire scale. The pre-test and post-test used in this study had a reliability coefficient of 0.83. The CSOT item details are summarized in Table 3.5.

Table 3.5

Pre-test and post-test item details

Subtopic	Components	Item Number	Coefficient
1. Introduction to computer system	Internal computer component	21	0.84
2. Computer Assembly and installation	Assembling internal computer component	9	0.82
Total		30	0.83

3.6.2 User Engagement Scale

O'Brien's User Engagement Scale (UES) (O'Brien's, 2018) used to measure the students' learning engagement toward using MARCO treatment modes. Baker, Bakar & Zulkifli, (2018) provided an in-depth analysis of the work of O'Brien's (2018) showing the relevance of UES factor which are consistent with AR engagement element. As noted by Doherty and Doherty (2018) UES approaches support rich description by partially which is readily applicable and can facilitate a detailed analysis. UES was designed to measure element of engagement that involve four factors or dimensions which is Focus Attention (FA), Perceived Usability (PU), Aesthetic Appeal (AE) and Reward Factor (RW). Each factor consists of a particular engagement element. Focus Attention gauges the extent of user captivation by the interface, clarity of the purpose and task relevance; Perceived Usability measures users' perceptions of the system's functionality, spatial awareness and seamless interaction; Aesthetic Appeal assesses the visual attractiveness of the interface, information clarity and integration; and the Reward Factor captures the degree to which the system provides meaningful and satisfying outcomes (O'Brien's, 2018). These dimensions could translate to MARCO treatment modes procedure, where users interact with virtual elements integrated with the physical elements (Bailenson, Sun & Beggiato, 2021). The engagement elements are outlined in Table 3.6.

Table 3.6

Engagement element factors

Engagement Elements			
(FA)	(PU)	(AE)	(RW)
Focus Attention	Perceived Usability	Aesthetic Appeal	Reward Factor
• Novelty	• Control	• Aesthetics	• Motivation
• Attention	• Usability	• Interest	• Goal
• Feedback	• Positive Effect	• Awareness	• Interactively
• Time	• Negative Effect		• Challenge
• Interruptions			

This Likert-style scale instrument has 30 items of four (4) subscales. Seven items are listed under FA, eight items are listed under PU, five items listed under AE and ten items listed under RW. The scales value for each statement is: (a) 1 – Strongly Disagree, (b) 2 – Disagree, (c) 3 – Neither Agree nor Disagree, (d) 4 – Agree and (e) 5 – Strongly Disagree.

The reliability of this UES is 0.83 (O'Brien's, 2018). The internal consistency reliability coefficient for this instrument conducted using the sample participated in this pilot study. Pilot test have been done and the finding of the internal consistency reliability coefficient is 0.84. The Cronbach's Alpha scores for the instrument exceed the threshold of 0.7, indicating acceptable to high reliability (Gay & Airasian, 2009). This ensures consistent measurement of variables, enhancing the credibility of findings. Table 3.7 provides a summary of Cronbach's Alpha reliability coefficient for each of the UES factors**.**

Table 3.7

UES reliability score

UES Factor	**Items**	**Cronbach's Alpha Coefficient (O'Brien's, 2018)**	**Cronbach's Alpha Coefficient (Pilot Study, 2019)**
Focus Attention	1-7	0.82	0.88
Perceived Usability	8-15	0.86	0.84
Aesthetic Appeal	16-20	0.84	0.83
Reward Factor	21-30	0.81	0.82
Total	**30**	**0.83**	**0.84**

3.6.3 Instructional Material Motivational Scale (IMMS)

The Instructional Material Motivational Scale (IMMS) is utilized to assess students' motivation in relation to the utilization of MARCO treatment modes. The purpose of IMMS was to assess responses to instructional materials that individuals use to teach themselves (Keller, 2010). According to Keller (2010), IMMS can be applied to printed self-directed learning, computer-oriented learning, and online learning. This Likert-style scale instrument has 36 items of four (4) subscales. Nine items are listed under Relevance and Confidence subscales respectively, the Satisfaction subscale has six items, and the Attention subscales consist of 12 items. The scales value for each statement is: (a) 1 – not true, (b) 2 – slightly true, (c) 3 – moderately true, (d) 4 – mostly true and (e) 5 – very true.

Estimated reliability based on the Cronbach alpha was adequate at 0.96 (Keller, 2010). The internal consistency reliability coefficient for this instrument conducted using the sample participated in this pilot study and it was stated that the internal consistency reliability coefficient of 0.85. Table 3.8 provides a summary of Cronbach's Alpha reliability coefficient for each of the IMMS factors.

Table 3.8

IMMS reliability score

ARCS Elements	**Items**	**Cronbach's Alpha Coefficient (Keller, 2010)**	**Cronbach's Alpha Coefficient (Pilot Study, 2019))**
Attention	12	0.89	0.86
Relevance	9	0.81	0.82
Confidence	9	0.80	0.82
Satisfaction	6	0.92	0.88
Total	**36**	**0.96**	**0.85**

3.6.4 Spatial Visualization Ability Test Instrument (SVATI)

Spatial Visualization Ability Test Instrument (SVATI) will be used to measure the students' visualization level to determine the ability of the student to visualize characteristics of the object from all angles. SVATI test are included with pattern matching test which is appropriate to use for identifying student ability to visualize and recognize computer parts in three-dimensional objects (Maizam, 2002). This test question consists of 28 items designed to see how well students can visualize the rotation of three-dimensional (3D) objects. Three types of spatial visualization task were used in SVATI: (i) Cube Construction Task, (ii) Engineering Drawing Task and (iii) Mental Rotation Task. SVATI measures multiple aspects of spatial visualization, offering a broader picture than tests targeting a single aspect (Hegarty & Kozhevnikov, 2019). Students who score higher than 50% in the test will be categorized as high visualization, while those students who score less than 50% in the test will be classified as low visualization. SVATI items allocation can be referred in Table 3.9.

Table 3.9

SVATI item allocation

Tasks	Items	Descriptions	Types of Ability
Cube Construction Task	1-10	The student, will be presented 10 shapes in 2D pattern and student needs to identify which is the correct 3D shape for each 2D pattern.	Mental rotation
Engineering Drawing Task	11-21	Student will be presented with 11 3D shapes and student needs to identify which is the correct 2D pattern for each 3D shapes. (Decomposing 3D shapes/object)	Mental rotation
Mental Rotation Task	22 - 28	Student will be presented with 7 3D shapes and student needs to identify different view and angle of each 3D shapes	Spatial visualizat ion

SVATI was published by Maizam in (2002). The internal consistency (reliability) for this instrument is conducted using the sample participated in this pilot study and it stated that the internal consistency reliability coefficient of 0.74. Table 3.10 presented a description of Cronbach's Alpha reliability equation for each of the SVATI variables. Additionally, SVATI has undergone rigorous development and validation, signifying its reliability and effectiveness in measuring spatial visualization abilities (Liu, He, & Chen, 2022). Moreover, SVATI focuses specifically on spatial visualization that ensure a targeted assessment of relevant skills (Lohman, & Nichols, 2021).

Table 3.10

SVATI reliability score

SVATI Elements	Cronbach's Alpha Coefficient Maizam in (2002)	Cronbach's Alpha Coefficient (Pilot Study, 2019))
Cube Construction Task	0.74	0.72
Engineering Drawing Task	0.72	0.70
Mental Rotation Task	0.80	0.82
Total	**0.70**	**0.74**

3.7 Research Procedures

Nine primary stages in research procedures were applied in this study. First step is identifying research subjects, second step is design of Instructional Design model (ID) model of mobile augmented reality, third step design and development of instructional materials of MARCO application, fourth step is evaluation and expert reviews, fifth step is validity of research instruments, sixth step is reliability of research instruments, seventh step is conduct of pilot study, eighth step is conduct of quasi-experiment and the last step is data collection and analysis. The research procedure diagram is represented as in Figure 3.5 and elaborated as follows. The detailed explanation on ID model design process and MARCO application is described into following chapter 4.

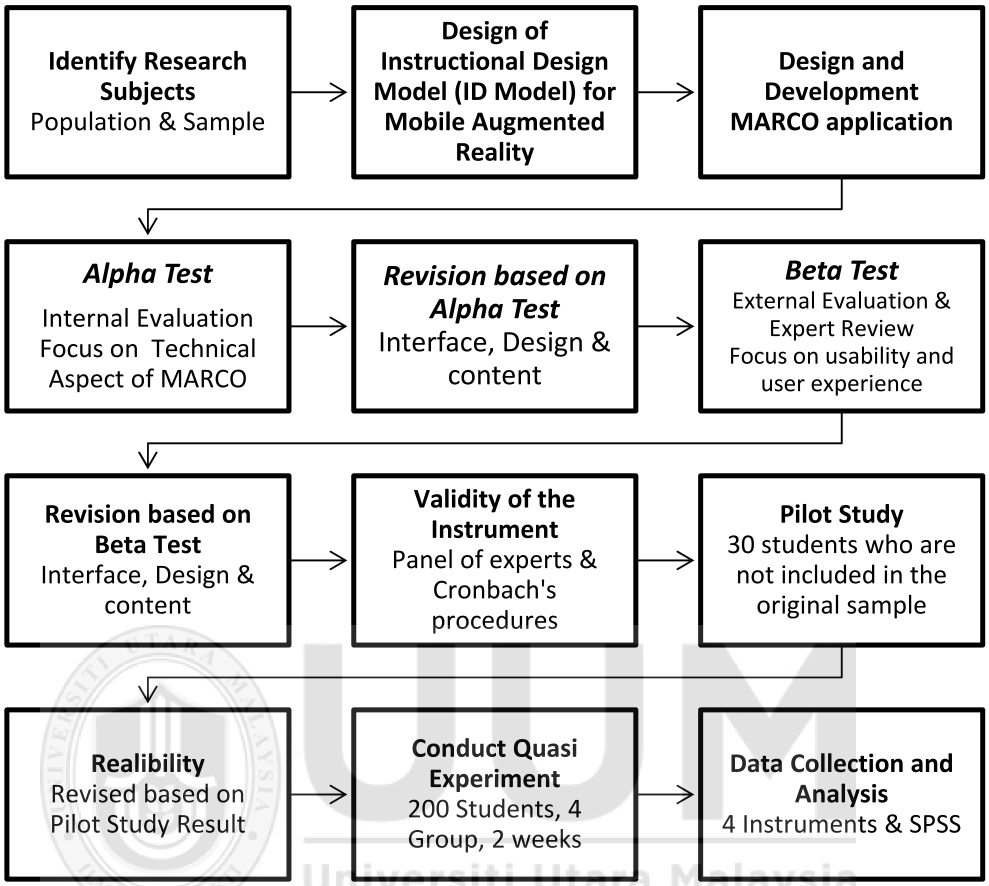

Figure 3.5 : Research procedure diagram

3.7.1 Identify Research Subjects

In the initial step, need analysis and the useful information is required in order to determine the desired learning results. The aim of MARCO implementation in this study is to enhance the understanding, learning participation and encouragement of the students towards learning computer hardware. This learning content are based on the DFC1033 Introduction to Computer System (ICS) course syllabus provided by the Polytechnics Curriculum Division (2018). The population consisted of 413 Semester 1 students from four Malaysian National Polytechnics offering DDT program from north region. These students are from the Department of Information Technology and Communication (DICT) from four northern region polytechnics. A sample of 200 students from this population was randomly selected from four National Polytechnics.

3.7.2 Design of Instructional Design Model of Mobile Augmented Reality

After identifying research subjects, the development of the Instructional Design (ID) model was carried out through a structured process involving several key steps. First, related models were identified through a comprehensive review of existing literature, ensuring the inclusion of well-established frameworks relevant to the study. Next, these models were analyzed to extract essential components and principles that align with the instructional objectives. Subsequently, the key features of these models were synthesized, allowing for the integration of complementary elements into a unified framework. Finally, the combination of these components culminated in the development of a conceptual ID model, specifically tailored to address the requirements of the instructional context for mobile augmented reality. This approach ensured a methodologically sound and contextually relevant model. The design and development of the ID model has been explained in detail in subchapter 4.2. After the completion of these ID model design phase, the next phase is to proceed with design and development of MARCO application based on the integration of ID model to guide the process, ensuring the MARCO application aligns with the instructional goals and outlined in the model.

3.7.3 Design and Development of MARCO application

After identifying research subjects, researcher collected information on significant resources to support the development of instructional materials (e.g., instructional materials, reference books, printed materials, storyboard wireframe sheets and growth files) before both MARCO treatment modes are designed and developed. The researcher also takes into account the constraints imposed by the project, such as application constraints, copyright and permission of existing content. After the primary data and information gathering is completed, the researcher will start the design and development process. The design and development process were guided by the characteristics of the two MARCO treatment modes. This involved creating a MAR platform, designing user interfaces design, developing 3D visuals, animations, videos, audio and application sequences. The detailed process is explained in subchapter 4.3. After the completion of the design and development phase, it is essential to proceed with evaluation through alpha and beta testing, as well as expert review, to ensure the robustness of the application's functionality and usability.

3.7.4 Evaluation and Expert Reviews

The processes involved evaluation of the concept: alpha test and beta test based on the design of the Instructional Design System (2001) by Alessi and Trollip. Throughout the alpha test, internal group of content & application developer, instructional designer and interface designer evaluated the MARCO treatment modes. The focus is on identifying bugs, glitches, and other issues in the application to verified either the

MARCO treatment modes worked as intended. Each MARCO treatment modes component was tested, debugging, and evaluated using MARCO application alpha evaluation form (Appendix G). Upon alpha test completion, the treatment modes were then revised and went through second evaluation phase (i.e., beta pilot test). In this beta test, where a group of external experts gets to test the application in a real-world environment. Experts evaluated the MARCO treatment modes for analyzing materials, 3D models and animation used, instructional materials order, user's interface design, application flow and navigational aspects. The focus is more on usability and user experience.

For this review, three types of experts were appointed, namely the content experts, instructional design expert and technology expert. The selected experts are all from Polytechnics. It is the responsibility of the content experts to evaluate the accuracy, significance, sequencing and comprehensiveness of the content using MARCO application content evaluation form (Appendix H). Then, the instructional design experts will discuss the user interface (UI) and user experience (UX) architecture and analyze the functionality and navigational features of MARCO treatment modes, while technology experts will advise on the implementation of MAR technologies using MARCO application beta evaluation form (Appendix I). All the experts chosen to review the developed instructional materials are qualified and well experienced in their field respectively. Details background of the expert is on table 3.17. Both MARCO treatment modes were revised and improved based on experts' feedback and recommendations. The collected feedback and improvement were assessed via two stages: alpha and beta testing. Table 3.11 clarifies the procedure for assessing, providing feedback and enhancing the MARCO treatment modes.

Table 3.11

The MARCO evaluation, feedback and improvement process during the alpha and beta test phases

Phase	Evaluation	Feedback	Improvement
Alpha	MARCO alpha application evaluation form (Appendix G) Content & Apps Developer	• The 3D animation of assembling a computer was too fast and instruction of the assembling process are not clear • Delay on images and 3D graphic projection while processing the augmented reality markers. Some AR markers were difficult to detect.	• Animation timing had been adjusted to decent speed • Improve AR marker detection and angle sensitivity
Beta	MARCO beta application evaluation form (Appendix I) Technology Expert	• Handheld device require student has to hold mobile phone while rotating the markers cause limitation on controlling the markers. • Phone compatibility issue, certain mobile phones screen resolution not supported.	• Adding object rotation & zoom control • Updating android support version for the application
Beta	MARCO application content evaluation form (Appendix H) Content & Instructional Design Expert	• Text information provided for each 3D models, animation and images are insufficient. • Step by step of assembly simulation are not complete	• Adding detail information for each visual projection • Enhance more detail step by step animation

3.7.5 Validity of Instruments

Apart from the MARCO application design, development and evaluation process, it is a prerequisite for any successful research that the instruments administered are valid. The degree of success or failure of any research is, to a considerable extent governed by the validity of the research instruments (Gay & Airasian, 2000). Gay and Airasian (2000) suggested that content validity to be achieved by expert judgement. In this study, all research instrument was tested for validity. The CSOT Pre-test and Post-Test questions were validated by a panel of experts from the Polytechnics (Appendix M) while for SVATI, UES and IMMS instruments were validated by the original researcher and only need to check its internal consistency through Cronbach's procedure.

3.7.6 Reliability of the Instruments

The reliability of the CSOT Pre-test and Post-Test questions, SVATI, UES and IMMS questionnaires will be calculated based on the pilot study results. The reliability of all research instruments used in this study were tested. Internal consistency reliability procedures of CSOT Pre-test, Post-Test, SVATI, UES and IMMS questionnaires were carried out using Cronbach 's procedure to establish the coefficients of the instruments.

3.7.7 Pilot Study

A pilot study holds significant importance as it helps identify potential issues and ensure the effectiveness of data collection procedures. The technique entails conducting preliminary tests on the procedures intended for use in the primary research and subsequently modifying the procedures depending on the findings from the tests. It aids in determining the feasibility of the research design and provides valuable insights for enhancing the quality of the main study (Hair et al., 2022). Unarguably, doing pilot testing serves as a reliable deterrent against mistakes in actual research. In this study, MARCO treatment modes took two weeks to complete pilot study, and it piloted on 30 students from DDT programs (30 students, who are not included in the original sample) who already enrolled the DFC1033 Introduction to Computer System (ICS) course during the previous semester which is June 2020 session.

3.7.7.1 Administration of the Pilot Test

The pilot test was aimed to identify the arising issues with the MARCO treatment modes developed as well as to validate the research procedures. This was meant to determine whether the students were experiencing any trouble using the MARCO treatment modes during the course of treatment, either technically or academically.

At the first session, a lecturer's guideline (Appendix J) and student's guideline (Appendix K) was provided to ensure course lecturer and students knew the procedure administered. Spatial Visual Ability Test Instrument (SVATI) and Computer System

Organization Test (CSOT) Pretest were distributed to students. The next step is course lecturer given briefed to students for approximately 15 minutes concerning the instruments and on how the procedure administered. Students were given the Spatial Visualization Ability Test Instrument (SVATI) test in order to classify them as either high spatial visualization ability or low spatial visualization ability. CSOT pre-test question was provided before the implementation of the treatment using MARCO modes. Both tests were conducted in a 60-minute period. Students were advised to answer the Pretest on their own without discussing or referring course notes. After each test was completed, students were divided into two groups randomly for the MARCO-FR and MARCO-PR. Next, students were briefed on the use of MARCO treatment modes and given 60 minutes to explore the MARCO treatment modes. The students were allowed to discuss with the lecturer and friend before the session end. This is to allow students to become familiar with the application.

The second phase was taken place after a week, to mitigate the threat of history and maturation. After using MARCO treatment modes, the students responded depending on their interpretation. Firstly, the course lecturer again was briefed for approximately 15 minutes on how the procedure administered. After that, the MARCO treatment modes were given randomly to the students and underwent the MARCO treatment modes respectively in the 60-minute period whereby students were divided into two groups for the MARCO-PR and MARCO-FR. There were two groups involved which were the treatment and control group. The pilot study begun after the lecturers introduced the MARCO treatment modes and explained the treatment procedures. The students were allowed to discuss with the lecturer and friends. The researcher's role was to monitor the pilot study being introduced and to provide technical assistance. The researcher identified improvements in the actions of the students while they are using MARCO treatment modes. After 60 minutes of exploration and treatment of MARCO modes, students were given 30 minutes to answer the CSOT post-test. After they finished, the students filled out the research procedure in the UES and IMMS questionnaires. Feedback on the MARCO modes and instruments was obtained for improvement in the actual research for data collection. Finally, the researcher interviewed the students based on a semi structured general testing interview questionnaire (Appendix O) at the end of the session to get their verbal opinions on the MARCO modes. Refer to the comments and feedback received from the students considered to improve the actual implementation of MARCO treatment modes. Figure 3.6 illustrates the pilot study procedure that had been conducted.

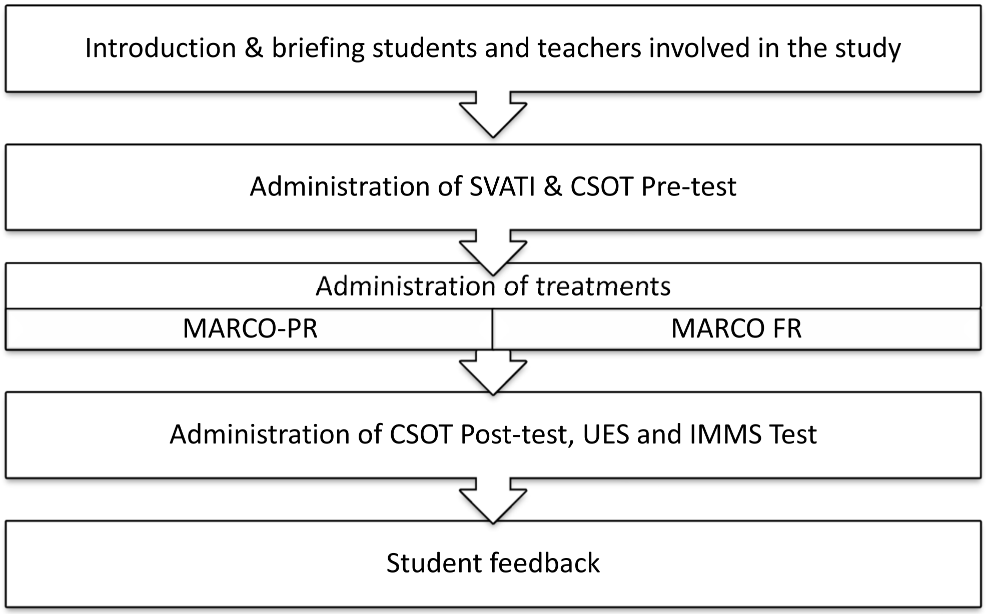

Figure 3.6 : Pilot study procedure

Pilot testing helps the researcher to gain information and issues that arise relating to the treatment of the instruments. Several issues were recorded from the pilot study as below:

i. Students bring their own mobile phone; however, some mobile phone have compatibility problems. Android operating system version need to be updated.

ii. Student having difficulty handling AR projection on mobile phone while rotating the markers as a first time using the application.

iii. Certain students not able to participate continuously as some technical issue (Low battery, phone crash) occurs during the treatment.

iv. Treatment session schedule in the lab need to be improved in term of course lecturer and student's preparation time.

In addition, according to the findings of the pilot test some parts of the testing procedures need to be changed. A proper briefing and demo should be arranged to the lecturers who will be guiding the pilot test and also the actual experiment to avoid any problems and issues during the test. This additional procedure is including the preparation of checklist and instruction manual for lecturer so they can be prepared and confident. Students also need to come to the lab and their attendance taken and marks given. Thus, students were informed by the course lecturer that teaching and learning methods have been changed to give more time for students to prepared. Class time was run as usual without any lecturing by the course lecturer.

After completing the pilot study procedure, the data obtained were analysed using Social Science Statistical Package (SPSS) that aimed to determine the improvement of the further MARCO (i.e., adjustment, testing procedures and instruments). Based on the pre-test and post-test result, the finding of the pilot test and instrument's reliability were presented in Table 3.12 and Table 3.13, respectively.

Table 3.12

Pilot test result

Mode		**Scores**		**Performance**
		Pretest	**Posttest**	**Score**
MARCO-FR	N	15	15	15
	Mean	56.25	85.95	29.70
	Standard Deviation	3.17	3.73	0.56
MARCO-PR	N	15	15	15
	Mean	61.15	81.60	20.45
	Standard Deviation	5.23	6.93	1.70
	N	30	30	30
Total	Mean	58.70	83.78	25.08
	Standard Deviation	4.20	5.33	1.13

Table 3.13

Instrument reliability

Test	**Reliability Coefficient**
Computer System Organization Test (CSOT)	0.83
User Engagement Scale (UES)	0.84
Instructional Materials Motivation Scale (IMMS)	0.85
Spatial Visualization Ability Test Instrument (SVATI)	0.74

Based on the table above, the results show that while both groups improved significantly from pre-test to post-test, there was a large difference between the mean scores for MARCO-FR and MARCO-PR used by students. This reveals the advantages of MARCO-FR in improving student comprehension, learning engagement and perceived motivation in learning CSO. However, this could not have used as a proof the results, therefore, the results of the field study are explained in detail in chapter 5. All data, feedback and comment obtained from the pilot study were subsequently incorporated into the refinement of the actual quasi experiment procedure.

3.7.8 Conduct Quasi Experiment

This quasi experiment was carried out on session June 2020, involving 200 students of DDT students from four northern region polytechnics. Each group are defined as a class from different polytechnic and consist of semester 1 class DDT students who enroll the DFC1033 Introduction to Computer System (ICS) course. To order to avoid contact between students, each participant explicitly assign to only one treatment mode, either the MARCO-PR or the MARCO-FR. Using different populations for each mode in a quasi-experiment can indeed help address threats to internal validity, such as experience effects and maturation, and maintain the study's intrinsic validity and avoid contacts by ensuring observed differences are due to the intervention itself. In these two MARCO modes, student learned the same learning content which is the ‘Chapter 1: Introduction to Computer System’ and ‘Chapter 2: Computer Assembly and Installation’ for the duration of two weeks. The experiment sessions were facilitated by course lecturers from the particular Polytechnics. The researcher has the role of providing technical support during the experiments. Table 3.14 presented the actual experiment and Table 3.15 presented the sampling distribution of this study.

Table 3.14

Summary of two phase of actual experiment

		Session June 2020			
		Week 1			
Session 1	**Tests/ Treatments**	**Times (Minutes)**			
		15	60	30	30
	Briefing / Introduction	■			
	Treatment (MARCO-FR/ MARCO-PR)		■		
	SVATI			■	
	CSOT Pretest				■
		Session June 2020			
		Week 2			
Session 2	**Tests/ Treatments**	**Times (Minutes)**			
		15	60	30	30
	Briefing / Introduction	■			
	Treatment (MARCO-FR/ MARCO-PR)		■		
	UES			■	
	IMMS			■	
	CSOT Post-test				■

Table 3.15

Research sampling distribution

DDT_A	DDT_B	DDT_C	DDT_D
MARCO FR	**MARCO FR**	**MARCO PR**	**MARCO PR**
50 student	50 student	50 student	50 student

A -Polytechnic A
B -Polytechnic B
C -Polytechnic C
D -Polytechnic D
DDT –Diploma Digital Technology
SVATI – Spatial Visual Ability Test Instrument
UES – User Engagement Scale
IMMS – Instructional Material Motivational Scale
CSOT – Computer System Organization Test

3.7.9 Data Collection and Analysis

The data acquired were analyzed using the Statistical Package for Social Science (SPSS). All data were computed at an alpha level of significance of 0.05. Pre-intervention assessment includes Spatial Visualization Test Instrument (SVATI), which is administered in order to classify the students, as either high visualization or low visualization. User Engagement Scale (UES) way employed to assess student learning participation, and IMMS was used to measure MARCO students ' perceived inspiration. The analyses which carry out are descriptive statistical analysis, reliability analysis, one-way and two-way analysis of variance (ANOVA). All instrument was measured using ordinal scale as its categories with a meaningful order. Table 3.16 showed details of data analyses.

Table 3.16

Details of data analysis

No	Hypothesis	Instrument	Statistical Test
1.	H1a: There is no significant difference between MARCO modes on student's comprehension.	Computer System Organization Test (CSOT) (Pretest and Posttest)	One-way ANOVA
2.	H1b: There is no significant difference between students' spatial visualization ability on student's comprehension regardless of MARCO modes.	Computer System Organization Test (CSOT) (Pretest and Posttest)	One-way ANOVA
3.	H1c: There is no significant interaction effect between the MARCO modes and students' spatial visualization ability on students' comprehension.	Computer System Organization Test (CSOT) (Pretest and Posttest)	Two-way ANOVA
4.	H2a: There is no significant difference among MARCO modes on students' learning engagement.	User Engagement Scale (UES)	One-way ANOVA
5.	H2b: There is no significant difference between students' spatial visualization ability on the students' learning engagement regardless of MARCO modes.	User Engagement Scale (UES)	One-way ANOVA

6.	H2c: There is no significant interaction effect between MARCO modes and students' spatial visualization ability on students' learning engagement.	User Engagement Scale (UES)	Two-way ANOVA
7.	H3a: There is no significant difference among MARCO modes on students' perceived motivation.	Instructional Material Motivational Scale (IMMS)	One-way ANOVA
8.	H3b: There is no significant difference between students' spatial visualization ability on the students' perceived motivation regardless of MARCO modes.	Instructional Material Motivational Scale (IMMS)	One-way ANOVA
9.	H3c: There is no significant interaction effect between MARCO modes and students' spatial visualization ability on students' perceived motivation.	Instructional Material Motivational Scale (IMMS)	Two-way ANOVA

The specific features of the analyses were as follows:

i. Descriptive statistics were calculated to determine the mean and standard deviations, while reliability analyses were conducted to assess the internal consistency reliability of the CSOT pretest and post-test, SVATI, IMMS, and UES tests.

ii. A one-way analysis of variance (ANOVA) was employed to ascertain whether there were significant differences between the experimental group and the control group in relation to students' comprehension during the pretest, which comprised both pre-test scores and learning engagement scores. An ANOVA was conducted to see whether there was a significant difference between the two groups in terms of their perceived motivation toward instructional materials and learning engagement.

iii. A two-way ANOVA was conducted to evaluate the effect of two independent variables on a dependent variable. It assesses not only the main effects of each factor but also their interaction effects.

3.8 Summaries of Mapping

This section examines the relationships between the Research Problem (RP), Research Objectives (RO), Research Questions (RQ), Research Hypotheses (RH), and Research Methodology (RM) to ensure alignment in the research framework. The RP serves as the foundation, guiding the formulation of RO that seek to address specific aspects of the problem. These RO are further refined into actionable RQ, which outline the study's intended purpose. The RH is constructed to provide testable propositions based on the RO and RQ, serving as a basis for empirical investigation. Finally, the RM is developed to implement the research process systematically, ensuring the effective examination of the RH and fulfillment of the RO. This interconnected framework establishes a clear pathway for addressing the RP and contributes to the methodological rigor of the study. The relationships among these elements are detailed in Table 1.1, providing a clear and concise representation of their alignment.

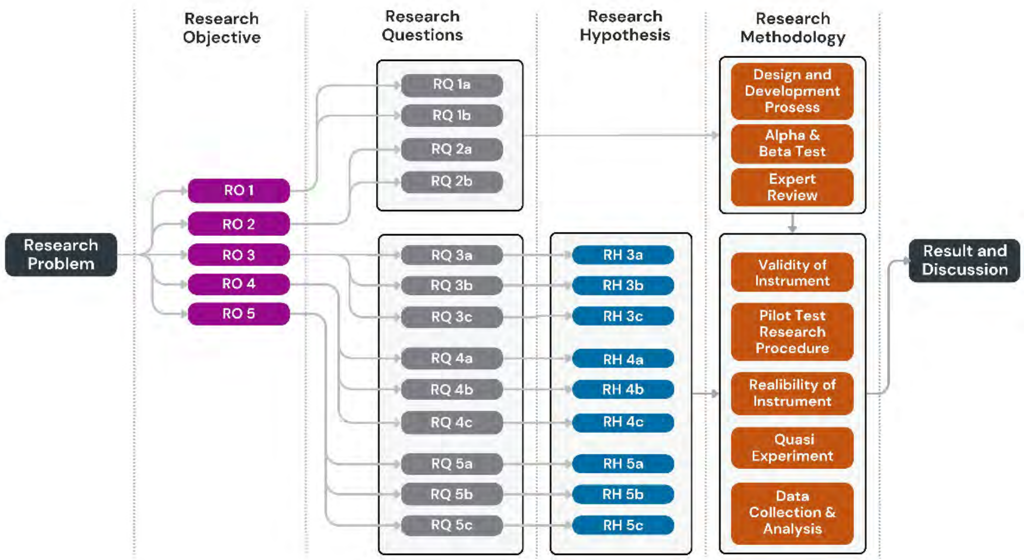

Figure 3.7 : Summaries of mapping

The diagram suggests a systematic approach to research, starting with defining objectives and problems, developing and testing instruments, and ensuring validity and reliability before moving to data collection and analysis. Each step is interconnected, ensuring a comprehensive and rigorous research process.

3.9 Internal and External Validity

This study comparing the efficacy of two types of treatment modes offers both strengths and weaknesses for this particular role. While it is worthwhile to decide which of the two treatments is best suited to a specific task, there may be methodological problems which may lead to an invalid conclusion (Gliner, 1989). The internal validity and external validity criteria must be satisfied to draw valid conclusions from the study (Gliner, 1989). Internal validity commonly refers to the control of the design which makes it possible to assume that changes in the dependent variables were due to manipulation of the independent variables (Cambell and Stanley, 1966).

The following steps were taken to track the critical variables that can influence the outcome of this experiment design as closely as possible:

i. The quasi-experimental study performed for two weeks to minimize the threat of experience and maturation and to maintain this study's intrinsic validity.
ii. The associated pretest and post-test questions were arranged in a concurrent order to avoid any potential conflict between the two tests, and the time difference between pre-test and post-test is one week to reduce the testing and instrumentation threat.
iii. To avoid interactions and minimize the effect of differential selection, the students were randomly assigned to treatment modes MARCO-FR and MARCO-PR.
iv. To maintain continuity in instructions and procedures, the lecturers of each class were presented with the detailed description of procedures as described in the lecturer's manual (Appendix J).

While internal validity refers to design control, external validity refers to the generalizability of study populations, treatment and settings results (Cambell and Stanley, 1966). External validity, on the other hand, is the level of which the results generalize populations and conditions outside the study context or relate to findings

(Gay & Airasian, 2009). The MARCO treatment modes were specifically designed and developed according to Mobile Augmented Reality Instructional (MARID) model. Evaluation series were performed by the panel of experts who assessed the functionality and user interface (UI) and user experience (UX) architecture and review the MARCO modes flow and navigation as well as the implementation of MAR technology. The experts are subject matter experts, technology expert and instructional design expert. The subject matter experts reviewed the material's relevance, importance and usefulness. Technology expert advised on the implementation of MAR technologies while the instructional design specialist examined the functionality and usability of the MARCO UI and UX design application. Enhancements were made to the MARCO treatment modes based on the experts ' feedback and comments. In addition, an expert panel were provided with an evaluation form for the course ware that served as a guide for evaluation.

The selected participants (from four polytechnics in the northern region) were similar in terms of academic achievement, cultural background and socio-economic status to ensure that the research subjects are equal and homogeneous in their current knowledge of the topic of interest before engaging in the study. The research instruments were adapted and tested in advance. All instruments used in this analysis were checked with a reliability coefficient of 0.7 and above for accuracy of validity and precision.

The selected experts are chosen to review the developed MARCO and research instruments and are well experienced in their relevant fields. Table 3.17 showed the list of expert background and qualification.

Table 3.17

List of expert's background and qualification.

Content Expert	Post	Expertise	Qualification
Expert A	• Head of Department Information & Communication Technology • 2015-present • Senior Lecturer (2002-present)	Lecturer in Software Development Teaching experience in 17 years Field of Expertise: Software Development, Image Processing	PhD Engineering of Electrical & Electronic, Universiti Sains Malaysia Professional Technologist (Information & Computing Technology) CISCO Certified Network Professional (CCNP) CISCO Certified Network Associate (CCNA)

Expert B	i.	Head of Program Diploma in Digital Technology	Lecturer in Software Development	M.Sc., Information Technology (Information System), Universiti Tun Hussein Onn.
	i.	Track Software Application Development	Teaching experience in 10 years	
	i.	Senior Lecturer (2011-present)	Field of Expertise: Android Mobile Applications, Software Development	Android Certified Application Developer (ACAD)
				Professional Technologist (Information & Computing Technology)
Expert C	v.	Senior Lecturer (2009-present)	Lecturer in Software Development	PhD in Computer Science, Universiti Teknologi Malaysia
			Teaching experience in 10 years	Researcher at the Media and Game Innovation Centre of Excellence (MaGICX), UTM.
			Field of Expertise: Computer Graphics and Information Technology (Augmented Reality and Human-Computer Interaction)	

3.10 Summary

This chapter outlined the methodology and procedures of the study. In this research, the quasi-experimental architecture of 2 X 2 will be used to draw a conclusion on the impact of standard e-learning training and digital e-learning immersive training on perception of technical skills and technological skills. The quasi-experimental design process will take into account the internal and external influences that can affect the feasibility and efficiency of the analysis, so that the external factors do not influence the results. Therefore, the study results can be generalized with similar characteristics to other populations. In addition, it also addresses the techniques and strategies for analyzing data. Throughout the execution of the analysis the guidelines and procedures will be applied methodically to ensure the reliability and generalization of the findings are obtained. The next chapter addressed MARCO's design and development, and the application of the macro and micro model used in this study.

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CHAPTER FOUR
DESIGN AND DEVELOPMENT

4.1 Overview

This chapter provides an explanation on the design of Mobile Augmented Reality Instructional Design (MARID) model and also detail elaboration on the design and development of the two modes of Mobile Augmented Reality for Computer Organization (MARCO) treatment modes. MARID is a structured approach to designing educational content that leverages Augmented Reality (AR) technology to enhance learning experiences. MARID integrates established instructional design frameworks which is Alessi & Trollip Instructional Design Model (2001), Spatial Cognition Theory (1993), O'Brien Model of Engagement (2018), RASE Model and Keller's ARCS Model (1987) to create cohesive and engaging learning materials. Ensures that both instruction and technology work together to enhance learning outcomes. As for the instructional applications, the MARCO incorporate two distinct modes: Physical Realism (MARCO-PR) and Functional Realism (MARCO-FR). MARCO-PR integrates AR with real-world components, providing detailed visual simulations of computer hardware. This mode emphasizes seamless alignment of virtual objects with real-world textures and spatial features, enabling learners to interact with physical components while receiving immersive, step-by-step visual instructions. Conversely, MARCO-FR focuses on functional simulations, offering dynamic 3D models that replicate the behaviours, properties, and interactions of virtual objects. This mode allows learners to explore and manipulate digital representations of hardware in a virtual environment, fostering a deeper understanding of functionality. Together, these modes cater to diverse learning needs, leveraging augmented reality to enhance spatial visualization, comprehension, and engagement. Building on this, MARID model serves as a guiding framework for the design and development process of MARCO treatment modes.

The proposed MARID model is developed through the integration of multiple established frameworks and theories, including Alessi and Trollip Instructional Design model (2001) incorporates with Spatial Cognition Theory (1993) for its systematic approach to instructional development and to address spatial reasoning within augmented environments. Churchill, King, & Fox RASE Model (2013) model act as a macro strategy to design instructional content structure. While, Keller's ARCS Model of Motivational Design (1987) is to enhance learner motivation and, O'Brien's Model of Engagement (2018) is to foster meaningful and sustained learner interaction as well as it were used as a micro strategy in the MARCO content. This approach integrates theoretical foundations and practical insights, ensuring that MARID model aligns with both instructional principles and the capabilities of MAR technology.

4.2 Design of Instructional Design Model for Mobile Augmented Reality

Mobile Augmented Reality Instructional Design (MARID) model was proposed and design tailored specifically for Mobile Augmented Reality (MAR) applications, emphasizing the aspects of implementation, comprehension, engagement, and motivation. MARID model addresses the distinctive features and challenges of MAR technology, offering a structured framework to enhance the design process and ensure instructional effectiveness. By leveraging MARID model, MAR applications can achieve greater alignment with instructional objectives, resulting in improved learner comprehension, learning engagement, and perceived motivation. MARID is an instructional design model that offers explicit direction on how to develop an instructional mobile augmented reality-based application that emphasizes on comprehension, learning engagement and motivation elements.

MARID model is derived from a set of instructional design models and theory which is Alessi and Trollip Instructional Design model (2001), Spatial Cognition Theory (1993), Churchill, King, & Fox RASE Model (2013), Keller's ARCS Model of Motivational Design (1987) and O'Brien's Model of Engagement (2018) with solid capability obtained after refining process to enriched MAR learning experience. These models were identified through a comprehensive review of existing literature, ensuring the relevancy to the study. The refining process is by analyzing the essential dimension and components of MAR present in each of these models and theories that can be integrated and align into a unified instructional model encompassing all these aspects, namely comprehension, learning engagement, and perceived motivation.

There are 8 dimensions of MAR that had been identified and extracted which is objective, challenge, interface, interactivity, content, time, feedback and asset. Each of these dimensions. All dimensions of the MAR have been systematically mapped, aligned, and matched to the corresponding components derived from the models and theories, ensuring a cohesive integration that addresses the instructional objectives comprehensively. Figure 4.1 showed the mapping of MAR dimension. Each distinctive shape represents components for particular models and theory.

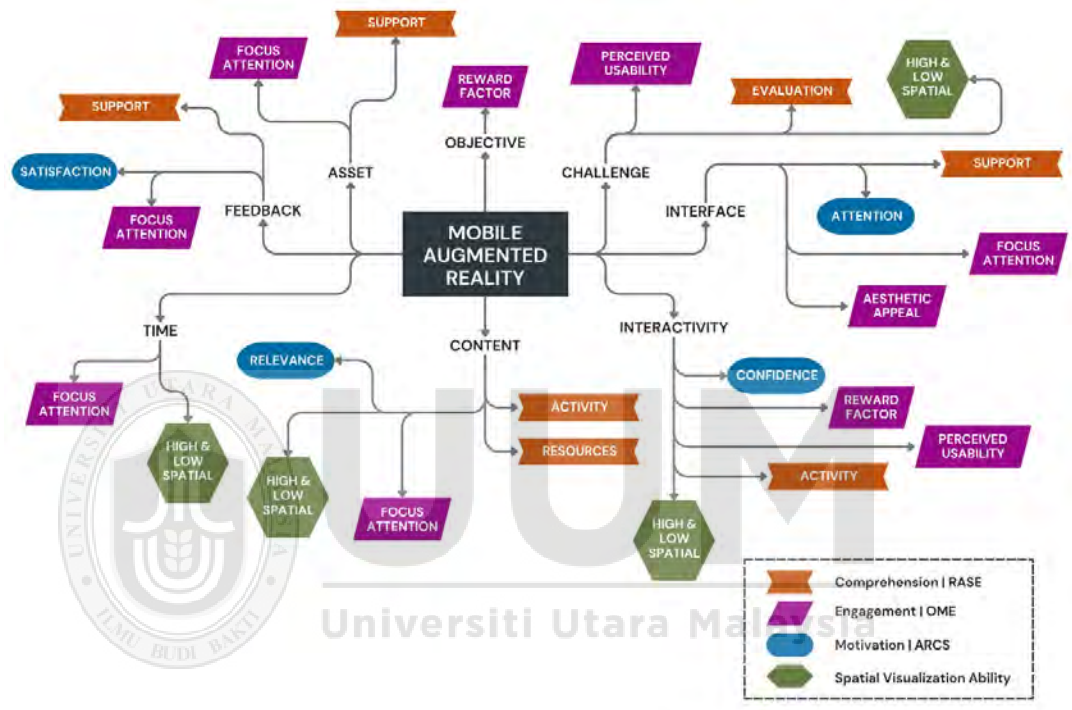

Figure 4.1 : Mobile augmented reality dimension mapping

After all components have been systematically mapped, the next stage involves aligning the relationships among the components of each model and theory, integrating them into a unified model, and transforming into a complete and comprehensive MARID model. The model begins with MAR as the central technology driving the model. It acts as the foundation, enabling improvements in various aspects of the design process. MAR functions through key elements (e.g., objectives, challenges, interactivity, feedback, interface, content, assets, and time). These elements underpin the MAR modes, which are groups into functional realism and physical realism, ensuring covering all levels of visual spatial and immersive augmented environment. MAR enhances spatial visualization ability abilities (high and low spatial visual ability), which is a critical factor for understanding complex, spatial visual oriented content.

Spatial Visualization Ability (SVA) acts as a moderating factor, tailoring the learning experience to accommodate learners SVA level (High and low) through differentiated content, feedback, and activities. SVA directly impacts motivation, modeled using the ARCS Model of Motivational Design (1987). SVA plays a vital role in sustaining motivation. Learners who can successfully process spatial information get more attention, feel more confident and satisfied, which ties directly to the ARCS Model of Motivation component (Attention, relevance, confidence and satisfaction).

While motivation affects engagement which is modeled through O'Brien's Model of Engagement (2018). By emphasizing focus attention, perceived usability, aesthetic appeal, and rewards factor, the model creates an engaging and immersive environment that enhances comprehension and supports the achievement of learning objectives. Higher engagement leads to improved comprehension, facilitated by structured resources, activities, support, and evaluation components which is modeled using the Churchill, King, & Fox RASE Model (2013). Table 4.1 shows the description and relationship for each component in MARID model.

Table 4.1

MARID model component relationship

Component	Description	Relationship
Mobile Augmented Reality (MAR)	Central technology enhancing the framework through functional and physical realism.	Drives the entire process by enabling interaction with MAR elements and modes.
MAR Elements	Objectives, challenges, interactivity, feedback, interface, content, assets, and time.	Foundation for MAR modes and influence the user learning experience.
MAR Modes	Functional realism and physical realism.	Enhance the effectiveness of MAR applications for SVA learners
Spatial Visualization Ability (SVA)	Ability to understand and process spatially oriented content, categorized into high and low spatial.	Enhanced by MAR and impacts motivation.
Motivation (ARCS Model)	Consists of attention, relevance, confidence, and satisfaction.	Impacted by SVA and drives engagement.
Engagement (O'Brien's Model)	Consists of focus attention, perceived usability, aesthetic appeal, and reward factor.	Driven by motivation and enhances comprehension.
Comprehension (RASE Model)	Incorporates resources, activities, support, and evaluation.	Result of engagement, facilitating learning and understanding.

The dynamic flow emphasizes the interplay between aesthetic appeal, challenge, and relevance, making it a holistic approach to leveraging MAR for educational purposes. Figure 4.2 illustrates a MARID Model, presenting the flow and relationships among its components.

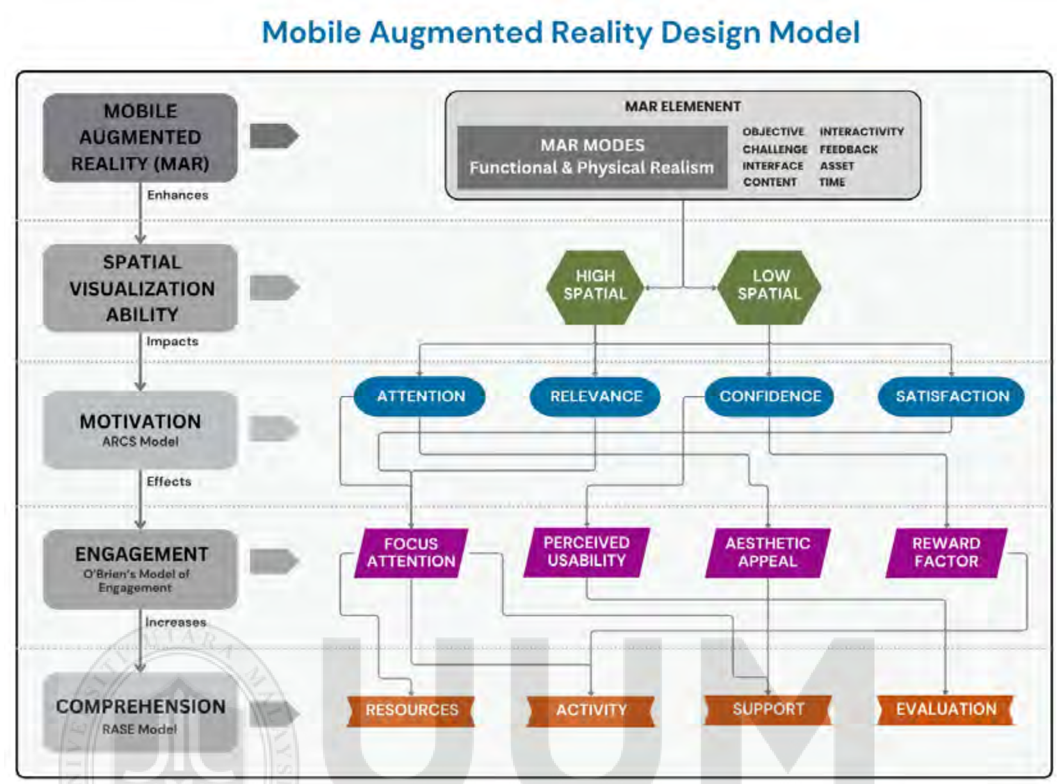

Figure 4.2 : Mobile Augmented Reality Instructional Design (MARID) Model

This model illustrates an integrated process, wherein MAR technology activates a series of improvements, encompassing spatial visualisation, motivation, engagement, and comprehension, so assuring a seamless flow toward comprehensive and efficient instructional design for MARCO applications. MARID builds on foundational theories and models, such as Alessi & Trollip's Instructional Design Model (2001), the RASE Pedagogical Model (2013), O'Brien's Model of Engagement (2018) and the ARCS Motivational Model (1987), to guide the creation of comprehending motivating, engaging and effective educational experiences. The model emphasizes planning, designing, and developing MAR-based instructional materials tailored to learners with diverse spatial visualization abilities.

Essentially, the MARID model integrates macro and micro strategies. The macro strategies, informed by the RASE model, focus on resources, activities, support, and evaluation, ensuring holistic learning. The micro strategies incorporate the ARCS Motivational Model and O'Brien's Engagement Model to enhance motivation and engagement. The model's outputs include improved comprehension, engagement, and motivation, particularly in technical subjects like Computer System Organization (CSO), supported by two instructional modes: MARCO-PR (Physical Realism) and MARCO-FR (Functional Realism). MARCO-PR lays the foundation by introducing learners to the physical aspects of computer components, making abstract ideas tangible. While MARCO-FR builds on this by simulating the functionality, enabling learners to engage with more complex concepts interactive. This model is iterative, with real-time feedback guiding refinements to optimize learning outcomes.

The MARID model, which serves as the foundational framework was systematically designed and subsequently applied to guide the design and development of the MARCO applications, as detailed in the following subchapter.

4.3 Development of Mobile Augmented Reality Computer Organization

The researcher developed and designed two modes of Mobile Augmented Reality for Computer Organization (MARCO) for this study using Mobile Augmented Reality

(MAR) technology. Application experts assisted in testing and validating the final version of MARCO. The design and development process of MARCO was guided by the Alessi and Trollip Instructional Design Model (Alessi & Trollip, 2001) due to its clear technique for designing effective modal presentation material. ATID model is designed for development and design phase whereas incorporates component of the instructional system design approach that are organize into particular phase. The Alessi & Trollip Multimedia Design subsist three core components are planning, design and development phase.

According to Alessi & Trollip (2001) the model is suitable to use in innovative design and can be applied in any subject areas. The designer can adapt the stage of development model by reorganizing, adding or reducing the certain level of capability depending on the current needs. In addition, Alessi & Trollip (2001) highlight this model can be flexible as well as give the designer freedom to be more creative in the variety of computer software and hardware. Equally important, since the key element of MAR technology is the visual-spatial characteristics, the design and development process incorporate Spatial Cognition Theory (1993) as an underpinned theory.

Whereas Mobile Augmented Reality Instructional Design (MARID) was used as a guidance for the perceived motivation, learning engagement and comprehension elements. This study is mainly about improving the students' course comprehension on learning computer component and assembly; therefore, Churchill, King, & Fox RASE Model (2013) was used as the guidelines to design the instructional content structure and course comprehension aspects. The learning contents used in developing effective MARCO treatment modes were based on the DFC1033 Introduction to Computer System (ICS) course syllabus (Polytechnics Curriculum Division, 2018). Therefore, Alessi & Trollip (2001) and Spatial Cognition Theory (1993) serve as main guidance in the design and development of MARCO, while Churchill, King, & Fox RASE Model (2013) serve as macro strategies for its development. In addition, the design and development of this learning material were further enhanced by incorporating two micro strategies: Keller's ARCS Model of Motivational Design (1987) and O'Brien's Model of Engagement (2018). Keller's ARCS Model of Motivational Design (1987) serves as the specific technique utilized as a framework for the motivational part of MARCO, while O'Brien's Model of Engagement (2018) is employed to enhance MARCO's learning engagement. The process of designing and developing the MARCO treatment modes takes place over a six-month period, divided into three main phases: planning, design, and development.

Figure 4.3 demonstrates the implementation of the macro and micro strategies in the design and development of MARCO. The subsequent subsections provide an extensive discussion of each strategy.

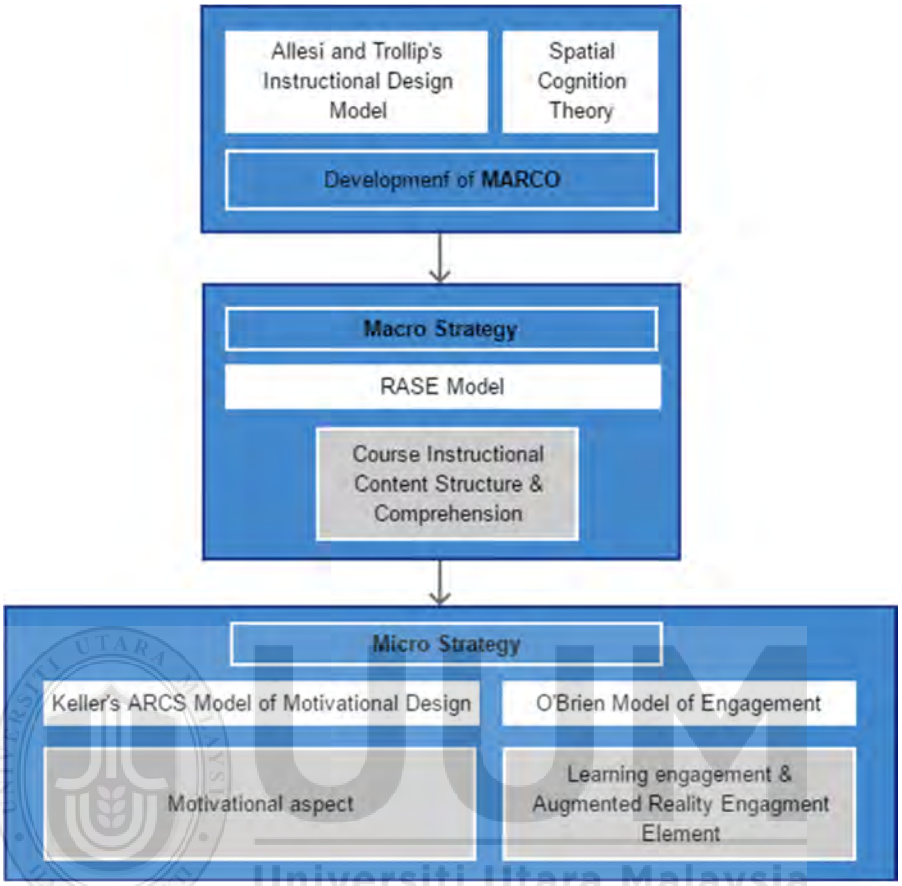

Figure 4.3 : Macro and micro strategies

4.4 Alessi and Trollip's Instructional Design Model

The MARCO was designed and developed using Alessi and Trollip's Instructional Design (ATID) model (2001). This model offers a method that is based on established standards but also allows for adaptability. It incorporates a systematic process of planning, evaluating, and reviewing. The model consists of three distinct phases: planning, design, and development. The study's requirements are met by dividing and customizing each step. This model also incorporates continuous evaluation throughout the three phases, hence mitigating the occurrence of issues towards the end of the development process. Figure 4.4 depicts the primary phases employed in this study, as proposed by Alessi and Trollip (2001).

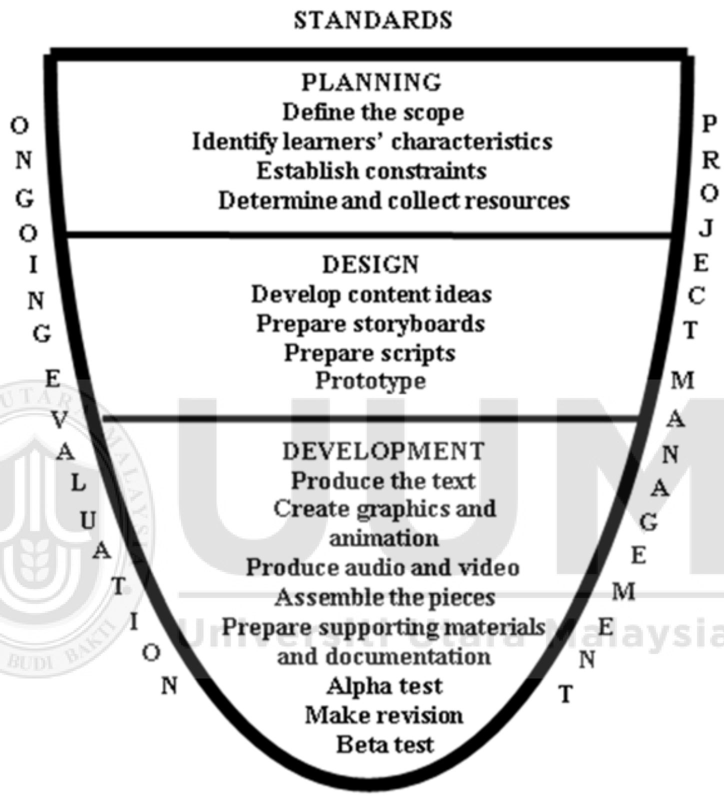

Figure 4.4 : Alessi and Trollip's Instructional Design Model (Alessi & Trollip, 2001)

The main justification for utilizing the ATID model in the design and development of MARCO lies in the model's suitability and adaptability. This strategy was chosen for its focus on fostering creativity. The ATID model is a design-oriented instructional material development model that provides principles for developing MARCO with appropriate combinations of challenge, support, direction, and structure. The guidelines are divided into smaller components. By directing attention towards smaller components, it becomes feasible to increase the number of options available and adjust more precisely to the learning event. The ATID model, as described by Alessi and Trollip (2001), is a set of guidelines for constructing an adaptive and efficient multimedia product like MARCO. It presents methods for planning, constructing, and incorporating different elements of multimedia technology, including Augmented Reality (AR). Furthermore, ATID is a flexible model that may be customized to suit the specific needs and work preferences of developers (Alessi & Trollip, 2001). The development approach of this model can be modified to fulfill the requirements and preferences of developers. The design of the system is implied that it could be updated and adjusted accordingly, and the designer could change the instructional material developed at any time.

There are six of key approaches that underpin this model to ensure the success and quality the built-in design of the instructional development MARCO which are features are follows as:

i. The application development applies the standard based between the customer and the developer should be agreeing on the standards as a guide MARCO development.
ii. This model based on a practical approach refers to the development of the MARCO is based on a series of drafting and reviewing to ensure the quality of

learning materials. This model also emphasizes the process of trying out, reviewing and retrying so that the results really work well.

iii. This model applies a good time and resource management from the beginning to the end of the stage.

iv. This model guide learning process of generating ideas in implementation stage level according to appropriate time planning.

v. This model underlining creativity on the development of MARCO is an essentials element in the designing attractive content.

vi. This model encouraging a teamwork by involving several important individuals such as content expert on AR, mobile application and programming.

Apart from the six guidelines stated above, this model includes three attributes and three stage whereas presented together.

4.4.1 First Stage: The Planning Phase

A valuable outlining is an important to ensure the development of MARCO achieve the objective in this study. In the development of MARCO, consist of five stages has been chosen as part of the planning stage. The phase is (a) defining the scope, (b) identifying characteristic of learner, (c) establishing the constraints, (d) determining and collecting resources, and (e) defining the look and feel of the product. Each of the steps is explained as follows:

i. Define the scope: To certify the content and scope of MARCO is significant and relevant;

ii. Identify the characteristics of learners: Understanding the demographic attributes of the target group, including age, educational attainment, spatial visualization ability, computer proficiency, and level of motivation. The demographic samples chosen for this study consisted of students enrolled in the Polytechnic Diploma Digital Technology (DDT) program;

iii. Establish constraints: To limit product needs: budget, timeline, proposed hardware, software and permission of content (sound, graphical, animation, 3D models);

iv. Determine and collect resources: Define and gather all the resources required to develop MARCO application.

Figure 4.5 showed the step involved in the planning phase

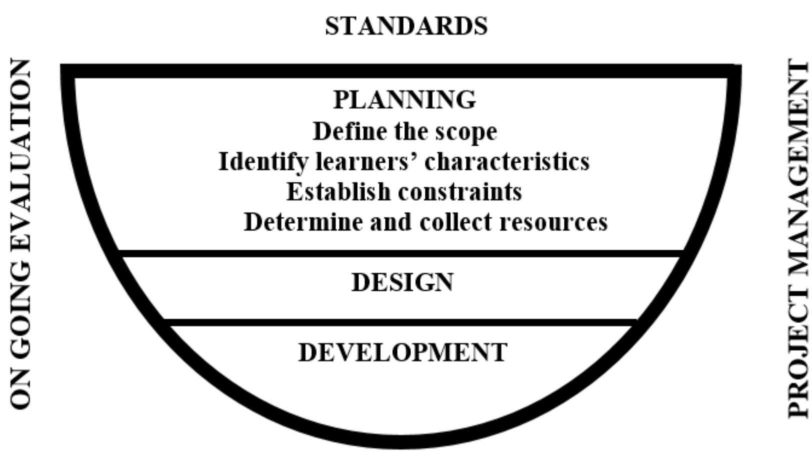

Figure 4.5 : The planning phase (Alessi & Trollip, 2001)

4.4.1.1 Defining The Scope of the Content

Initially, it is crucial to ascertain the scope, the intended outcome and the proficiency level of the learners (Alessi & Trollip, 2001). In this study, the scope of the content was Computer System Organization (CSO) comprehension and goal of MARCO was to improve students' comprehension and increase learning engagement as well as to improve motivation to learn this course. Theoretical framework defined the boundaries of the contents. This MARCO application is based on the DFC1033 Introduction to Computer System (ICS) syllabus approved by the Polytechnics Curriculum Division in 2018. The purpose is to select a topic that may be taught via interactive multimedia instruction. Therefore, the researcher made the decision to focus on the specific aspect of the subtopic, which is the 'Introduction to the personal computer' and 'Computer assembly and installation' as the learning content. This subtopic was also selected as it is the most subtopic that involve computer hardware and components acquire for the students to practical exercise to understand how the computer system works. Based on course review report also state that this particular subtopic attainment is below average. Learners' levels of ability needed for this study are spatial visualization ability.

Referring preliminary study, stated that factor that influence student did not perform well in CSO course is because of lack of computer equipment that causes students to have to share equipment during the practical session. Inadequate learning material and practical exercise will lead to decrease of spatial visualization ability level among students that will affects student in learning CSO (Mustapha, 2018). Learners had tough involvement to visualize the computer hardware components and how to assemble it. Develop a learning environment using AR will support students to understanding more in that subtopic.

The Course Learning Outcomes for this topic is focuses on the computer hardware component and functionality which students need to understand and visualize in detail how it works. The MARCO application content has been reviewed by a content expert.

The objective developing MARCO are stated below:

i. To provide visualization in AR learning environments towards understanding the CSO.
ii. To improve the students' comprehension in learning the CSO.
iii. To increase the students' engagement and motivation while learning CSO in a classroom.

4.4.1.2 Identifying the Learner Characteristics

The target learners in this study are students in Diploma in Information Technology (Digital Technology) who enroll DFC1033 Introduction to Computer System course in semester 1. Knowing the learners' prior knowledge, skills, and background helps in aligning the instructional content with the desired learning outcomes. It ensures that the instruction is neither too advanced nor too elementary for the target audience. The table in 4.2 useful as a guideline the learners' characteristic for the purpose of this study. Data of the target learners had been collected by using Learner's Characteristic Form (Appendix F).

Table 4.2

Learner characteristics for this study

Age	: Between 19-20 years old
Gender	: Male and female
Education level	: Diploma Digital Technology
Reading skill	: High
Capability to operate/use computer	: High
Motivation of learning	: Low to Medium
Interest in Topic	: Medium
Access to Internet	: Medium (Most of student have mobile phone but with limited internet access)
Spatial Visualization Ability	: High and Low
Mobile phone usage	: High and Low

4.4.1.3 Establishing Constraints

Alessi and Trollip (2001) explained that the constraints under which the project would be carried out are important to establish. It was clarified that all the challenges facing the project design and development as well as production and the operation of the final product should be systematically reviewed by the developer. Such restrictions include hardware and software requirements, current ownership for content and authorization restrictions. Throughout the planning stage, constraints in designing and developing the MARCO application need to consider the software, hardware, budget and time period to implement the entire process. The Table 4.3 are describing the constraints in this study.

Table 4.3

Types of constraints and resources for the MARCO

Kinds of Constraints	**Resources**
Hardware	A mobile phone or tablet equipped with Android Operating System with internet connection data plan and high-resolution camera.
Software	Unity 3D Vuforia Engine Blender Adobe Premium Suite C# Windows Sound Recorder
Content	Most of the elements in MARCO application produced by researcher. However, some of the elements such as 3D model were taken from other open sources.
Duration	The researcher acquired 4 months to design and develop the MARCO application

4.4.1.4 Determining and Collecting Resources

The final step in this planning phase involves determining and collecting resources. This encompasses all sources of information that are essential or capable of providing support for instructional development. (Alessi and Trollip, 2001). The three forms of resource materials: (i) relevant to the subject matter, (ii) important for instructional design, and (iii) relevance to the delivery system.

Following Alessi & Trollip (2001), there are three types of resources for the development materials as follows:

i. The resources of material appropriate 3D model and animation of computer components and its functionality.
ii. The resources of material relevant to the instructional development
iii. The resources of material suitable to the content, design, development and equipment.

The Table 4.4 are describing the types of resource.

Table 4.4

Three types of resources

Types of resources	**Resources**
3D model of computer hardware and its functionality.	Course outline DFC1033 Introduction to Computer System Curriculum for academic session June 2020 syllabus, textbook, laboratory modules, printed material by Department of Information Technology and Communication, reference book and also consultation by subject matter expert, namely, course coordinator.
MAR application instructional development	Resources include text and manuals about instructional design of MAR application such as storyboarding sheets, flow charts, Gantt charts, 3D models, source codes and computer software for the development stages such as Adobe Premium Suite, Unity 3D, Vuforia and Blender.
Content, design and development	The MAR application treatment modes require basic to medium specs of Android based mobile phones or tablet with good quality of camera phone in order to detect AR marker.

After reviewing existing resources in planning phase, the course outline and content materials will be use in this research as a guideline. The researcher and subject matter expert will analyze the ideas on an approach to the output as well as on the look and feel of the final project. After all requirements, resources and constraints are determined, the next step is the design phase.

4.4.2 Second Stage: The Design Phase

The design phase involves organizing the content and determining how it might be presented in a way that promotes both instruction and interaction. This is done to help learners achieve their desired learning outcomes. In the ATID model (2001), the design phase consists of four steps: (i) developing content ideas, (ii) preparing a storyboard, (iii) writing scripts, and (iv) prototypes. The description of each step is as follows:

i. Develop content ideas: to develop and design educational sequences through objectives for learning, application structure, and a flowchart that outlines the navigation and task analysis of the content.

ii. Prepare storyboard: Create a comprehensive visual presentation of the product design that encompasses the arrangement of the interface, specific textual elements, images, and other pertinent inputs related to the product.;

iii. Prepare scripts: Text description for each 3D animation and simulation, menus and application guide.

iv. Prepare prototype: Develop prototype with a working system, but with limited working functions and visual appearances.

(Alessi & Trollip, 2001)

The steps involved in the Design phase of this model are illustrated in Figure 4.6.

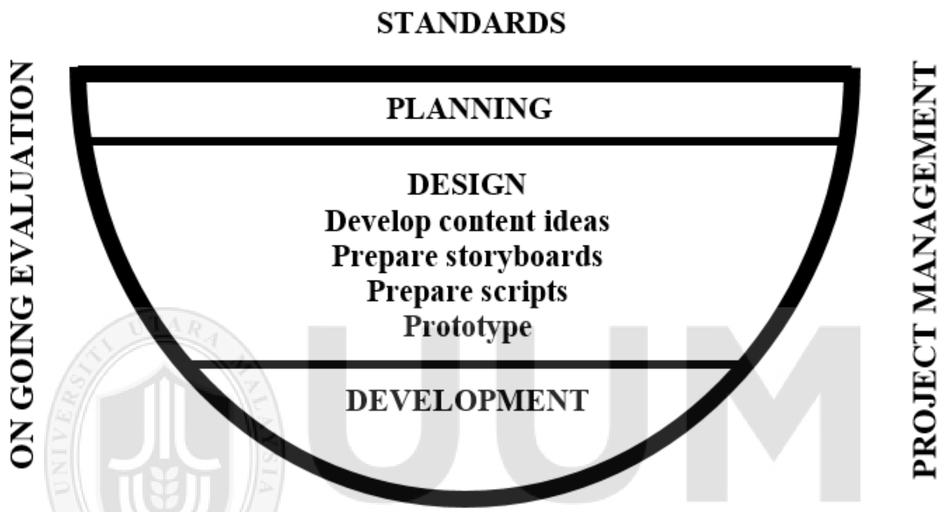

Figure 4.6 : The design phase (Alessi & Trollip, 2001)

4.4.2.1 Develop Content Ideas

The first step in the design phase is the development of content ideas. Two processes for developing initial content ideas; namely, brainstorming and learning methods and exclusion of some preliminary ideas. (Alessi and Trollip, 2001). The procedure of generating content ideas and learning approaches for this study involved collaborating with the CSO course lecturers from the selected Polytechnics who possess extensive knowledge of the learning topic and are subject-matter experts.

The next step is designing user interface element for instance the main interface of the application, navigation, button, font type, size and colors, 3D model and animations consistent with the content design which was apply in the development phase. Navigation styles used for MARCO is using buttons hyperlinks and fingertip zooming techniques. Another dynamic features that MARCO offers are interactive learner control to cater to both sequential and non-sequential type of navigation which is a characteristic of Spatial Visualization Ability (SVA) learners. The background color chosen for MARCO is white which gives better contrast with the button and text and also comforts the readers view. As for 3D model and animation used in MARCO was design using Unity 3D software. The resolution of the is fit based on mobile phone or tablet resolution.

This step also underlined Mobile Augmented Reality (MAR) architecture. This study focuses on the development of a marker-based MAR application intended for Android-based mobile device systems. Solihah (2018) found that polytechnic students have a significant level of exposure to android-based learning. This study utilizes a MAR application on the Android platform to enhance the learning experience. The main objectives are to increase student motivation and engagement by offering high-quality visual content and immediate feedback.

The MARCO application is built based on the Android software development kit (SDK). The primary software components consist of an interface/view component, an application controller, a renderer component, and a tracking component. The MARCO interface is mostly designed using Adobe Illustrator and then integrated and developed using the Android SDK in Unity 3D software. The rendering module, which is used to recognize, process images is based on Unity 3D real time rendering engine. The tracking module which is used to track AR marker is based on Vuforia Engine. While the controller module which contain user application navigation control is implemented using Visual Studio and coded using C# language (Figure 4.5).

The primary function of the MARCO interface component is to impose mechanisms for all interface processing, including those for the AR view camera. The AR view camera controller detects events triggered by the user's interaction with a marker or the execution of a gesture. Every existing interaction event is handled and sent to the controller. The primary function of the controller component is to manage the appearance of all selected 3D models that are required to be displayed for a particular task. Each 3D model is allocated a distinct ID that is linked to a marker ID. Controller component will maintain a list with all association ID and enable/disable 3D model visibility when the related ID are match or mismatch. Next component is tracking component. Utilizing markers as a basis for identification or tracking. MAR utilizes marker-based continuous object tracking. The tracking component utilizes the AR view camera to identify and analyze images from cell phones or tablets. It then identifies markers within these images and calculates the precise location and orientation of each marker. The marker's identification is subsequently transmitted to the control component, while the marker's position is transmitted to the rendering component. The final element of the MARCO is the rendering component. This component produces the AR display, which integrates the virtual 3D objects. All 3D objects are rendered, which is superimposed on the camera view of a mobile phone.

Figure 4.7 shows an overview of the application architecture of MARCO including all subcomponents and their functions.

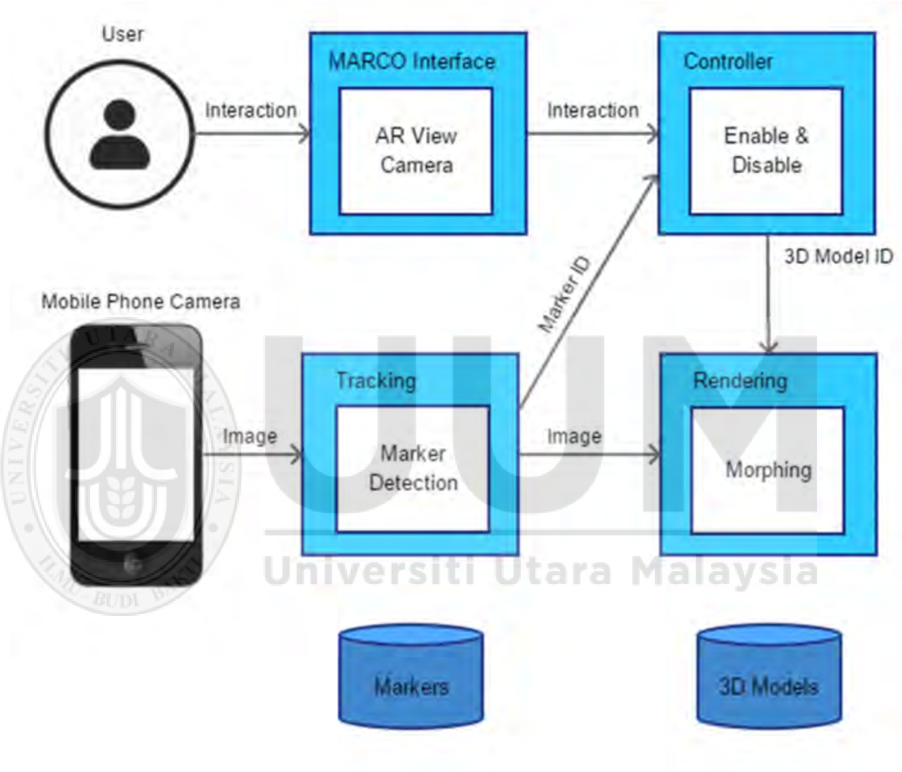

Figure 4.7 : Application architecture of MARCO

Next stages of design are the development of MARCO treatment modes. MARCO consists of two treatment modes. The first mode is MARCO-FR and the second modes is MARCO-PR. Spatial Cognition Theory (1993), offers important insights into the development of these MARCO treatment modes which is support both high and low SVA learners.

Table 4.5 summarizes MARCO treatment modes design specifications guided by spatial cognition theory and relationship with SVA where Visual-Spatial Configurational Knowledge (VSCK) applied in MARCO-PR and Visual-Spatial Procedural Knowledge (VSPK) applied in MARCO-FR. In the same way AR visualization can enclose both Visual-Spatial Haptic Space and Visual-Spatial Pictorial Space (VSHS & VSPS) are implemented to gain visual-spatial knowledge consistently. The visualization proses of MARCO modes start from device camera capturing image, object recognition and tracking, information rendering and followed by image visualization through device screen. To sum up, the framework by Bayu (2013) has been adopted to illustrate the visualization process as shown in figure 4.8.

Table 4.5

MARCO treatment modes design specifications

Item	**Spatial Cognition Theory Topology**	**MARCO FR**	**MARCO PR**	**High SVA**	**Low SVA**
1	Visual-spatial knowledge topology - *Procedural Knowledge*	√			√
2	Visual-spatial knowledge topology -*Configurational knowledge*		√	√	
3	Visual-spatial spaces topology – *Haptic Space*	√	√	√	√
4	Visual-spatial spaces topology – *Pictorial Space*	√	√	√	√

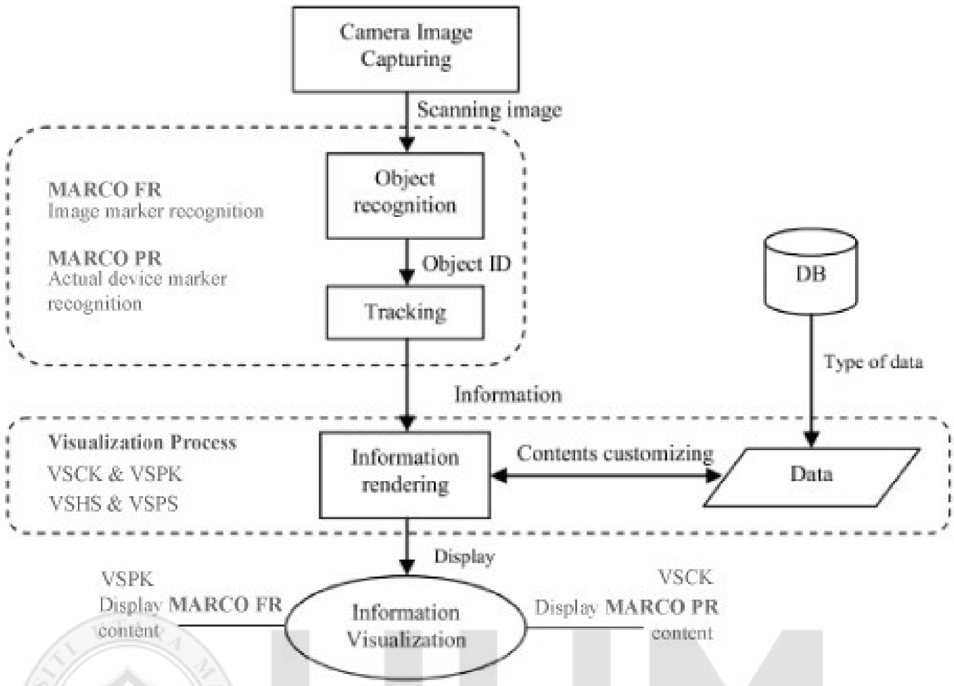

Figure 4.8 : AR visualization process

Procedural knowledge allows a 3D view and enables the user to experience it in a virtual environment, as the 3D models are rotating, zooming or animated. Figure 4.9 showed print screen of MARCO-FR functionality that allow users to rotating, zooming and animated the 3D models of computer components by pressing the control buttons below screen, wherease for configural knowledge, the interactive modalities where a user holds a physical object and views the entire geographical space from the perspective of his own. Figure 4.10 showed print screen of MARCO-PR functionality that allow users to hold a component and control the distances, orientation as well as relative position while additional information overlay virtually on the component. Both of the MARCO modes also enclose both haptic and pictorial space where physical action and visual input are implemented to gain visual-spatial knowledge correspondingly.

Figure 4.9 : MARCO-FR procedural knowledge implementation

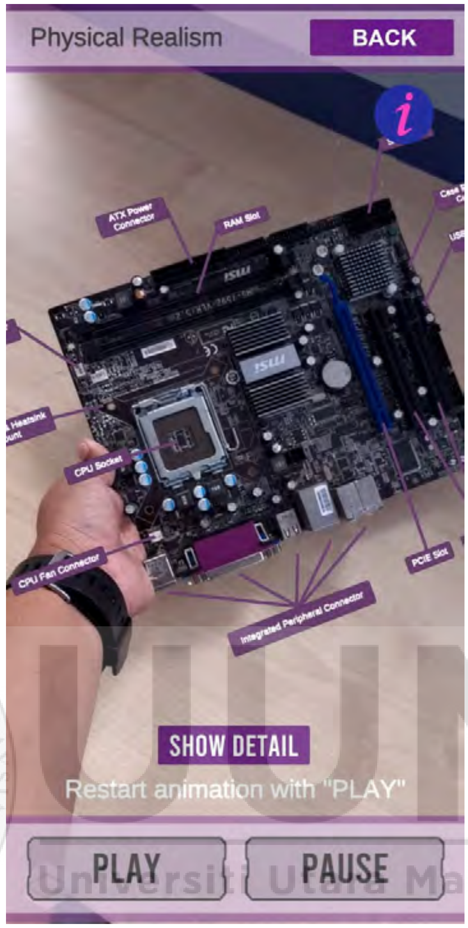

Figure 4.10 : MARCO-PR configurational knowledge implementation

The following step of the design phases is to carry out task analysis and concept analysis. Good learning practice should initiate with skills that only necessitate the learners to use and integrate with skills that they previously possess, to learn more complex materials (Alessi and Trollip, 2001). Hence, task analysis was carried out for procedural skills that involves carrying out a procedure, which is a sequence of activities to achieve a goal. Task analysis for the chapter 1 and chapter 2 topic of

Introduction to Computer System (ICS) was created and implement into the contents of MARCO. Figure 4.11 illustrates the task analysis of the topic

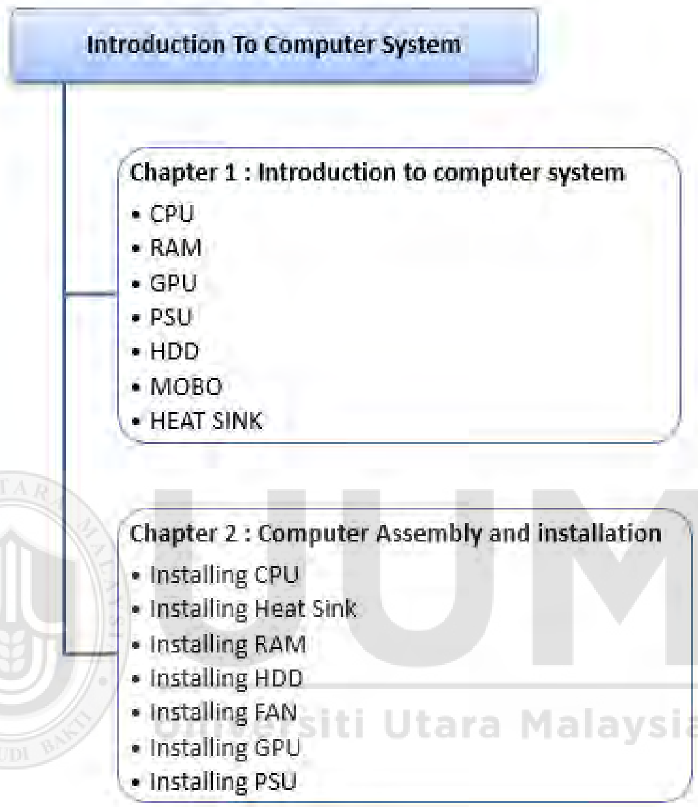

Figure 4.11 : Task analysis of ICS topic in MARCO

While task analysis is used mainly for procedural skills, whereas concept analysis is commonly used for viewing concepts and their interrelationships (Fei, 2012). A concept analysis was represent using a flowchart that show the structure and sequence of chapter 1 and chapter 2 topic for MARCO. Figure 4.12 shows the flowchart of the MARCO content. It is a detail representation of the content flow of MARCO. Both MARCO modes application is developed with task oriented, sequential and non-sequential with time flexibility and visually insightful learning content to cater both High Spatial Visual Ability (HSVA) and Low Spatial Visual Ability (LSVA) learners.

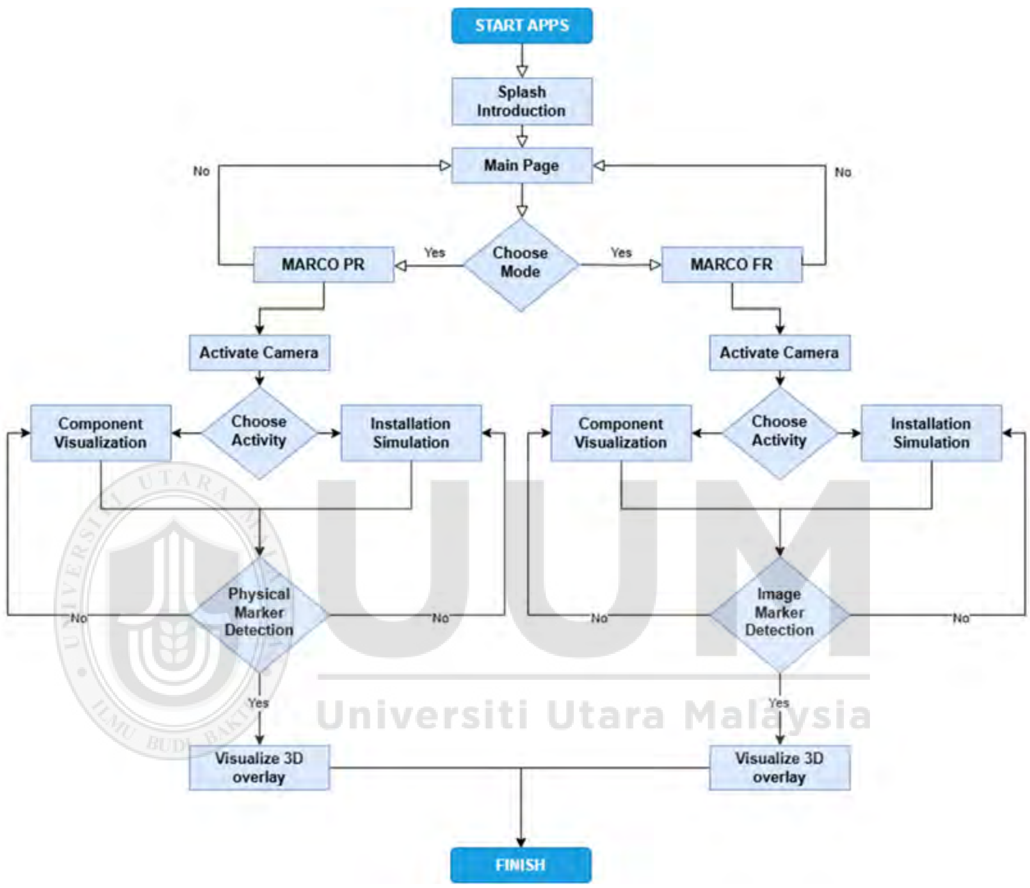

Figure 4.12 : Content flowchart of MARCO

4.4.2.2 Prepare Storyboard

Storyboard is a process to visualize the sequences of graphic to transfer the interactive media sequences. The importance of storyboard to communicate the ideas between visual representations to produce the quality project. The advantages prepared the storyboard can save the time and at the same time can refer the sequences once development process.

One of the storyboard techniques for mobile apps development is the use of wireframe sequence. Wireframes is a key tool for outline the visual flow and interaction design of the mobile apps. It is a tool to underline mobile app features, structures and content. (Herbert, 2015). It distinguishes the app graphics element from the functional elements in such way users are easily able to understand how the app interacts. Designing a good wireframe is a key aspect of mobile application development. It represents the skeletal framework of a mobile app. It is a visual guide that shows all connecting pathways between each screen and where they can lead, keep the design and concept consistently and also give a rough idea of the final application to be produced. Wireframe use low fidelity graphics, greyscale and minimal color usage

Whereas storyboards consist of a collection of wireframes ordered in a sequential manner to depict the flow of the application and its instructional material. The wireframe storyboards served as the researcher's recommendations for describing the interactions, navigation, layout, and presentation aspects on each screen of the MARCO treatment modes. Figure 4.13 is a sample arrangement of the MARCO wireframe storyboard. The whole wireframe storyboard is included in Appendix N.

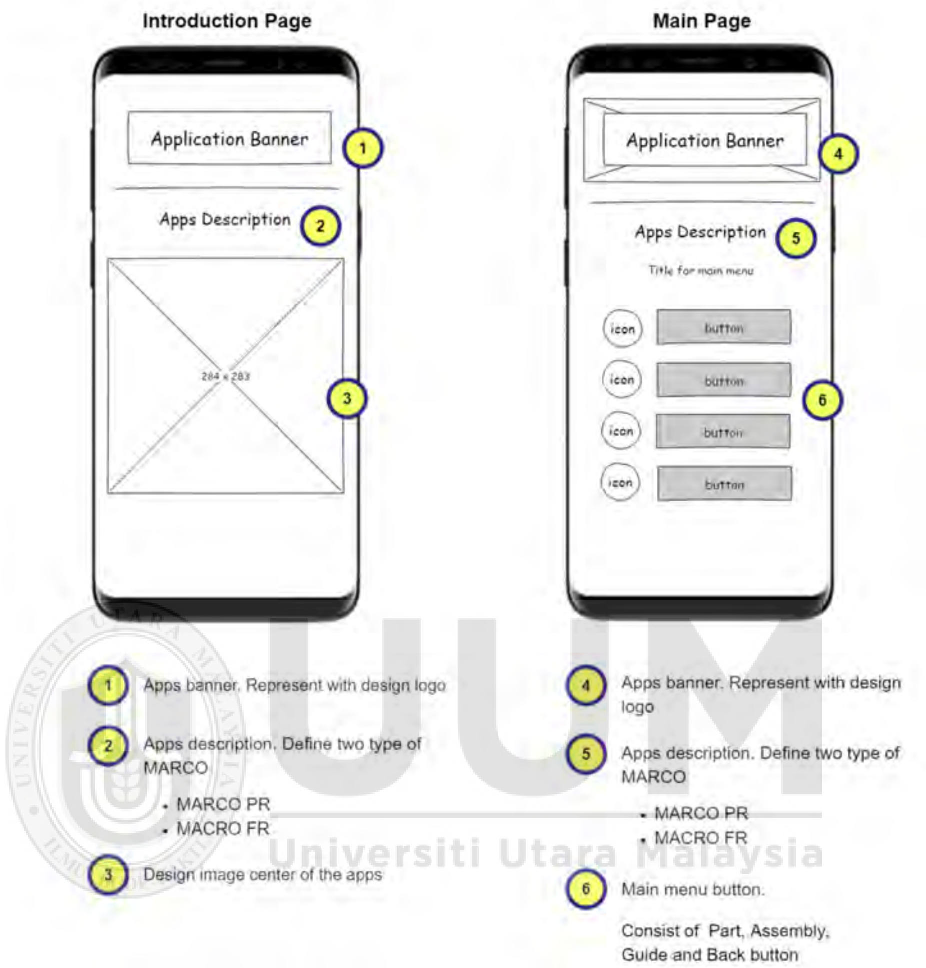

Figure 4.13 : Sample layout of MARCO storyboard wireframe

The MARCO storyboards underwent evaluation by a panel of experts from Polytechnics. This is to evaluate the consistency, rationality, and clarity of the written material and graphics, as well as other specific details. The wireframe storyboards were further changed based on the feedback from the reviewers in order to enhance the efficacy of the instructional material for the ICS course. The rest of MARCO application wireframe storyboard are in Appendix N.

4.4.2.3 Prepare Script

Scripts are mainly the text description for 3D animation, simulation and additional information of each task in the MARCO application. It a vital feature to attract, inform and engage users. It serves as guidance for users to understand the purpose and functionality of specific features within the apps. Both MARCO modes (MARCO-PH & MARCO-FH) use in this study are includes description text for each 3D model and simulation. All description text was produces based on MARCO meticulously derived from the specifications and installation steps of the actual components, ensuring accurate representation and instructional value.

4.4.2.4 Prepare Prototype

Prototype is the initial development of a full version of MARCO application. The MARCO prototype design was designed using Adobe Illustrator software. This prototype design contains screen layouts of the working application, which represent the user interface (UI) and user experience (UX) of the application with limited working functions and visual appearances. Developing a UI and UX design provided the researcher a basic idea of usability, ease of use, interaction, presentation and interactivity, look and feel of an actual functional MARCO application (Robert, 2017). This prototype was reviewed by the panel of experts, and based on their comment, the prototype was revised for enhancement. Figure 4.14 shows the splash screen page and Figure 4.15 illustrates the main menu of the prototype.

Figure 4.14 : Title page of MARCO prototype

Figure 4.15 : Main menu of MARCO prototype

4.4.3 Third Stage: The Development Phase

The third phase is the carrying out process of implementing previous prototype's design into fully functional application. This process includes the production of text, images, graphics, 3D model and animation, fully functional interface, supplemental materials document for MARCO and also all programming language code required to develop a functional feature of MARCO, (Alessi & Trollip, 2001). The development phase includes the process of transforming the storyboard and prototype to an actual application. The phase is consisting of text, audio, image, graphics and animation production and development, assemble all the pieces, prepare the support materials, perform an alpha test, make revision and perform the beta test. The development phase also consists of assessment and fine-tuning of the application. Figure 4.16 illustrate the steps involve in this phase and explained as follows:

i. Produce text, graphic, image, audio, 3D models and animation including all necessary programming codes to manipulate the 3d model and animation: All font properties, color scheme, button, graphics, animations that were used in the treatment modes are finalized;
ii. Assemble the pieces: All the component developed and produced were compiled together into one complete application.
iii. Prepare the support materials: The manuals for teachers and student and it contained information on how to use the application and instruction.
iv. Do an alpha test: Panel of expert and students reviewed the treatment modes.
v. Make revision: Changes were carried out after the alpha test feedbacks and comments received.
vi. Do the beta test: Full test of the final improvised version of the application by panel of expert and students.

(Alessi & Trollip, 2001)

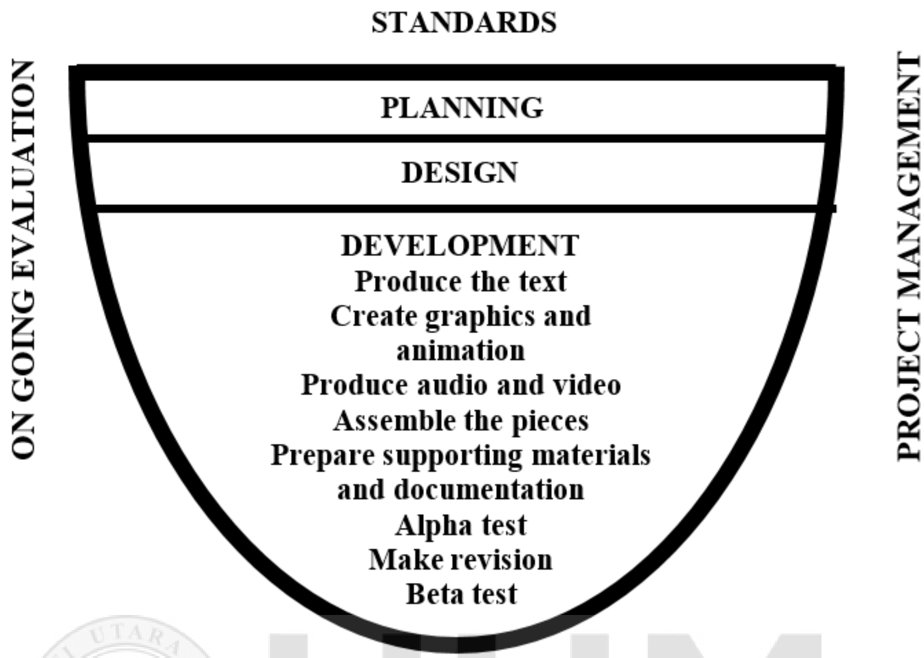

Figure 4.16 : The development phase (Alessi & Trollip, 2001)

4.4.3.1 Produce Text

Text is used in most applications and can be combined with other media in a meaningful way to present information and instructional content. In MARCO application, text was use for definitions, descriptions, responses for every 3D model and 3D simulations. Text also was used to design main menu of the MARCO. Typeface used in MARCO were *Arial* and font size used are varied from 12 to 50, while font color used are contrast with background to improve readability.

4.4.3.2 Create Graphics and Animation

In this study, there are two types of graphics designed for MARCO which is UI graphic and 3D model and animation graphics. These UI graphics were created using Adobe Illustrator and Adobe Photoshop CS6 while for 3D model and animations simulations were produces using Blender 3D and Unity 3D. In producing 3D models and animations with high degree of realism, two techniques were used in this study:

i. **UV Mapping**

UV mapping is the process by which 3D objects are generated by using 2D representation for achieving realistic texture or pattern of an 3D objects (Lai, Wu, Phothong, Wang, Liao & Lee, 2018). Figure 4.17 shows the process of wrapping a flat 3D model with details textures in Blender 3D software. Each 3D models used in the MARCO application are refined with detailed textures using UV Mapping techniques to produce realistic effects.

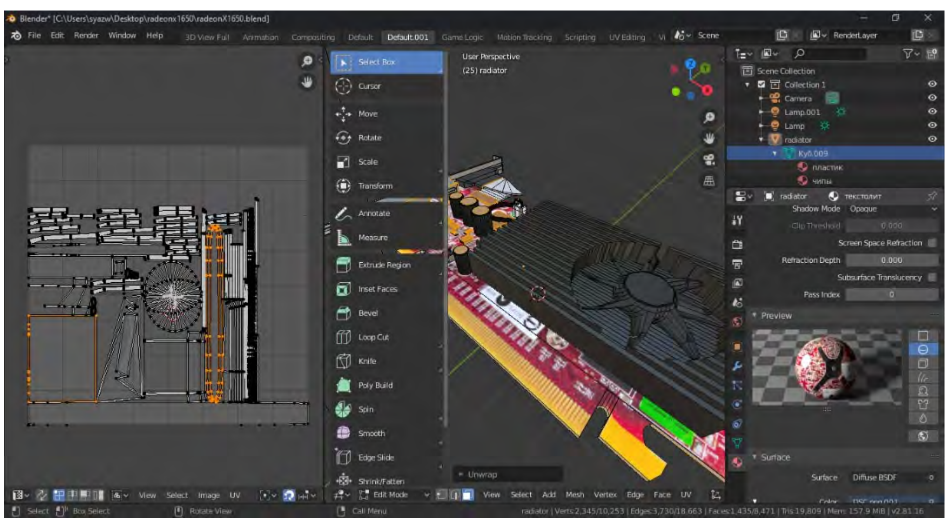

Figure 4.17 : Process of UV Mapping on 3D model in Blender 3D software

ii. Object Recognition

Object recognition techniques used to identify the physical 3D object and tracks the shape of the object. The 3D physical object then functions as triggers or markers that display virtual content (Vuforia Developer Library, 2017). Object recognition gives sense of realism to the physical 3D object, making it conceivable in the virtual world. This provides better engagement for better experiences with 3D objects realism (Sekar, 2016). Figure 4.18 shows partially process of detecting actual computer hard disk feature point. The dots indicated feature point of the physical 3D object depending on the complexity of the geometric shape. The more complicated structure a physical 3D object resembles the more feature points it has and these feature point define how quick markers can be recognized (Sihombing & Coors, 2018). All process obtaining object feature point from physical 3D object used in MARCO were acquired using Vuforia Object Scanner through mobile device camera.

Figure 4.18 : Point scanning process to generate a realistic texture for computer component

4.4.3.3 Produce Audio

For this study, the instant button audios effect was adding to give auditive feedback when user press a button and narration audio to provide sense of interactivity as well as engaging learners while conducting task in MARCO. All instant button audios effect was created in 3D Unity Software. MARCO also contained narration voice that phonate the on-screen instruction text as is important to assisted students understand and focus on the instruction for each task. The narration audios were recorded using Windows Sound Recorder and edited using 3D Unity Software.

4.4.3.4 Assemble the Pieces

The integration and compilation of all multimedia elements such as 3D model assets, audio assets, videos and animations into a complete application for delivering a functional MARCO. This process was done using three main software Unity 3D, Vuforia Engine and Visual Basic.

Unity 3D is a platform for developing virtual and AR based software and application, a 3D rendering engine integrated with a range of intuitive tools and rapid development for creating interactive 3D and 2D content. Unity 3D has an active developer community that can aided the new developers, provided 3D unity add-on modules that can be downloaded and also provided example coding that can be used in application development.

Figure 4.19 showed the integrated development environment (IDE) interface of Unity 3D used to develop the MARCO modes. IDE or Unity Editor is the creative hub where it provides tools and facilities for developer to create 3D models, animation, designing application interface, integrated links, compiling, debugging, scripting and manage all extensions.

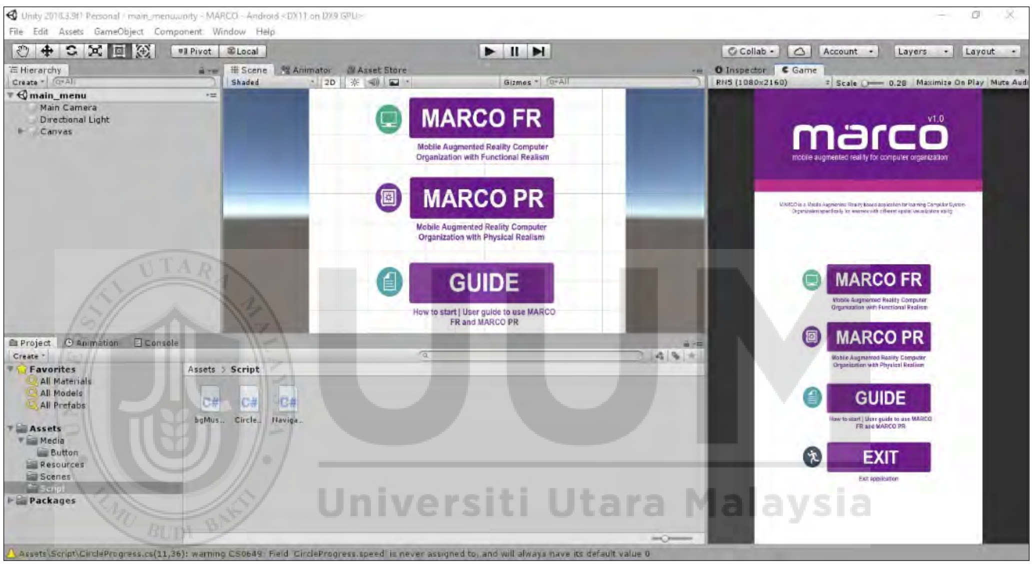

Figure 4.19 : Unity 3D IDE

Another essential software platform to support AR application development for Android is Vuforia Engine. This software is a versatile platform for developing AR applications that can be used on several operating systems. It has strong tracking capabilities and performs well on various hardware, including mobile devices. It enables developers to construct AR applications for Android using a user-friendly authoring workflow that involves dragging and dropping elements. In addition, the integration of Vuforia with Unity enables developers to construct advanced

AR applications by incorporating advanced computer vision capabilities into any application. This allows the application to identify images and objects, store images in databases, and interact with real-world environments.

Figure 4.20 showed the Vuforia Engine Target Database (VETD) for MACRO application. This Target Database allows all MARCO application assets to be manage properly.

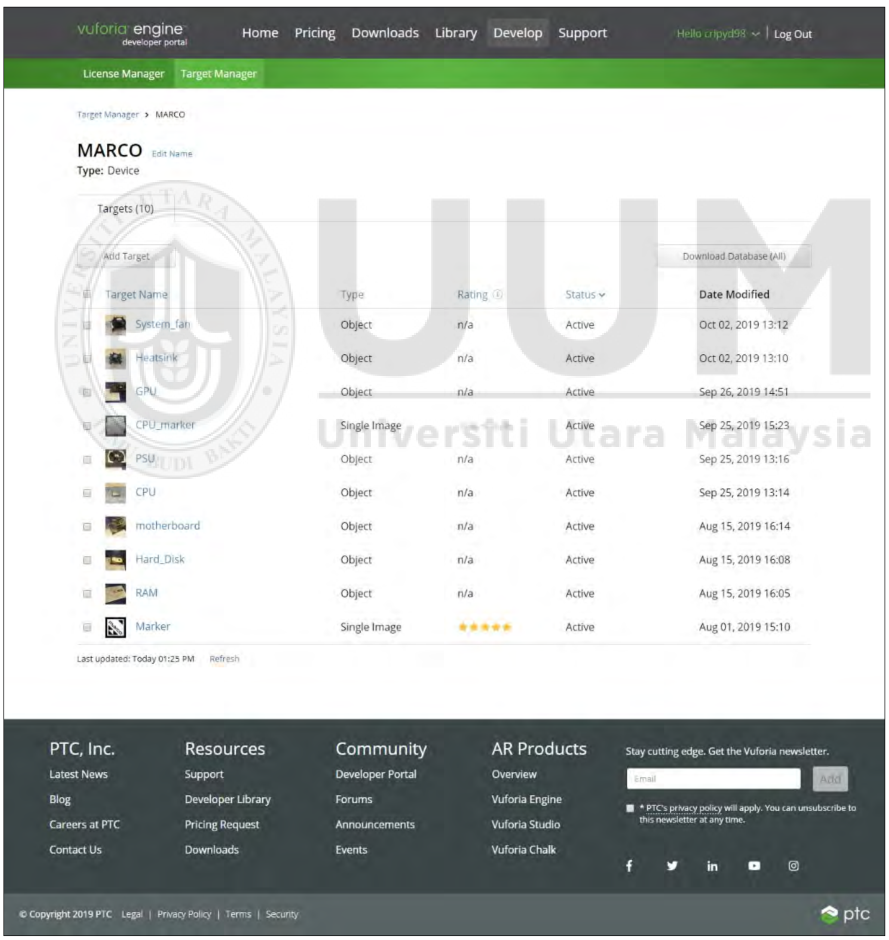

Figure 4.20 : VETD for MARCO integrated with Unity 3D

In addition, Visual Studio software was also used to write a script code for all 3D objects and animation. Code scripting creates interaction with 3D engine to give instructions which is rely on user action. User enabled to play animation and control 3D object rotation, scaling and zooming. The programming language applied in this application development is namely C#. C# is a hybrid of C and C++ programming language, and it developed by Microsoft. This programming language is object-oriented programming language used with XML-based Web services on the .NET platform and designed for improving productivity in the development of Web applications. Figure 4.21 showed the Visual Studio IDE in which developer creating programs codes. Visual Studio IDE offers a set of tools that assist developer to write and modify the code for MARCO and also provide tools for detecting and correcting errors in applications.

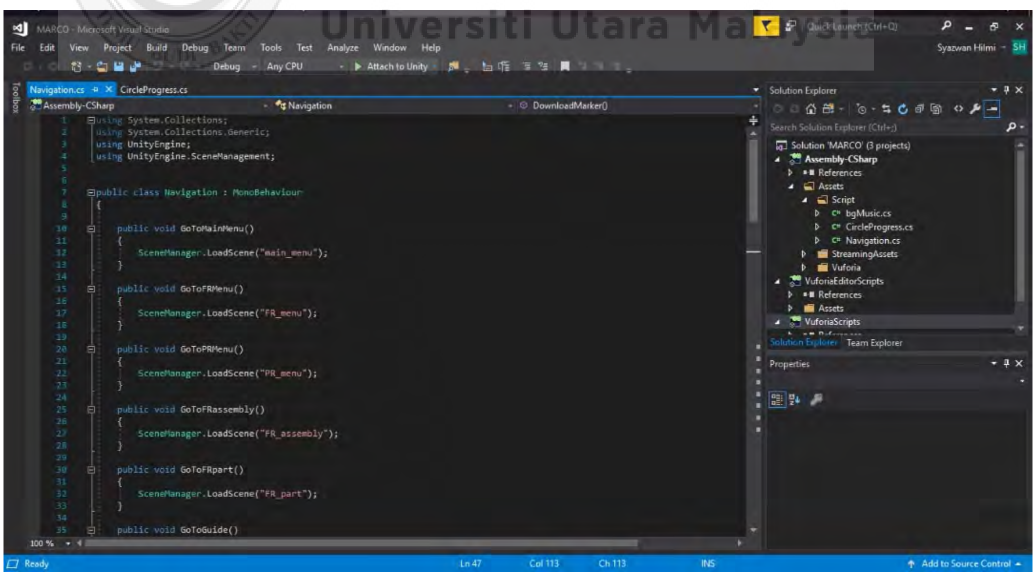

Figure 4.21 : Visual Studio IDE

4.4.3.5 Prepare Supporting Materials and Documentation

This user manual was subsequently produced as support materials. It provided detail information of hardware requirement, installation procedures, application operating instruction and accessing learning materials. The user manual was in .pdf format files and can be downloaded via MARCO application itself.

4.4.3.6 Expert Reviews

The expert review validation process was also conducted at the same time of alpha test on the MARCO treatment modes. Improvements and revisions were carried out after the alpha test involved a detailed review of panel of experts. There were three groups of experts identified for this study, namely, the content experts, instructional design expert and technology expert. All expert is from the Polytechnics. The content experts' responsibility is to evaluate the accuracy, significance, sequencing and comprehensiveness of the content and the instructional design expert examined the user interface (UI) and user experience (UX) design and evaluate the flow and navigational aspects of the MARCO modes while technology expert advised on the implementation of MAR technologies. The detail description of expert’s review was in subsection 3.7.3.

4.4.3.7 Alpha Test

Alpha Test with the design and development team is the main test of the program (Alessi and Trollip, 2001). This study performed an alpha test for the two MARCO treatment modes that were developed. 30 users from Polytechnics were requested to review the treatment modes to evaluate overall content and function of the MARCO treatment modes. Modifications and amendments were carried out after the alpha test for further improvement of MARCO. The detail description of alpha test was in subsection 3.7.3.

4.4.3.8 Make Revision

The final revision of MARCO treatment modes was implemented according to previous evaluation feedback and comments which is the alpha test and expert review. Furthermore, the supporting documentation were also updated based on the changes made to the MARCO.

4.4.3.9 Beta Test

The final step is to conduct a beta test, with a small group of users. The beta test is a full test of the final application (Alessi and Trollip, 2001). 10 students explore the overall functionality and content of improved version of MARCO treatment modes respectively. The feedback from this beta test were used to identify the user thread of experience, intensity of engagement element and to facilitated for future upgrade of the MARCO modes. This beta test was done before the actual experiment were perform. The detail description of beta test was in subsection 3.7.3.

4.5 Macro Strategy Used in the Design of MARCO

This section presents the discussion on the application of Churchill, King, & Fox RASE Model (2013) as the macro strategy used to design the MAR treatment modes.

This strategy is used as guidelines in designing the content structure of the MAR treatment modes.

Churchill, King, & Fox RASE Model (2013) is a pedagogic student-centered learning model. The model has four components: Resources, Activity, Support and Evaluation (RASE). It explores a practical, visualization-based learning design model with application of technology which can be imply with AR technology to improve student learning outcomes. This model was used to design the instructional content structure, which was based on RASE components (Daniel, Mark, Beverly & Bob 2013). Descriptions of the strategy and how it is implied in the MARCO application are further discussed in the next subsection.

4.5.1 Churchill, King and Fox RASE Model (2013)

The design of the instructional content structure and motivational aspects of MARCO was based on Churchill, King, & Fox RASE Model (2013). The RASE model was designed to improve learning outcomes and satisfaction of students by implementing or integrating technology. (Churchill, King & Fox, 2013; Churchill, King, Webster & Fox, 2013).

The reason for utilizing the RASE model to create the instructional content for MARCO is that this model offers a straightforward and organized sequence of instructional processes that can facilitate the course design of MARCO treatment modes. The RASE model is justified in the MARCO design because it emphasizes the use of technology to enhance student learning outcomes. According to DDT course review report on DFC1033 Introduction to Computer System (ICS) course, state that Course Learning Outcome (CLO) 2, which are applying knowledge of computer technology, hardware, maintenance and troubleshooting for computing standard were in average percentages. (Polytechnic TVET Coordination Department, 2018). Begin by analyzing the CLO (Course Learning Outcomes) and using the RASE model to aid the researcher in identifying the specific information, skills, and their practical application that students must exhibit in order to successfully fulfill the course requirements.

After identifying the CLO, a range of materials were carefully chosen and developed to assist students in completing activities that will enable them to get the desired learning objectives. The initial phase of the RASE model is focused on identifying and assessing available resources. Resources encompass several elements such as course materials including texts, videos, notes, animations, graphics, and teaching tools. Additionally, mobile phones equipped with AR applications serve as a valuable resource. The second phase of the RASE model involves engaging in various activities. Activities should be strategically developed to provide students with constant opportunities to gain the necessary information, skills, and applications in order to accomplish the Course Learning Outcomes (CLO) and effectively complete the course. Activities that can be implemented include coursework, experiments, problem-solving activities, or projects that require students' participation to make progress toward accomplishing the CLO. Student-centered and achievable activities, based on real-life situations, are the most effective. The third phase of the RASE model is dedicated to providing support. Support is crucial in anticipating students' needs and is particularly vital in providing guidance for students to efficiently navigate their courses, both independently and collaboratively with their classmates. The evaluation is the fourth phase of the RASE process. Evaluation offers students feedback to monitor and contemplate their own learning progress and identify the necessary enhancements required to attain their learning outcomes.

RASE emphasizes four elements of attentive design in order to attain the desired learning outcomes:

i. The first element is resources. A genuine content is created to actively include and support students in the process of learning. Various educational resources such as videos, experiments, demonstrations, presentations, or readings. Additionally, it enables students to engage in active learning rather than passive learning when utilizing these resources.

ii. Second element is activity. Student activity involves acquiring knowledge from instructional resources. These activities encompass instructional opportunities where students acquire knowledge, validate hypotheses, or apply knowledge, such as conducting experiments, analyzing case studies, or engaging in problem-based exercises. Students engage in learning activities as a means of acquiring knowledge and skills. Effective learning activities strive to empower students to enhance their learning and attain the specified learning outcomes.

iii. The third element is support. Support encompasses any resources or assistance provided to students to enhance their educational process. Support might take the form of a teacher-student relationship, a student-student resource, or a student-learning resource. The last component is evaluation. The student learning evaluation offers feedback to facilitate students' growth and enhance their attainment of learning outcomes. Figure 4.22 provides a graphical representation of the RASE pedagogical model.

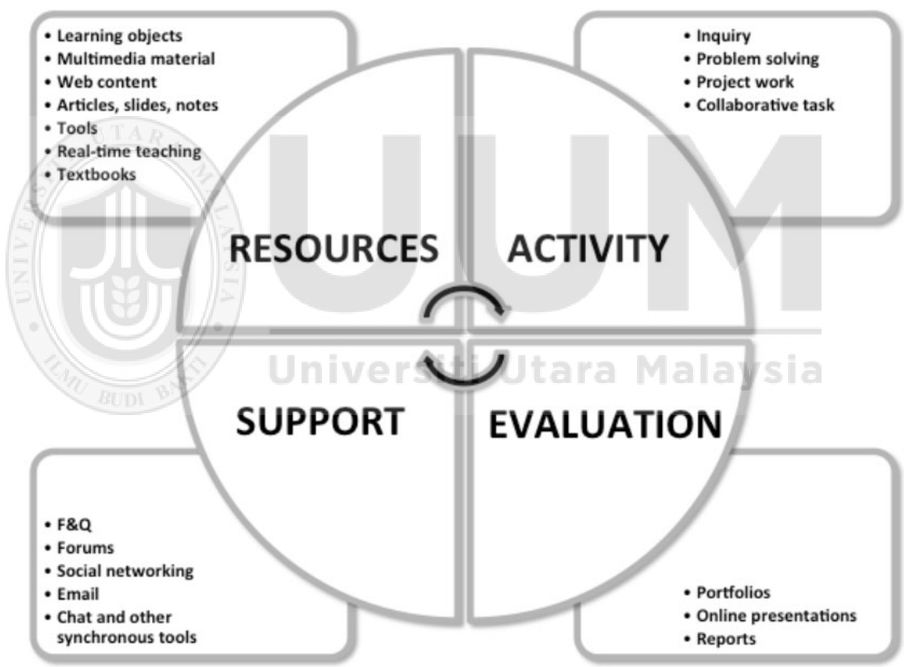

Figure 4.22 : Churchill, King, & Fox RASE Model (2013)

Table 4.6 summarizes the integration of the Churchill, King, & Fox RASE Model (2013) model in the MARCO design.

Table 4.6

Application of RASE Model in MARCO design

DFC1033 Introduction to Computer System		
Course Learning Outcomes (CLO 2)		
Apply knowledge of computer technology, computer hardware and computer maintenance and troubleshooting that comply with computing standard		
RASE components	**Strategies**	**Application in MARCO**
Resources	Strategies for facilitating students' progress in activities that would enable them to attain the desired learning outcomes of the course	Mobile Augmented Reality application, visuals 3D graphic, animations and text used in MARCO
Activity	Strategies to provide students with constant opportunities to gain the necessary knowledge, skills, and practical abilities needed to meet the Course Learning Outcomes.	Computer components visualize with 3D graphic and animation, additional text supporting each computer component, animation for computer component assembly.
Support	Anticipating students' needs and employing successful strategies are crucial for leading students in their learning process, both individually and collaboratively.	MARCO application support teacher-student, student-student, and student-learning resource with user-friendly interface, function, helps and tips button function.
Evaluation	Strategies that offer students feedback to evaluate and reflect their own learning progress and to highlight the necessary enhancements required for achieving the desired learning outcomes.	Immediate feedback and response for every activity in MARCO application. Every activity in MARCO provided with tips functions.

4.6 Micro Strategies Used in the Design of MARCO

Micro strategies used in this study to design MARCO treatment modes are Keller's ARCS Model of Motivational Design (1987) and O'Brien's Model of Engagement (2018).

Keller's ARCS Model of Motivational Design (1987) is a problem-solving method used to design the motivational aspects of MARCO treatment modes. Its purpose is to increase and maintain students' motivation to learn (Keller, 1983, 1984, 1987). This model consists of four major parts for creating engaging and effective instructional material which is attention, relevance, confidence, and satisfaction.

While O'Brien's Model of Engagement (2018) was used to guide the design of learning engagement of MARCO treatment modes which will captive the learners' attention and involvement. This model state that 22 Mobile Augmented Reality (MAR) element of engagement include Aesthetic, Novelty, Usability, Feedback, Motivation, Attention, Perceived Control, Curiosity, Enjoyment, Self-Efficacy, Friendliness, Social Skill Durability, Interest, Immersion, Challenge, Satisfaction, User, Autonomy, Improvement, Supportive, Trust and Interaction. These MAR engagement elements will help the development of MARCO application to comprehend the appropriate usage of these MAR engagement elements and at the same time these MAR engagement elements that had been selected must be incorporated together for better engaging result (Esraa, Juliana & Abdul 2018).

The subsequent sections outline the two micro strategies and how their implications in the MARCO treatment modes.

4.6.1 Keller's ARCS Model of Motivational Design (1987)

The motivating aspects of MARCO were designed based on Keller's ARCS Model of Motivational Design (1987). This approach has been extensively utilized in instructional materials (Means, Jonassen & Dwyer, 1997; Shellnut, Knowlton & Savage, 1999; Song & Keller, 2001) and serves as a well-documented design model that emphasizes the motivational aspects of learners (Mills & Sorensen, 2004). The idea has had a significant impact on the development and delivery of instructional materials since it provides an outline for creating and presenting a unit of instruction that motivates learning (Keller, 1987).

The motivating aspects of MARCO were based on Keller's ARCS Model of Motivational Design. The ARCS model consists of four essential components to develop instructional materials that are motivating: attention, relevance, confidence, and satisfaction.

The initial component of the ARCS model includes the acquisition and sustenance of the student's attention. Attention is both a component of motivation and a necessary condition for learning. The primary focus is on acquiring and maintaining attention through incentives. As a component of the learning process, the focus is on guiding attention towards the relevant stimuli. Nevertheless, merely capturing attention is insufficient. An actual difficulty lies in maintaining it, in generating a sufficient degree of focus throughout a period of teaching. In order to do this, it is imperative to cater to the inclination of students towards seeking new and exciting experiences (Zuckerman, 1971) and to stimulate their desire for acquiring knowledge (Berlyne, 1965), while ensuring that they are not excessively stimulated. The study included precise 3D models and animation to capture the students' attention during the initial portion of the MARCO content. Furthermore, a variety of 3D models, animation, and other multimedia elements were utilized to sustain the students' engagement and convey the content in an engaging manner.

Relevance is the second element in the ARCS paradigm. There is a lack of relevance when students persistently question the necessity of studying this course or its topics. When an explanation that is persuasive and compelling is not provided, it indicates a problem with relevancy. In order to address this inquiry, numerous course designers and instructors' endeavor to ensure that the education appears pertinent to the current and future professional prospects of the students. Some individuals, who adhere to a more traditional approach, hold the belief that education should be pursued for its own sake, as a valuable and cherished experience that students can derive pleasure and satisfaction from. While both of these factors can hold significance, it is worth noting that there exists a third alternative. If a course of instruction provides possibilities for an individual to fulfill their requirements, including these and others, they will have a sense of perceived relevance. In this study, MARCO was designed with interactive instructional contents that related to the computer organization course. These contents were delivered by using accurate 3D model and animation that imitate the function of computer components and description that relate to the students' current. These content also are incorporates using AR technology that can make learning more efficient, faster and much more fun. AR is one of the emerging technologies in education that offer new different learning experience (Jorge, 2014).

Confidence is the third element in the ARCS model. It has the ability to impact a student's perseverance and achievement. Multiple factors influence an individual's degree of confidence or their expectation of achieving success. Confident students typically credit their success to factors like skill and effort, rather than luck or the level of difficulty of the assignment (Weiner, 1974; Dweck, 1986). Additionally, they have a tendency to be focused on engaging in the work at hand and derive pleasure from the process of learning, even if it entails making errors. Moreover, students who possess confidence are inclined to have the belief that they can successfully achieve their objectives through their actions, as suggested by Bandura (1977) and Bandura & Schunk (1981). Clearly defining the objectives fosters an increase of confidence (Lee & Kim, 2012). In order to increase confidence in a technology-based instructional material application, it is advisable to grant students autonomy over the lesson and the necessary time to complete the lessons (Keller, 1987). In MARCO, students have the capability to manipulate application navigation, rotate, inspect, zoom, and closely analyze 3D models. The autonomy granted to users to explore MARCO at their own discretion, at their convenience, instilled the confidence necessary to maintain motivation throughout the course.

Satisfaction, as the final element of the ARCS model, comprises studies and practices aimed at fostering a sense of contentment and fulfillment in individuals regarding their achievements. Reinforcement theory suggests that individuals are likely to be more motivated when the goal and the reward are well specified, and when an adequate reinforcement schedule is implemented. When a student is obligated to perform a task in order to receive a reward that is under the control of an educator, it may lead to feelings of resentment. This is because the educator has encroached upon the student's autonomy and authority over their own life. (Lepper & Greene, 1979). In relation to MARCO modes, the ARCS model's satisfaction component is implemented by offering informative notification feedback for each task and activity carried out in the application. The ARCS model is effective for instructional materials that utilize AR due to its ability to efficiently capture attention, boost relevance, instill confidence, and create gratifying learning experiences. Figure 4.23 depicts the utilization of the ARCS Model of Motivational Design components in the development of MARCO treatment modes.

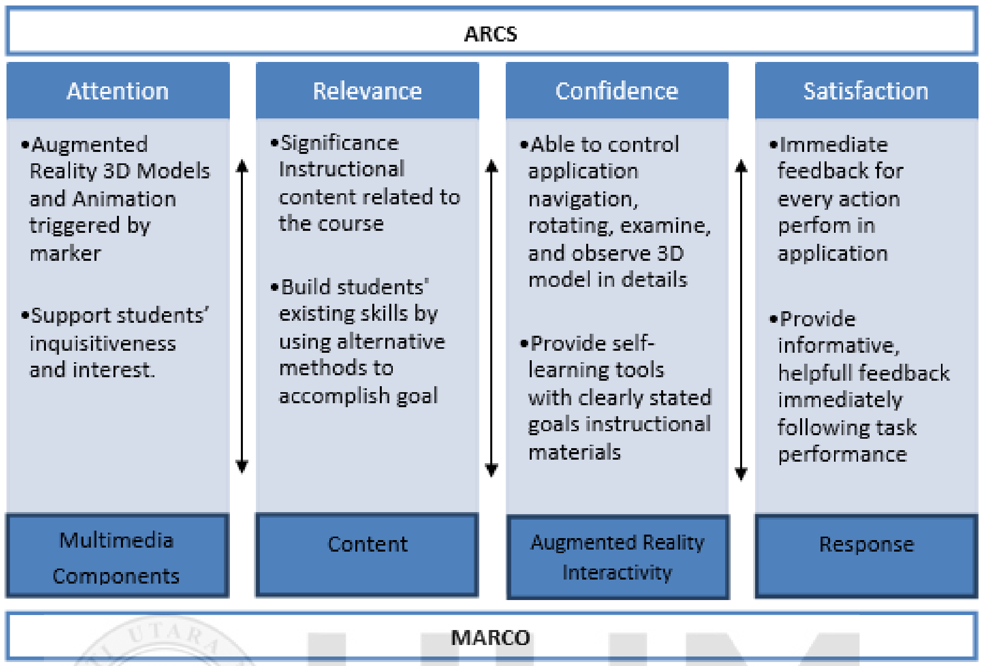

Figure 4.23 : Application of ARCS Model components and strategies in MARCO design

4.6.2 O'Brien Model of Engagement

MARCO instructional design is also supported by a user engagement with technology model known as O'Brien's Model of Engagement (2018) proposed by Heather L. O'Brien. O'Brien's Model of Engagement (2018) can be adapted for AR based application because it provides a strong framework for assessing engagement in technology-based context. O'Brien's Model of Engagement (2018) is a process model of user engagement to identify the key components that make up engagement. It is a depiction of the user engagement process and elements that is refine in order to allow for better understanding. This model provide insight into user engagement which defines which elements of engagement are most prominent during each phase in the engagement process. (O’Brien & Toms, 2010; 2008).

O’Brien’s Model of Engagement is consisting with four distinct stages: point of engagement, sustained engagement, disengagement, and re-engagement. These stages represent a process of user engagement, where users' application begins and sustains engagement, disengage from the application or task, and perhaps reengage multiple times during a single interaction with the application.

According to O’Brien & Toms (2010; 2008), user engagement is defined as a quality of user involvement during task that is compose by sensual, emotional and spatiotemporal thread. Sensual thread involves visual, auditory and interactive component of a students’ involvement with the task. Emotional thread pertains to affective involvement of students’ interactions, motivation and maintained their use of application during task involvement. Spatiotemporal thread involves students’ perception of time, internal states and external environments during task involvement. This engagement process also is defined by the presence of multiple elements that vary in intensity depending on a combination of users’ expectation and experience with technology, type of interaction and the technology itself and also system attributes that emerge during the interaction. Each particular stages have its own characterize elements. Element of engagement involve four factors which is Focus Attention (FA), Perceived Usability (PU), Aesthetic Appeal (AE) and Reward Factor (RW). Each factor consists of a particular engagement element. Focus Attention gauges the extent of user captivation by the interface, clarity of the purpose and task relevance; Perceived Usability measures users' perceptions of the system's functionality, spatial awareness and seamless interaction; Aesthetic Appeal assesses the visual attractiveness of the interface, information clarity and integration; and the Reward Factor captures the degree to which the system provides meaningful and satisfying outcomes (O'Brien's, 2018). The engagement elements are outlined in Table 4.7.

Table 4.7

Engagement element

Engagement Elements			
(FA)	(PU)	(AE)	(RW)
Focus Attention	Perceived Usability	Aesthetic Appeal	Reward Factor
• Novelty	• Control	• Aesthetics	• Motivation
• Attention	• Usability	• Interest	• Goal
• Feedback	• Positive Effect	• Awareness	• Interactively
• Time	• Negative Effect		• Challenge
• Interruptions			

Taking advantage of the threads of experience framework serves as a proficient method for categorizing the findings of this study (McCarthy & Wright, 2004). The elements that arise at each stage of the engagement process are organized and structured according to the emotional, spatiotemporal, and sensual threads of experience. The table 4.6 does not include reengagement because it has the same characteristics as the point of engagement in the process.

Based on the pilot study and beta test procedure conducted, 16 engagement elements were identified and tested. All information was gain using User Engagement Scale (UES) instrument and semi structured general testing interview questionnaire session during beta test procedure. Table 4.8 summarizes engagement elements and implementation of the O'Brien's Model of Engagement (2018) model in the MARCO design.

Table 4.8

Summary of the engagement attributes

Compositional Thread			
Process of engagement			
MARCO Element			
Threads of experience	**Point of Engagement (and Reengagement)**	**Engagement**	**Disengagement**
Sensual	**Aesthetic:** User interface of MARCO application are pleasing to view, easy to control and navigates, simple straight forward interface and consistent theme. **Novelty**: Novelty of the information presented in MARCO application. Custom design 3D model and	**Attention:** 3D graphic and animations keep attention and evoke realism. **Interest:** Users gain involvement to act explore MARCO functionality by the users. **Feedback:** Positive information provided by MARCO application that will enhance	**Interruptions:** Environment (distraction from friends) technology issue. (Marker not detect) **Challenge:** Inability to intact with features of technology. Lack of/too much challenge to complete in

	animations, content and layout.	passionate reactions which will promote positive performance **Usability:** Element of flexibility, ease of use, user friendly interface and learnability of MARCO application **Interactively:** User will simply interact and instantly get feedback when performing task in MARCO application	MARCO application.
Emotional	**Goal:** Expectation or goal in mind when begin or without specific goal but have an engaging experience. **Motivation**: Gain motivate to accomplish a task in MARCO application and eager to have a new experience by learning using augmented reality technology	**Motivation:** Motivation is sustained throughout the session by providing interesting and informative content for each task in MARCO application**.** **Control:** How "in control" users feel over their experience with the technology while using MARCO.	**Negative affect:** Uncertainty, lost attention, information overload, frustration and not confident with workability of the apps and boredom while using MARCO **Positive affect:** Feelings of success and accomplishment of

			task in MARCO application
Spatiotemporal	**Awareness:** User consciousness of physical surroundings and bodily functions. (noise, crowd).	**Awareness:** Lack of user awareness of physical surroundings and stay focus and concentrating on what they were doing while using MARCO application. **Time:** Participants were highly focused and remarked that they were frequently "surprised at how much time passes"	**Challenge:** Not having sufficient time to interact with or to complete task in MARCO application

(Adapted from O'Brien & Toms, 2010)

According to Esra, Juliana & Abdul (2018), to design MAR application which will captive users' attention and involvement, the structure of MAR should consider suitable usage of 16 engagement attributes of MAR application development, namely, Aesthetics, Novelty, Motivation, Attention, Interest, Feedback, Usability, Interaction, Challenge, Control, Perceived Time, Interruptions, Positive Effect, Negative Effect, Goal and Awareness. These attributes also are a component of adaptability, convenience and learnability of MAR application.

The compositional thread clearly outlined a systematic process that depicts engaging experiences which is consists of a point of engagement, a period of sustained engagement, disengagement, and reengagement associated with variation of engagement element. The point that students were not always engaged and defined the disengagement and the reengagement in the same session highlights that a particular session contains a variety of intensely engaging experiences O'Brien's Model of Engagement (2018) indicated the level of intensity each engagement element and in what stages that element is related. The application of this model in MARCO is shown in Figure 4.24. The higher attributes positions point to higher intensity of elements involved in engagement process which mean the element appeared more than once.

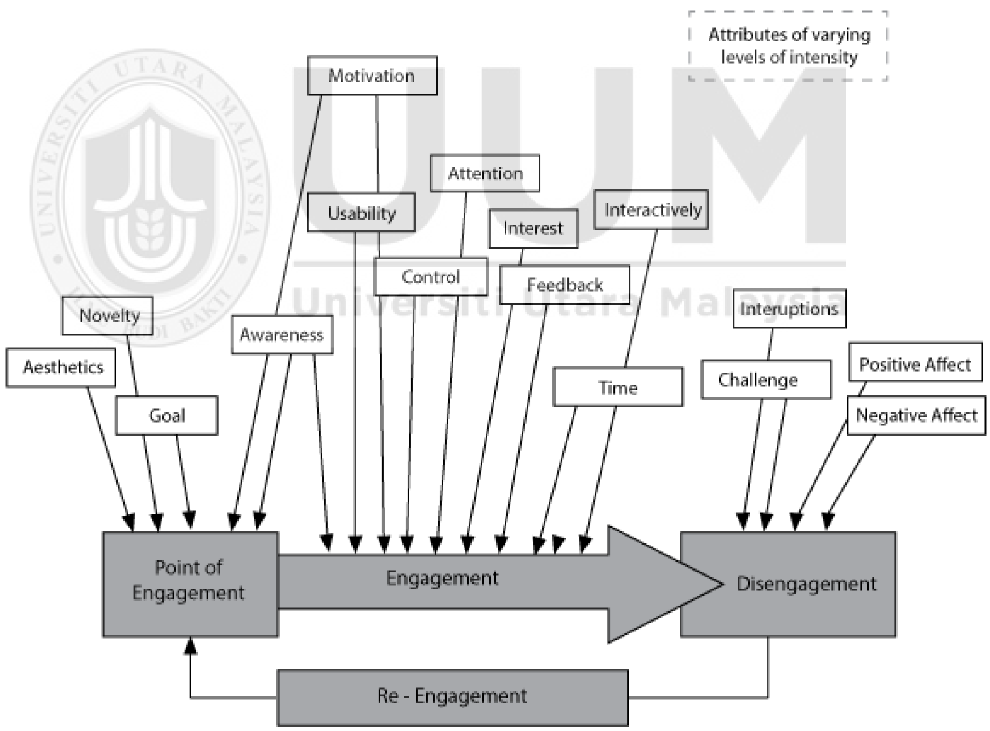

Figure 4.24 : MARCO user engagement and its attributes.

4.7 Summary

This chapter provided a comprehensive explanation of the development process for an instructional design model for mobile augmented reality as well as of the specific procedures involved in designing and implementing MARCO, which served as the treatment methods in this study. The ATID (Alessi and Trollip's Instructional Design) model (2001) was crucial in providing the necessary assistance and guidance for developing the treatment modes during the planning, design, and development phases. The evaluation and revision processes were conducted continuously during the development of the MARCO.

The designs and development of the MARCO treatment modes were assisted by Mobile Augmented Reality Instructional Design (MARID) model. MARID model is derived from a set of instructional design models and theory which is Keller's ARCS Model of Motivational Design (1987), O'Brien's Model of Engagement (2018) and Churchill, King, & Fox RASE Model (2013), This model contributed to the motivating, engagement and comprehension aspect of MARCO application. In the next chapter, the data analysis of the study is discussed in detail.

CHAPTER FIVE
DATA ANALYSIS

5.1 Introduction

This chapter presents the study's findings based on the data analysis. This study investigated the effects of the Mobile Augmented Reality Computer Organization (MARCO), namely MARCO Functional Realism (MARCO-FR) and MARCO Physical Realism (MARCO-PR) on student comprehension, learning engagement and motivation among Polytechnic Diploma Digital Technology (DDT) students in learning Computer System Organization (CSO). The independent variables were MARCO-FR and MACRO-PR. The dependent variables were the students' comprehension score, learning engagement and motivation while the moderator variable was Spatial Visual Ability (SVA). The students' comprehension data was obtained from the discrepancy between the pretest and the posttest scores in the Computer System Organization Test (CSOT). The learning engagement data were acquired using O'Brien's User Engagement Scale (UES) (O'Brien's, 2018) scores, while motivation data was gathered using the Keller's Instructional Materials Motivation Scale (IMMS) scores. The moderator variable was employed by implementing the Spatial Visualization Ability Test Instrument (SVATI), which was designed by Maizam (2002).

The intervention was implemented for a duration of two weeks specifically targeting the DDT students that enrolled in the CSO course. This intervention was for two topics. The first chapter is an introduction to the computer system, and the second chapter is instructions on how to assemble and install the computer using MARCO-PF and MARCO-FR. The purpose of this chapter is to discuss the normality test, the homogeneity test, the reliability test, the descriptive statistics, and the inferential statistical differences that are associated with the hypothesis of the study. For the purpose of demonstrating the effects that both MARCO modes have on variables, the data have been arranged in a logical order in accordance with the research hypothesis.

A study was conducted to evaluate the effects of MARCO modes and students' Spatial Visual Ability (SVA) on the students' comprehension, learning engagement, and perceived motivation. The data that was obtained on the utilization of MARCO modes was used for this study. The effects of the treatment modes were acquired, and the conclusions of the descriptive and inferential statistical analyses are reported together with extensive interpretations of the findings. In summary, the research hypotheses' findings were presented.

5.2 Samples Characteristic

The participants were chosen by purposive sampling. Purposive sampling was employed to select students for the Diploma in Information Technology (Digital Technology) (DDT) program, as they demonstrated homogeneous academic performance based on their SPM results, meeting the standardized criteria set by Polytechnics Student Recruitment Division (2020) for admission. The selected group consists of students from various states across Malaysia, yet they share similar qualifications and academic readiness, ensuring they are well-suited for the program's requirements and objectives. This study includes a sample of 200 students from four national Polytechnics. Each group are defined as one class from different polytechnic and consist of semester 1 class DDT students who enroll the DFC1033 Introduction to Computer System (ICS) course. The samples were allocated into four groups using a random selection process. Each group was allocated to either the MARCO-FR treatment mode or the MARCO-PR treatment mode, with 100 students in each group. Table 5.1 presents the descriptive data of the four experimental groups employed in this study.

Table 5.1

Distribution of samples for treatment modes

Treatment Modes	**Number of Students**	**%**
MARCO-FR Polytechnic A	50	25
MARCO-FR Polytechnic B	50	25
MARCO-PR Polytechnic C	50	25
MARCO-PR Polytechnic D	50	25
Total	**200**	**100**

5.2.1 Spatial Visual Ability Classification

A total of 200 Semester 1 students from four national Polytechnics were selected as the sample for this study. These students were randomly divided into different treatment modes, ensuring that the distribution of spatial visual ability was randomized for each mode. The students were designated by their Spatial Visualization Ability

(SVA) using SVATI instrument. The descriptive statistics are used to analyze the SVATI scores of the students and the results are provided in Table 5.2.

Table 5.2

SVATI descriptive analysis

Variable	Mean	Std. Deviation	Minimum	Maximum
SVA (n=200)	10.4	4.2	1.00	21.00

***** n represents number of students

A score of 10.4 is indicative of the overall average for SVATI. On the basis of the estimated mean score, the samples were classified as either having a Low Spatial Visual Ability (LSVA) or a High Spatial Visual Ability (HSVA). An LSVA classification was assigned to students whose scores on the SVATI test were lower than 10.00, while an HSVA classification was assigned to students whose scores were higher than 10.00. A breakdown of the number of students who fall into each SVA group is presented in Table 5.3.

Table 5.3

Distribution of high spatial visual ability or low spatial visual ability in MARCO treatment modes

Moderator Variable	MARCO-FR	MARCO-PR	Total
HSVA	58 (49.2%)	60 (51.3%)	118 (50.3%)
LSVA	42 (50.8%)	40 (48.7%)	82 (49.7%)
Total	100	100	200

There was a total of 58 students identified as HSVA and 42 students identified as LSVA who utilized the MARCO-FR treatment mode. While a total of 60 students identified as HSVA and 40 students identified as LSVA in the MARCO-PR treatment mode. A total of 200 students categorized as HSVA, whereas 82 students classed as LSVA as indicated by the data that is presented in Table 5.3.

5.3 Normality Test

A normality test was conducted to verify the validity of the variables used in this study. These tests are used to assess how instances are distributed within these variables. These evaluations enhance the visual assessment of variable normality. According to a study by Nor Aishah, Yin, Abdul Rahman, and Che Rohani (2011), the Shapiro-Wilk test is highly effective in identifying outliers in datasets, especially for datasets of small to medium sizes.

5.3.1 Normality Test for MARCO-FR

The normality measures in this study were categorised according to the two groups. Upon examining, the data distribution in the MARCO-FR group, no outliers were detected. A later normality test was conducted, and no outliers were identified. Table 5.4 shows that the Skewness and Kurtosis of MARCO-FR variables are within the normality range which is skewness value close to range ±0 [-0.34, -0.155, -0.400] and kurtosis value close to range ±3 [2.461,2.591,2.769] (George & Mallery, 2010), thus confirming the normal distribution of the experimental group. Skewness and Kurtosis serve as preliminary checks that offer insights into the shape and symmetry of data distribution prior the actual dedicated statistical tests, such as the Shapiro-Wilk test, which assesses normality.

Table 5.4

Skewness and Kurtosis scores of the MARCO-FR

Variables		**Comprehension**	**Engagement**	**Motivation**
N	Valid	100	100	100
	Missing	0	0	0
	Mean	4.15	4.10	4.01
Skewness		-.034	-.155	-.400
Std. Error of Skewness		.282	.282	.282
Kurtosis		2.461	2.591	2.769
Std. Error of Kurtosis		.576	.282	.282

The characteristics of data solely pertain by Skewness and Kurtosis and do not affect the sensitivity of normality tests. The size of the sample can affect the sensitivity of the normality test. The researchers also conducted the Shapiro-Wilk test to assess the normality of the data, as presented in Table 5.5 (Nor Aishah et al., 2011).

Table 5.5

Shapiro-Wilk test for the MARCO-FR

Variables	**Statistic**	**df**	**Sig.**
Comprehension	.971	99	.108
Learning Engagement	.973	99	.140
Perceived Motivation	.974	99	.158

According to the findings in Table 5.5, the Shapiro-Wilk test suggests that all the variables have a normal distribution, as the $p > 0.05$ [0.108, 0.140, 0.158] (Coakes, 2013). As part of the study, the experimental group was subjected to additional analysis using parametric techniques, specifically the one-way ANOVA and two-way ANOVA analysis.

5.3.2 Normality Test for MARCO-PR

The MARCO-PR has no outliers that needed to be replaced or removed from the data. Therefore, Table 5.6 shows the skewness and kurtosis scores for MARCO-PR group are within the normality range which is skewness value close to range ±0 [-0.32, -0.256, -0.310] and kurtosis value close to range ±3 [2.661,2.797,2.862] (George & Mallery, 2010). This result suggests that the cases in the MARCO-PR group are normally distributed. Skewness and kurtosis serve as first assessments that offer insights into the shape and symmetry of data distribution prior to doing specific statistical tests, such as the Shapiro-Wilk test, to assess normality.

Table 5.6

Skewness and Kurtosis scores of the MARCO-PR

Variables		**Comprehension**	**Learning Engagement**	**Perceived Motivation**
N	Valid	100	100	100
	Missing	0	0	0
	Mean	3.98	4.02	4.14
Skewness		-.032	-.256	-.310
Std. Error of Skewness		.287	.288	.288
Kurtosis		2.661	2.797	2.862
Std. Error of Kurtosis		.570	.288	.288

Normality test for MARCO-PR also use the same Shapiro-Wilk test. Table 5.7 below shows that all the MARCO-PR variables have $p > 0.05$ [0.108, 0.138, 0.158], thus confirming that the normal distribution of the control group. Therefore, the control group was subjected to further analysis.

Table 5.7

Shapiro-Wilk test for the MARCO-PR

Variables	**Statistic**	**df**	**Sig.**
Comprehension	.968	99	.108
Learning Engagement	.970	99	.138
Perceived Motivation	.968	99	.158

5.3.3 Homogeneity of the Two Experimental Groups

In order to conduct one-way ANOVA and two-way ANOVA analyses, the Levene's test was used to verify that the assumption of homogeneity of variances has not been broken. Levene's test is a diagnostic tool used in the pre-analysis phase to verify if the assumptions required for accurate ANOVA findings, namely the assumption of homogeneity of variances, are satisfied. Table 5.8 shows the results of the test are not significant (p>0.05) [0.173, 0.706, 0.337], therefore the population variances for each group are approximately equal.

Table 5.8

Test of homogeneity of variance

Variables	**Levene Statistic**	**dfl**	**df2**	**Sig.**
Comprehension	1.850	1	199	.173
Learning Engagement	.140	1	199	.706
Perceived Motivation	.915	1	199	.337

5.4 Reliability Test

The acceptable reliability score for this study was set to 0.7 (Nunnally, 1978, as cited in Ogunkola & Archer-Bradshaw, 2013). Performing a reliability test ensures that the measurements collected from a research instrument are reliable, consistent, and appropriate for drawing accurate conclusions in a research study. Two variables in the MARCO-FR variables had high reliability scores (e.g., Assembling Internal Computer Component (0.892), and Attention (0.899)). The reliability of MARCO-FR variables as showed in table 5.9.

Table 5.9

Reliability statistics for the MARCO-FR variables

Variables	Cronbach's Alpha	No. of Items
Comprehension (CSOT)	0.851	30
• Internal Computer Component	0.810	21
• Assembling Internal Computer Component	0.892	9
User Engagement Scale (UES)	0.819	30
• Focus Attention	0.811	7
• Perceived Usability	0.834	8
• Aesthetic Appeal	0.791	5
• Reward Factor	0.838	10
Instructional Material Motivational Scale (IMMS)	0.846	36
• Attention	0.881	12
• Relevance	0.842	9
• Confidence	0.821	9
• Satisfaction	0.846	6
Spatial Visualization Ability Test Instrument (SVATI)	0.812	28
• Cube Construction Task	0.812	10
• Engineering Drawing Task	0.832	11
• Mental Rotation Task	0.791	7

While for MARCO-PR variables, two variables in the MARCO-FR variables obtained high reliability scores (e.g., Assembling Internal Computer Component (0.894), and Relevance (0.889)). The reliability of MARCO-PR variables as showed in table 5.10. All three variables in the MARCO-FR (α>0.7) [0.851, 0.819, 0.846, 0.812] and

MARCO PR(α>0.7) [0.857, 0.816, 0.854, 0.802] had acceptable reliability scores and favourable alpha values.

Table 5.10

Reliability statistics for the MARCO-PR variables

Variables	**Cronbach's Alpha**	**No. of Items**
Comprehension (CSOT)	0.857	30
• Internal Computer Component	0.820	21
• Assembling Internal Computer Component	0.894	9
User Engagement Scale (UES)	0.816	30
• Focus Attention	0.813	7
• Perceived Usability	0.832	8
• Aesthetic Appeal	0.790	5
• Reward Factor	0.832	10
Instructional Material Motivational Scale (IMMS)	0.854	36
• Attention	0.879	12
• Relevance	0.889	9
• Confidence	0.818	9
• Satisfaction	0.832	6
Spatial Visualization Ability Test Instrument (SVATI)	0.802	28
• Cube Construction Task	0.805	10
• Engineering Drawing Task	0.812	11
• Mental Rotation Task	0.788	7

5.5 Testing the Research Hypothesis

Two forms of analysis, namely one-way ANOVA and two-way ANOVA were employed in this study. One-way ANOVA is appropriate when one independent variable factor with more than two groups. This method is employed to ascertain if there are statistically significant disparities among the means of three or more groups. Two-way ANOVA is appropriate when two independent factors have an impact on the dependent variable. The assessment includes not only the primary impacts of each independent variable but also examines if there is a interaction effect between the two variables.

5.5.1 Testing of Hypothesis H1a

H1a: There is no significant difference between MARCO modes on student's comprehension.

An analysis of variance (ANOVA) was conducted to examine the significant difference between MARCO treatment modes on students' comprehension. The purpose was to determine if there were any significant differences between the MARCO modes in terms of their effect on comprehension. The research question H1a aims to ascertain whether there exists a statistically significant difference in the dependent variable, which is the comprehension of students, between the two MARCO modes, namely MARCO-FR and MARCO-PR. The students' comprehension scores were determined by subtracting the pre-test results from the post-test values. Prior to performing inferential statistical analysis, the mean and standard deviation of the pre-test, post-test, and comprehension scores were computed for each of the experimental groups. The Table 5.11 presents the analysis of variance (ANOVA). The table shows the descriptive statistics for the pre-test, post-test, and comprehension scores among the experimental groups.

Table 5.11

The descriptive statistics for the pre-test, post-test and comprehension scores

Mode of instruction	**Score**	**N**	**Mean**	**Std. Deviation**	**Std Error of Mean**
MARCO-FR	Pre-test	100	66.78	16.42	1.198
	Post-test	100	78.64	13.11	.935
	Comprehension	100	11.86	10.42	.724
MARCO-PR	Pre-test	100	64.50	16.39	1.142
	Post-test	100	75.18	14.92	1.032
	Comprehension	100	10.68	11.15	.798

From the Table 5.11 statistical analysis, 100 students used MARCO-FR and 100 students used MARCO-PR. In the empirical analysis of the interventions involving MARCO modes (MARCO-FR & MARCO-PR), the data reveals a notable distinction in the comprehension outcomes as measured by the pre-test and post-test scores. Specifically, the average pre-test score for participants using the MARCO-FR was 66.78, which increased to a post-test average of 78.64. In contrast, for the MARCO-PR, the mean pre-test score was recorded at 64.50, with the post-test score rising to 75.18. The statistical analysis indicates a mean increase in scores of 11.86 for the MARCO-FR, with a standard deviation of 10.42, signifying a significant enhancement in comprehension abilities post-intervention. On the other hand, the MARCO-PR exhibited a mean score increment of 10.68, with a standard deviation of 11.15. This differential outcome suggests a higher efficacy of the MARCO-FR in bolstering students' comprehension capabilities compared to the MARCO-PR. The results of this study suggest that the MARCO-FR potentially offers a more effective educational tool in improving student comprehension. Further research is warranted to explore the specific elements of the MARCO-FR that contribute to its superior performance in enhancing student comprehension outcomes.

In order to conduct an in-depth analysis of the hypothesis, the ANOVA test was performed using the data shown in Table 5.12. The results of the test reveal that there is a statistically significant difference in the mean scores of students' comprehension. The test yielded a value of $F(1,96) = 15.115$, with a p-value of 0.000. According to this outcome, there was a significant difference in students' comprehension scores while employing MARCO modes (MARCO-FR & MARCO-PR). Therefore, the data suggest that MARCO-FR outperforms MARCO-PR slightly in the posttest, indicating that the hypothesis H1a is rejected.

Table 5.12

ANOVA analysis of students' comprehension

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	107.532	1	107.523	15.115	.000
Within Groups	998.331	199	7.182		
Total	1105.8263	200			

5.5.2 Testing of Hypothesis H1b

H1b: There is no significant difference between students' SVA on student's comprehension regardless of MARCO modes.

A study employed an analysis of variance (ANOVA) to examine the effect of independent and moderator variables in both MARCO modes on students' comprehension scores, as indicated in the research question. The main objective of this study was to examine the effect of students' SVA on their comprehension, regardless of the MARCO modes. The mean and standard deviation of students' comprehension scores across the SVA groups were computed. The descriptive data for the comprehension scores of students in the experimental groups, both HSVA and LSVA, are presented in Table 5.13.

Table 5.13

Descriptive statistics for students' comprehension scores for SVA

Spatial Visualization Ability	Mode of instruction	N	Mean	Std. Deviation	Std Error of Mean
HSVA	MARCO-FR	58	16.757	8.634	.885
	MARCO-PR	60	11.904	10.154	1.047
	Total	118	14.343	9.705	.706
LSVA	MARCO-FR	42	10.923	11.618	1.211
	MARCO-PR	40	9.414	12.207	1.226
	Total	82	10.141	11.920	.862

Note: HSVA=High Spatial Visualization Ability, LSVA=Low Spatial Visualization Ability

Table 5.13 illustrates that 58 HSVA and 42 LVSA students used MARCO-FR while 60 HSVA students and 40 LSVA students used MARCO-PR. For both treatment modes, the HSVA students scored higher in their comprehension compared to the LSVA students. The mean score for LSVA students for MARCO-FR and MARCO-PR is 10.92 and 9.41 respectively. As for the HSVA, the students' mean scores are 16.76 and 11.90. The comparative study on the comprehension scores of high and low spatial visual ability (HSVA and LSVA) students, who utilized the MARCO-FR, yielded insightful findings. The statistical examination, as detailed in Table 5.13, underscores a significant difference in comprehension scores between the two groups.

Quantitatively, the HSVA group exhibited a superior performance, with an aggregate mean comprehension score of 14.34, surpassing the LSVA group's mean score of 10.14. This substantial difference elucidates that HSVA students benefitted more markedly from the MARCO-FR intervention, demonstrating enhanced comprehension abilities. The analytical outcomes of this study suggest a correlation between spatial visual ability and the efficacy of the MARCO-FR in improving comprehension. The higher performance of HSVA students indicates that their spatial visual prowess possibly facilitated a more effective interaction with the MARCO modes, leading to improved educational outcomes. Consequently, this research advocates for a differentiated instructional approach, tailored to the spatial visual capabilities of learners, to optimize the educational benefits of the MARCO-FR.

To further investigate the hypothesis, the result of the ANOVA test shows that the posttest scores among students with different SVA were significantly different [F (1,198) =9.540, p=0.000, p<0.05]. (Table 5.14). Based on this result, there was a significant difference between students' SVA on comprehension score using MARCO modes (MARCO-FR & MARCO-PR). Hence, the results indicated that both HSVA and LSVA students using MARCO-FR performs marginally better than the MARCO-PR in the posttest, indicating that the hypothesis *H1b* is rejected.

Table 5.14

ANOVA for students' comprehension and SVA

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	193.592	1	64.531	9.540	.000
Within Groups	915.230	198	6.681		
Total	1108.822	200			

5.5.3 Testing of Hypothesis H1c

H1c: There is no significant interaction effect between the MARCO modes and students' SVA on students' comprehension.

A one-way analysis of variance (ANOVA) was performed to assess the significant interaction between the independent variables and moderator variables in both MARCO modes on students' comprehension scores, as specified in the research question. The research question H1c aimed to investigate whether there is a significant interaction effect between students' SVA and MARCO modes on their comprehension. The study examines two independent variables known as MARCO modes, specifically MARCO-FR and MARCO-PR. Two moderator variables were identified: the students' spatial visualization ability (SVA), which was classified as either high spatial visualization ability (HSVA) or low spatial visualization ability (LSVA). In order to determine the specific groups that are responsible for the significant interaction effect that was observed, a pairwise comparison was performed. The findings of this comparison are shown in Table 5.15.

Table 5.15

Pairwise comparisons for student's comprehension scores

I (SVA/ Mode)	J (SVA/ Mode)	Mean Differences	Standard Error	Sig	95% Confidence Interval for Differences	
					Lower	Upper
HSVA/FR	HSVA/PR	1.510	1.727	.383	-1.895	4.917
LSVA/FR	LSVA/PR	4.854	1.371	.001	2.150	7.557
HSVA/FR	LSVA/FR	-5.834	1.494	.000	-8.781	-2.887
HSVA/PR	LSVA/PR	-2.490	1.621	.126	-5.687	.707

Note: SVA=Spatial Visual Ability HSVA=High SVA, LSVA=High SVA

The analysis of the pairwise comparison, as detailed in Table 5.15, revealed no significant difference in the comprehension scores of HSVA students when comparing the two MARCO treatment modes, MARCO-FR and MARCO-PR, with a p-value of 0.383 (p= 0.383). This finding suggests that HSVA students exhibited comparable performance levels across both MARCO treatment modes. Conversely, a significant interaction effect was observed in the comprehension scores of LSVA students across the two treatment modes, with a p-value of 0.001 (p= 0.001). This indicates that LSVA students achieved higher comprehension scores when engaged with the MARCO-FR as opposed to the MARCO-PR. Moreover, a significant interaction effect was noted between HSVA and LSVA students within the MARCO-FR, where HSVA students demonstrated superior comprehension outcomes compared to LSVA students, as evidenced by a p-value of 0.000. However, within the MARCO-PR, no significant interaction effect was detected between the students' SVA, with the p-value being

0.126 (p = 0.126), suggesting that students' comprehension scores were similar across SVA groups within this treatment mode. Therefore, these results underscore the differential impact of the MARCO modes on students' comprehension, contingent upon their SVA.

A 2x2 two-way ANOVA was conducted to further investigate the interaction effects of the MARCO modes on the comprehension scores of students with differing SVA. The findings, as illustrated in Table 5.16, show the p-values associated with the interaction effects between the MARCO modes and students' SVA. Significant main effects were observed for the MARCO modes [$F(1,198) = 10.594$, $p = 0.001$] and for SVA [$F(1,198) = 5.324$, $p = 0.023$], indicating significant effects on the comprehension scores of the students. However, the interaction between MARCO modes and SVA was not found to be statistically significant [$F(1,198) = 3.517$, $p = 0.063$]. This indicates that, although the main effects of MARCO modes and SVA on students' comprehension scores are significant, the specific interaction between these two factors does not significantly influence the comprehension outcomes.

Cohen (1992) provides a framework for classifying the effect size, where an effect size of 0.10 is considered small, 0.25 medium, and 0.40 large. In this study, as indicated in Table 5.16, the partial eta squared value was found to be 0.25, which explains 25% of the variance in students' comprehension scores due to the interaction effect between the MARCO modes and SVA. Therefore, the effect size for the interaction between these factors in learning computer system organization was determined to be medium. Despite this, the interaction effect between MARCO modes and students' SVA on comprehension was not statistically significant. From the overall analysis, it is concluded that the high spatial visual ability (HSVA) students exhibited greater success in comprehension across both MARCO treatment modes. This leads to the conclusion that hypothesis *H1c* cannot be rejected, signifying that HSVA students consistently performed better in terms of comprehension when engaged with the MARCO treatment modes.

Table 5.16

Two-way ANOVA of comprehension score by MARCO modes and SVA

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	220.544[a]	3	73.515	6.714	.000	.128
Intercept	84086.878	1	84086.878	8.593E3	.000	.984
Mode	115.998	1	115.998	10.594	.001	.072
SVA	58.292	1	58.292	5.324	.023	.037
Mode * SVA	38.512	1	38.512	3.517	.063	.025
Error	1500.109	196	10.950			
Total	97401.000	200				

5.5.4 Testing of Hypothesis H2a

H2a: There is no significant difference between MARCO modes on students' learning engagement.

An analysis of variance (ANOVA) was conducted to assess the effect of MARCO treatment modes on student learning engagement, specifically to determine if there were any significant differences across the modes. The research question H2a aimed to investigate whether there was a statistically significant difference in the dependent variable (learning engagement) between the two MARCO modes (MARCO-FR & MARCO-PR). The learning engagement scores of these students were obtained from the UES scores. Table 5.17 presents the descriptive statistic for the UES scores of the two MARCO modes, including the mean and standard deviation.

Table 5.17

Descriptive statistics of learning engagement scores

Dependent Variable	Mode	N	Mean	Std. Deviation	Std. Error Mean
Learning Engagement	MARCO-FR	100	4.651	.255	.0154
	MARCO-PR	100	4.195	.204	.0120

100 students used MARCO-FR and 100 students used MARCO-PR treatment modes. As illustrated in Table 5.17, the UES mean score for MARCO-FR (M=4.651, SD=.255) was slightly higher than MARCO-PR (M=4.195, SD=0.204). This shows that the students were more engaging in their learning when they used MARCO-FR.

Additional inquiry was undertaken to prove the hypothesis. The results of the ANOVA test of statistical significance on the mean scores of the UES score are presented in Table 5.18. The test yielded a value of F (1,198) = 5.494, a Mean Square of 2085.510, and a p-value of 0.001. The use of MARCO modes (MARCO-FR & MARCO-PR) resulted in a significant difference in students' learning engagement, indicating that the hypothesis H2a was rejected.

Table 5.18

ANOVA analysis of students' learning engagement

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2085.510	1	2085.510	5.494	.001
Within Groups	52768.462	198	379.629		
Total	54853.972	200			

5.5.5 Testing of Hypothesis H2b

H2b: There is no significant difference between students' SVA on the students' learning engagement regardless of MARCO modes.

A factorial analysis of variance (ANOVA) was conducted, succeeded by a post hoc test, to analyze the interaction between the independent and moderator variables across the presentation modes concerning students' learning engagement, as outlined in the research questions. Research question *H2b* was intended to determine whether significant differences in students' learning engagement existed among different levels of students' spatial visual ability (SVA), irrespective of the MARCO Modes.

Table 5.19 illustrates that 58 HSVA and 42 LVSA students used MARCO-FR while 60 HSVA students and 40 LSVA students used MARCO-PR. As a whole, Table 5.19 showed HSVA students who using both MARCO mode having higher learning engagement in learning CSO (mean score=14.34) compared to the LSVA students (mean score=10.14). Meanwhile, when analyzing from MARCO-FR, HSVA students having higher learning engagement (mean score=16.76) compared to LSVA students (mean score=10.92) in learning of CSO. For MARCO-PR, HSVA students also having higher learning engagement (mean score=11.90) compared to LSVA students (mean score=9.41) in learning of CSO.

Table 5.19

Descriptive statistics of students' learning engagement scores for SVA

Spatial Visualization Ability	**Mode of instruction**	**N**	**Mean**	**Std. Deviation**	**Std Error of Mean**
HSVA	MARCO-FR	58	16.757	8.634	.885
	MARCO-PR	60	11.904	10.154	1.047
	Total	118	14.343	9.705	.706
LSVA	MARCO-FR	42	10.923	11.618	1.211
	MARCO-PR	40	9.414	12.207	1.226
	Total	82	10.141	11.920	.862

To further investigate the hypothesis, the results of the ANOVA test, as presented in Table 5.20, indicated that there were significant differences in learning engagement among students with varying levels of spatial visualization ability [(1,198) =23.591, p=0.000, p<0.05)]. This analysis demonstrates that the student's spatial visualization ability significantly affects their learning engagement. Based on the result, there was a significant difference between students' SVA on learning engagement score using MARCO modes (MARCO-FR & MARCO-PR). Therefore, the results indicated that HSVA and LSVA students performs better using MARCO-FR compared to MARCO-PR, indicating that the hypothesis H2b was rejected.

Table 5.20

ANOVA of students' learning engagement and SVA

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	18684.719	3	6228.240	23.591	.000
Within Groups	36169.253	137	264.009		
Total	54853.972	140			

5.5.6 Testing of Hypothesis H2c

H2c: There is no significant interaction effect between MARCO modes with students' SVA on students' learning engagement.

An ANOVA was performed to ascertain the significant interaction effects of the independent and moderator variables on students' learning engagement scores within the different MARCO modes, as delineated in the research question. Research question *H2c* intentional to examine which students' SVA and MARCO modes have a significant interactions effect on students' learning engagement. In order to determine which groups were responsible for the significant relationship effect, a pairwise comparison was performed. The pairwise comparison result is shown in Table 5.21.

Table 5.21

Pairwise comparisons for students learning engagement scores

I (SVA/ Mode)	**J (SVA/ Mode)**	**Mean Differences**	**Standard Error**	**Sig**	**95% Confidence Interval for Differences**	
					Lower	**Upper**
HSVA/FR	HSVA/PR	1.510	1.727	.000	-1.895	4.917
LSVA/FR	LSVA/PR	4.854	1.371	.001	2.150	7.557
HSVA/FR	LSVA/FR	-3.834	1.494	.238	-8.781	-2.887
HSVA/PR	LSVA/PR	-1.490	1.621	.112	-5.687	.707

The results of the pairwise comparison, as presented in Table 5.21, indicate a significant effect in the students' learning engagement among HSVA students when comparing the MARCO treatment modes, specifically MARCO-FR and MARCO-PR (p = 0.000). The outcome suggests that the HSVA students demonstrated superior performance when utilizing MARCO-FR treatment modes as opposed to MARCO-PR. A significant relationship effect was observed in the students' learning engagement scores between LSVA students in both treatment modes (p = 0.001). LSVA students who utilized MARCO-FR demonstrated greater levels of learning engagement in comparison to LSVA students who utilized MARCO-PR. Therefore, it can be inferred that MARCO-FR was more effective in promoting learning engagement among LSVA students. There is no statistically significant difference in the effect on students' learning engagement between HSVA and LSVA students in the MARCO-FR study ($p = 0.238$). However, HSVA students who used MARCO-FR had better levels of learning engagement compared to LSVA students who received the same treatment mode. In the MARCO-PR treatment mode, there were no significant differences in the students' SVA, as indicated by a p-value of 0.112, which is greater than 0.05. The results indicate that HSVA students achieved higher learning engagement scores in the MARCO-PR treatment mode compared to LSVA students.

A 2 by 2 two-way ANOVA was performed to investigate the relationship effect of MARCO modes on students' learning engagement scores, taking into consideration various students' SVA. The table 5.22 shows the p-value of students' learning engagement for the interaction effect between the MARCO modes and students' SVA. The main effect of MARCO modes [$F(1,198) = 12.822$, $p=0.001$] and SVA [$F(1,198) = 3.314$, $p=0.019$] demonstrates a significant interaction effect on the students' learning engagement score. Nevertheless, the interaction effect between MARCO modes and SVA did not achieve statistical significance ($F(1,198) = 7.5527$, $p=0.058$).

In addition, as stated by Cohen (1992), the determination of the effect size can be classified into the following categories: small=0.10; medium=0.25; large=0.40. The partial eta square value of 0.12, as indicated in table 5.16, signifies that 12% of the students' learning engagement may be attributed to the relationship effect between the MARCO modes and SVA. Therefore, the magnitude of the interaction effect between them in the learning CSO was minimal. Thus, in summary, it can be inferred that the HSVA and LSVA students exhibited more success in their learning engagement when exposed to the MARCO-FR treatment modes. The hypothesis H2c is fail to rejected, suggesting that there is no significant interaction effect between MARCO modes and students' SVA on students' learning engagement.

Table 5.22

Two-way ANOVA of learning engagement score by MARCO modes and SVA

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	220.544[a]	3	73.515	12.114	.000	.128
Intercept	70086.888	1	70086.888	5.393E3	.000	.984
Mode	125.798	1	125.798	12.822	.001	.072
SVA	58.292	1	58.292	3.314	.019	.037
Mode * SVA	38.512	1	38.512	7.5527	.058	.012
Error	1500.109	196	10.950			
Total	97401.000	200				

5.5.7 Testing of Hypothesis H3a

H3a: There is no significant difference between MARCO modes on students' perceived motivation.

An analysis of variance (ANOVA) was conducted to examine the significant difference between MARCO treatment modes on students' perceived motivation. The research question H3a aims to ascertain whether there is a statistically significant difference in the dependent variable, which is students' learning engagement, between the two MARCO treatment modes, namely MARCO-FR and MARCO-PR. The motivation scores of these students were determined based on the IMMS scores. Table 5.23 presents the descriptive statistic for the IMMS scores of the two MARCO modes, including the mean and standard deviation.

Table 5.23

Descriptive statistics of perceived motivation scores

Dependent Variable	Mode	N	Mean	Std. Deviation	Std. Error Mean
Perceived Motivation	MARCO-FR	100	3.352	.124	.0124
	MARCO-PR	100	3.295	.115	.0118

100 students used MARCO-FR and 100 students used MARCO-PR treatment modes. As illustrated in Table 5.23, the IMMS mean score for MARCO-FR (M=3.352, SD=.124) was marginally higher than MARCO-PR (M=3.295, SD=0.115). This shows that the students were motivating in their learning when they used both MARCO modes yet MARCO-FR score higher compared to MARCO-PR.

Additional investigation was carried out to examine this hypothesis. The findings of the ANOVA test of statistical significance on the differences observed in the mean scores of the IMMS score are presented in Table 5.24. The test yielded a value of F (1,138) = 5.494, a Mean Square of 2085.510, and a p-value of 0.062. There was no significant difference in students' perceived motivation while utilizing MARCO modes. Both MARCO modes resulted in higher perceived motivation among students, indicating that hypothesis H3a was fail to rejected.

Table 5.24

ANOVA analysis of perceived motivation

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2085.510	1	2085.510	5.494	.062
Within Groups	52768.462	139	379.629		
Total	54853.972	140			

5.5.8 Testing of Hypothesis H3b

H3b: There is no significant difference between students' SVA on the students' perceived motivation regardless of MARCO modes.

To determine the interaction effect of the independent and moderator variables in both presentation modes on students' perceived motivation as indicated by the research questions, an ANOVA with a post hoc test was used. Regardless of MARCO treatment modes, research question H2b aims to investigate which students' SVA are significantly different in terms of students' perceived motivation. For each SVA group, the mean and standard deviation of the students' perceived motivation scores were determined. The descriptive statistics for the perceived motivation scores of LSVA and HSVA students between experimental groups are shown in Table 5.25.

Table 5.25

Descriptive statistics of students' perceived motivation scores for SVA

Spatial Visualization Ability	Mode of instruction	N	Mean	Std. Deviation	Std Error of Mean
HSVA	MARCO-FR	58	14.757	8.634	.885
	MARCO-PR	60	9.804	10.154	1.047
	Total	118	12.342	9.705	.706
LSVA	MARCO-FR	42	9.223	11.618	1.211
	MARCO-PR	40	8.414	12.207	1.226
	Total	82	9.842	11.920	.862

As an entire score, Table 5.25 showed HSVA students who applied MARCO-FR modes having higher perceived motivation in learning CSO (mean score=14.757) compared to the LSVA students (mean score=9.223). Meanwhile, when evaluating from MARCO-PR mode, HSVA students also having higher learning engagement (mean score=9.804) compared to LSVA students (mean score=8.414) in the learning of CSO. Total mean score for HSVA students' who used both MARCO modes are higher (12.342) compared to LSVA students (9.842). Therefore, as for the overall mean score, the HSVA students who used MARCO-FR with a mean score of 14.757 had the highest perceived motivation compared to the rest of the group.

To test the hypothesis further, the ANOVA test result (Table 5.26) reveals that there was a significant difference [(1,198=22.572), (p=0.000, p<0.05)] in the students' perceived motivation across students with different spatial abilities. Based on this result, there was a significant difference between students' SVA on perceived motivation score using MARCO modes (MARCO-FR & MARCO-PR). Therefore, the results showed that HSVA and LSVA students perceived better motivation using MARCO-FR compared to MARCO-PR indicating that the hypothesis *H2b* is rejected.

Table 5.26

ANOVA of students' perceived motivation and SVA

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	16634.412	1	5218.230	22.572	.000
Within Groups	26121.152	198	253.009		
Total	42755.564	200			

5.5.9 Testing of Hypothesis H3c

H3c: There is no significant relationship effect between MARCO modes with students' SVA on students' perceived motivation.

As indicated by the study question, an ANOVA was performed to determine the significant interaction effect of the independent variables and moderator variables in both MARCO modes on students' perceived motivation scores. Intentionally, Hypothesis H3c aims to investigate which SVA and MARCO modes of students significantly interact to effect students' perceived motivation. A pairwise comparison was conducted to identify the groups that were accountable for the significant relationship effect. Table 5.27 shows the outcome of the pairwise comparison.

Table 5.27

Pairwise comparisons for students perceived motivation scores

I (SVA/ Mode)	J (SVA/ Mode)	Mean Differences	Standard Error	Sig	95% Confidence Interval for Differences	
					Lower	Upper
HSVA/FR	HSVA/PR	1.620	1.727	.212	-1.793	4.817
LSVA/FR	LSVA/PR	4.754	1.371	.000	2.150	8.457
HSVA/FR	LSVA/FR	-2.934	1.494	.113	-7.781	-2.787
HSVA/PR	LSVA/PR	-1.380	1.621	.000	-5.587	.807

The results of the pairwise comparison, as presented in Table 5.27, indicate that there is no statistically significant relationship effect in the perceived motivation of HSVA students between the MARCO treatment modes, MARCO-FR and MARCO-PR (p = 0.212). The outcome suggests that the HSVA students achieved comparable results while employing both MARCO treatment modes. A significant relationship was observed in the perceived motivation scores of LSVA students in both treatment modes (p = 0.000). LSVA students who utilized MARCO-FR exhibited more reported motivation in comparison to LSVA students who utilized MARCO-PR. The study found no statistically significant relationship between students' perceived motivation and their type of visual impairment (HSVA or LSVA) in the MARCO-FR (p=0.113). This suggests that both HSVA and LSVA students experienced similar levels of perceived motivation when employing identical treatment modes. In the MARCO-PR treatment mode, there were significant differences observed in the students' SVA, with a p-value of 0.000, which is greater than 0.05. The results indicate that HSVA students achieved higher perceived motivation levels for the MARCO-PR treatment mode in comparison to LSVA students.

A 2 by 2 two-way ANOVA was performed to investigate the relationship effect of MARCO modes on students' perceived motivation score with different students' SVA. Table 5.28 shows the p-value for the interaction effect between the MARCO modes and students' SVA as it pertains to their perceived motivation. The main effects of MARCO modes [F (1,198) =12.822, p=0.001] and SVA [F (1,198) =3.314, p=0.019] demonstrate a significant interaction effect on the students' perceived motivation score. Nevertheless, the interaction effect between MARCO modes and SVA did not achieve statistical significance (F (1,198) =7.5527, p=0.062).

In addition, as stated by Cohen (1992), the determination of the effect size can be classified into the following categories: small=0.10; medium=0.25; large=0.40. The partial eta square value of 0.27, as indicated in table 5.28, signifies that 27% of the students' perceived motivation can be attributed to the relationship effect between the MARCO modes and SVA. Therefore, the magnitude of the interaction impact between them in the learning CSO was minimal. Thus, based on the comprehensive analysis, it can be inferred that the HSVA and LSVA students exhibited higher levels of perceived motivation in MARCO-FR mode. Hypothesis H3c fail to rejected, suggesting that there is no significant interaction effect between MARCO modes and students' SVA on students’ perceived motivation.

Table 5.28

Two-way ANOVA of perceived motivation score by MARCO modes and SVA

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	220.544[a]	3	73.515	12.114	.000	.128
Intercept	94086.888	1	94086.888	5.393E3	.000	.984
Mode	115.998	1	115.998	12.822	.001	.072
SVA	58.292	1	58.292	3.314	.019	.037
Mode * SVA	38.512	1	38.512	7.5527	.062	.027
Error	1500.109	196	10.950			
Total	97401.000	200				

5.6 Summary of Findings

The hypothesis test results of this research were summaries in Table 5.29. The results were derived from two methods of analysis: one-way ANOVA and two-way ANOVA. To summarize, a significant difference may indicate that there is a distinction among groups, whereas an interaction effect implies that the correlation between variables varies across different levels of another variable.

Table 5.29

Summary of hypothesis result

H	Hypothesis	Test of significant (*p*<0.05)	Hypotheses (Reject/ Fail to reject)
H1a	There is no significant difference between MARCO modes on a student's comprehension.	*p* =0.000 (Significant)	Rejected (MARCO-FR>MARCO-PR) Students' Comprehension
H1b	There is no significant difference between students' SVA on student's comprehension regardless of MARCO modes.	*p* =0.000 (Significant)	Rejected (MARCO-FR > MARCO-FR) Students' Comprehension
H1c	There is no significant interaction effect between the MARCO modes and students' SVA on students' comprehension.	*p*=0.063 (Not Significant)	Fail to reject
H2a	There is no significant difference within MARCO modes on students' learning engagement.	*p* =0.001 (Significant)	Rejected (MARCO-FR>MARCO-PR) Students' Learning Engagement
H2b	There is no significant difference between students' SVA on the students' learning engagement regardless of MARCO modes.	*p*=0.000 (Significant)	Rejected (MARCO-FR>MARCO-PR) Students' Learning Engagement

H2c	There is no significant relationship effect between MARCO modes with students' SVA on students' learning engagement.	p = 0.058 (Not Significant)	Fail to reject
H3a	There is no significant difference within MARCO modes on students' perceived motivation.	p = 0.062 (Not Significant)	Rejected (MARCO-FR≈MARCO-PR) Students' Perceived Motivation
H3b	There is no significant difference between students' SVA on the students' perceived motivation regardless of MARCO modes.	p = 0.000 (Significant)	Rejected (MARCO-FR>MARCO-PR) Students' Perceived Motivation
H3c	There is no significant relationship effect within MARCO modes with students' SVA on students' perceived motivation.	p = 0.058 (Not Significant)	Fail to reject

5.7 Summary

This chapter offers an in-depth discussion of the data analysis and findings derived from this research. The hypothesis was assessed and analyzed using one-way ANOVA and two-way ANOVA. One-way ANOVA is used to compare different groups and determine if there are statistically significant differences in the means of these groups. Conversely, two-way ANOVA is employed to assess the interaction impact between variables. The main goal of this data study was to determine the impact of Mobile

Augmented Reality (MAR) application on students' comprehension, level of engagement in learning, and perceived motivation, taking into consideration the varying spatial visualization ability (SVA) in learning CSO. This chapter provides an overview of the sample's characteristics and gives the statistical analysis of data pertaining to each hypothesis of the research questions. In addition, this chapter also included a presentation of the research findings summary. Significant statistical differences were observed in students' comprehension, engagement, and motivation while using MARCO modes. In order to understand the contextual factors behind the statistical results, the subsequent chapter will focus on the interpretation of the empirical findings. Additionally, this study examines the effects of the two treatment modes on students' SVA, students' comprehension, engagement and motivation. It also provides recommendations for future improvements.

CHAPTER SIX
RESULT AND DISCUSSION

6.1 Introduction

The purpose of the study is to develop a Mobile Augmented Reality Instructional Design Model of (MARID) with integration of engagement, motivation, and comprehension elements as a guidance to design and develop a Mobile Augmented Reality Computer Organization (MARCO) application application to investigate the effects of learning Computer System Organization (CSO) on student comprehension, learning engagement and perceived motivation among Polytechnic Diploma Digital Technology (DDT) students with different Spatial Visual Ability (SVA). The study employed a control group of quasi-experimental 2 x 2 factorial design as its research design. The study examined the MARCO modes as independent variables, specifically MARCO Functional Realism (MARCO-FR) and MARCO Physical Realism (MARCO-PR). The dependent variables included the students' comprehension score, learning engagement, and motivation. The moderator variable was identified as Spatial Visual Ability (SVA). A total of 200 students participated in the data gathering phase of this study.

This chapter is divided into four sections. The initial section presents the discussion of the research findings. These section encompass MARID design and development insights as well as the impact of the MARCO modes on students' comprehension, learning engagement, and perceived motivation, influenced by their SVA. Additionally, the study examines how the treatment modes and students' SVA interact with each other. The second section examines the implications of this study, while the third section offers suggestions for further research. Finally, the fourth chapter brings the research to a conclusion.

6.2 Discussion of Research Findings

The development and evaluation of the Mobile Augmented Reality Instructional Design (MARID) model have yielded significant insights into its effectiveness as a framework for creating engaging and motivating learning experiences. This section discusses the key findings related to MARID's role in enhancing comprehension, learning engagement, and motivation among polytechnic students with diverse Spatial Visualization Abilities (SVA). By integrating principles of functional realism, physical realism, and engagement approaches, MARID has proven to be a robust instructional design model for mobile augmented reality (MAR) applications. The discussion highlights the comparative effectiveness of MARCO-FR and MARCO-PR, the influence of SVA on learning outcomes, and the broader implications of MARID for technical education and augmented reality-based learning. These findings underscore the potential of MARID to address diverse learning needs and advance the field of educational technology. The study sample comprised 200 students from the DDT program of Northern Polytechnics. They were subjected to two distinct forms of MARCO: MARCO-FR and MARCO-PR. The MARCO modes were compared to determine the significant differences in the students' comprehension, learning engagement, and perceived motivation towards the CSO course. This comparison was influenced by their levels of spatial visualization ability (SVA). This section presents the empirical findings and their corresponding explanations.

6.2.1 Research Findings of the Theoretical Foundations of MARID

The Mobile Augmented Reality Instructional Design (MARID) model is a pedagogical framework designed to integrate Augmented Reality (AR) technology with instructional design principles. It addresses challenges in complex subject areas, such as Computer System Organization (CSO), by leveraging AR to enhance Spatial Visualization Ability (SVA), engagement, and motivation among learners. This subsection provides discussion on theoretical foundations and core components of MARID. Followed by the role of MARID in MARCO development as well as MARID iterative development and validation,

6.2.1.1 Theoretical Foundations of MARID

MARID is grounded in established instructional design model and theories that align with AR's immersive nature and provide a comprehensive foundation for MARID:

i. Alessi & Trollip’s Instructional Design Model (2001): Provides the planning, design, and development phases for structured content delivery.

ii. RASE Pedagogical Model (2013): Focuses on Resources, Activities, Support, and Evaluation, ensuring holistic learning experiences.

iii. Keller’s ARCS Model of Motivation (1987): Enhances learner engagement through Attention, Relevance, Confidence, and Satisfaction.

iv. Spatial Cognition Theory (1993): Addresses the varying spatial visualization abilities of learners by providing interactive and immersive AR experiences.

6.2.1.2 Core Components of MARID

The MARID model consists of four key components that form its conceptual foundation enabling the development of MARCO applications:

i. Content Realism: Ensures that AR visuals accurately represent physical components, enhancing recognition and comprehension.

ii. Functional Realism: Provides dynamic simulations of object behaviors, fostering a deeper understanding of system functionality.

iii. Engagement Strategies: Integrates gamification and real-time feedback to sustain learner interest and motivation.

iv. Flexibility and Accessibility: Designed for use on mobile devices, making learning accessible and adaptable to various contexts.

6.2.1.3 The Role of MARID in MARCO Development

The MARID conceptual model serves as the blueprint for the development of MARCO, translating its theoretical components into practical applications:

1. **Physical Realism (MARCO-PR)**
   i. Directly stems from MARID's emphasis on Content Realism.
   ii. Provides realistic 3D models of computer hardware components.
   iii. Supports learners with low spatial visualization abilities by making abstract concepts tangible.

2. **Functional Realism (MARCO-FR)**
   i. Builds on MARID's Functional Realism.
   ii. Simulates the dynamic operations of hardware systems, such as data flow in a CPU or motherboard.
   iii. Caters to learners with high spatial visualization abilities who require more advanced problem-solving opportunities.

3. **Integrated Engagement Mechanisms**
   i. MARCO incorporates ARCS-driven motivational strategies and O'Brien's Engagement Model from MARID to maintain learner focus and satisfaction.
   ii. Feedback mechanisms and gamified elements ensure sustained interest throughout the learning process.

6.2.1.4 Iterative Development and Validation of MARID

The development of MARID and its subsequent application in MARCO follows an iterative approach to ensure its effectiveness, usability, and alignment with instructional goals. This process involved multiple stages of conceptualization, prototype development, formative and summative evaluations:

1. **Phase 1: Conceptualization**

   MARID was developed through extensive literature review and expert consultations, ensuring its relevance to AR-based learning.

2. **Phase 2: Prototype Development:**

   MARID principles were applied to create MARCO-PR and MARCO-FR, focusing on targeted learning objectives.

3. **Phase 3: Formative Evaluation:**

   MARCO prototypes were tested with learners and subject matter experts, providing feedback for refinement.

4. **Phase 4: Summative Evaluation:**

   The final models were validated for usability, engagement, and learning outcomes, demonstrating MARID's efficacy.

MARID serves as a comprehensive conceptual model that bridges the gap between instructional design theory and AR technology. Its principles underpin the development of MARCO, providing a robust framework for enhancing learning in technical domains like CSO. By focusing on both physical and functional realism, alongside motivational and engagement strategies, MARID ensures that MARCO effectively addresses diverse learner needs while advancing the use of AR in education. The subsequent section discussed on the impact of the MARCO modes on students' comprehension, learning engagement, and perceived motivation, influenced by their SVA.

6.2.2 Research Finding of the MARCO Modes on Students' Comprehension

This study aims to ascertain the effects of utilizing MARCO modes on the learning of CSO course among DDT students. Therefore, it is important to highlight that the results of this study have prompted a different approach to exploring the process by which learners gain comprehension of the CSO course. The subsequent sections examine the interaction effects of the MARCO modes on the students' comprehension.

6.2.2.1 Effects of MARCO Modes on Students' Comprehension

The research results revealed a significant difference in students' comprehension scores when utilizing the MARCO application with two distinct treatment modes, namely MARCO-FR and MARCO-PR. The findings of this study indicate that students who utilized the MARCO-FR achieved notably higher results on the post-test compared to students who utilized the MARCO-PR in the CSO course.

Both MARCO modes, MARCO-FR and MARCO-PR, showed a positive impact on enhancing students' comprehension in learning CSO. This was demonstrated by the statistical findings, which indicated that both MARCO treatment modes achieved higher average scores for the students' understanding assessment. There are multiple potential causes for this outcome. One possible explanation for the notable improvement in students' comprehension due to MARCO modes is that the AR features help direct the students' focus toward the instructional content and facilitate their visualization of important material and processes.

On the other hand, according to the Churchill, King, & Fox RASE Model (2013), by providing simple and systematic phase of instructional steps and also integrating the AR elements according to O'Brien's Model of Engagement (2018), provides assistance to the students to comprehend and understanding course content (components visualization and assembly process) in MARCO application when CSO. This result was supported by Papacostas, Troussas, Krouska and Sgouropoulou (2021) who investigated the effectiveness of AR in spatial abilities training. The study discover AR offers unique advantages to the learners by improving learner's spatial ability, better understanding of the topic and gradually improved learner's comprehension toward learning materials.

Specifically, the study revealed that students who utilised MARCO-FR achieved notably higher scores for comprehension compared to students who utilized MARCO-PR. Consequently, the utilization of MARCO-FR resulted in enhanced comprehension skills among students. This contradicts the principles of Spatial Cognition Theory (1993), which serves as a framework for the development of MARCO-FR modes, in conjunction with the Alessi and Trollip Instructional Design model (2001). The theory suggested that student comprehend more effectively from Visual-Spatial Configurational Knowledge (VSCK) topology which is applied in MARCO-PR as this topology emphasize on information, relationship between objects and orientation that give better AR visualization experience. While in contrast to MARCO-FR, which applied Visual-Spatial Procedural Knowledge (VSPK) topology that emphasize on user experience in a virtual environment, as the 3D models are rotating, zooming or animated.

Although the finding showed contradiction result, this is consistent with what has been found in previous study. According to Akçayır & Keskin, 2023, applying Visual-Spatial Procedural Knowledge (VSPK) topology in AR based application will foster deeper comprehension and engagement in immersive and interactive learning. VSPK topology concept integrates virtual simulations with real-world environments, allowing learners to apply theoretical knowledge in practical contexts that promotes active learning and deeper understanding of procedural knowledge (Feng, Lin & Yu, 2023). This result corresponded with the arguments suggested by Guo, Xu, Yang and Wang (2023) that VSPK topology offers alternative ways to interact with and visualize information, benefiting learners with spatial challenges like Low Spatial Visual Ability (LSVA), leads to better knowledge retention and engagement in the learning process.

Moreover, MARCO-FR also applied another topology which is Visual-Spatial Haptic Space and Visual-Spatial Pictorial Space (VSHS & VSPS) to gain visual-spatial consistently which result better learning engagement (Chapter 4.3.2). This finding aligns with studies by Lee-Cultura & Giannakos (2020), who highlighting the potential of haptic and pictorial spaces will facilitate holistic understanding and skill development. In addition, according to Venkatesan, Banakou, Slater & Manivannan (2023), haptic feedback enhances spatial orientation and perceived realism in virtual environments, supporting the potential of VSHS for spatial learning. This highlights that MARCO-FR facilitates better learning comprehension than MARCO-PR even though each approach has its strengths for enhancing AR application learning engagement, but their effectiveness depends on the specific context of the application.

In summary, Churchill, King, & Fox RASE Model (2013) provide a clear framework to direct the student-centered learning process with the help of technology-based learning environments which is AR elements, while Spatial Cognition Theory (1993) and Alessi and Trollip Instructional Design model (2001) provide a systematic guidance in design and development of the MARCO application in order to optimize the learning outcomes and give better comprehension of the CSO course.

6.2.2.2 The Effects of MARCO Modes on Students' Comprehension with Different Spatial Visualization Ability

Spatial Visual Ability (SVA) is the ability to manipulate complex spatial information by many steps. It is commonly linked to complex, multi-step spatial manipulations (Chin, 2017). High SVA (HSVA) students are identified non-sequential, organizationally impaired learners. They tense to see the big picture of certain things before they go through the details, able to compose significant amounts of information from different domains and perform better in untimed situations. (Hindal, 2014). In contrast, Low SVA (LSVA) students are described as sequential and well organize learners. They tense to see segment by segment of certain things before go through the details, impossible to compose large amounts of information from different domains and always conscious about time (Hindal, 2014).

SVA is crucial for spatial cognition in the context of assemblies. It involves mentally manipulating 3D objects and analyzing design information to visualize the necessary constructs (Kwiatek, 2019). Several studies discussed that there are advantages of SVA that are important for learning CSO that required visualizing physical components, assembly processes and practical tasks (Majid & Husain, 2014; Shaaban, 2015; Ali et al., 2018; Vasavada, 2016; Pantelić 2017; Sommerauer & Müller, 2018). The HSVA seem to benefits more from visualization-based training outside the constraints of the classroom (non-sequential) and untimed situations. They are capable of processing visual from different domains, seeing the big picture of certain domains and consistently go through the details (Hindal, 2014; Duenser, Steinbügl, Kaufmann & Gluck, 2005). Nonetheless, the LSVA, in contrast positively affected by visualization-based training, but with specific assistance as they are sequential learner, difficult to compose large amounts of information from different domains, meticulous with details and conscious abut time (Chin, 2017). In this study, the MARCO modes were designed with features that stimulated HSVA learner potential and improve LSVA visualization ability due to its media attributes (visual rotating, zooming into details, animations, highlighting aspects, etc.) and immersive learning environment (Tuker, 2018).

This elucidates the results of the aforementioned study. The HSVA students achieved considerably higher scores in course comprehension compared to the LSVA students in both MARCO application modes. The MARCO application modes offer an individualistic, task-oriented, non-sequential activity with flexible timing and visually informative learning content. Additionally, the MARCO application implements visual-spatial elements in its AR parts. These characteristics are the preferred attributes of HSVA students that motivate them to outperform LSVA students. Contrary to this, the LSVA students showed a preference for utilizing the sequential learning assistance offered in the MARCO application and requiring supervision from the instructor, in contrast to their peers.

This finding is consistent with the investigation carried out by Yanuarto and Iqbal (2022) about the utilization of AR to improve students' comprehension of geometric principles. HSVA learners experience a more significant positive effect in their studies. Further examination indicated a significant difference in the outcome of HSVA learners between the experimental and control groups, whereas there was no statistically significant difference in the performance of LSVA learners in either group. The results suggest that the comprehension of HSVA learners was significantly enhanced by the MARCO modes in comparison to LSVA learners.

The finding of this study is also consistent with the finding from the study done by Kuhl, Fehringer and Munzer (2022). They investigated the effect of visualization design in educational materials in different forms on SVA students. Two types of visualization design: (1) optimized visual design and (2) suboptimal design was used with four multimedia learning experiments among SVA students to examine the effect of this visualization design form SVA students' ESL comprehension ability. The results showed that HSVA students can compensate for suboptimal visualization design while this compensating effect of SVA is not required when learners receive an optimized visualization design. Similar to the effects of MARCO modes, this significant difference in achievement between HSVA and LSVA students indicate that the MARCO-FR (Optimized Visualization Design) is more effective for both HSVA & LSVA students compare with MARCO-PR (Suboptimal Visualization Design) which only HSVA comprehend better than LSVA.

6.2.2.3 Interaction Effects of MARCO Modes on Students’ Comprehension with Different Spatial Visualization Ability

The findings of the two-way ANOVA showed that there was no significant interaction effect on students' comprehension between MARCO modes for HSVA students. However, there was a significant interaction effect for LSVA students. The study demonstrated that the impact of the MARCO modes on the acquisition of CSO knowledge was greatly affected by the students' SVA. However, the findings indicated that MARCO-FR was more effective in enhancing students' comprehension skills compared to MARCO-PR. This is because of the features offers in MARCO-FR that enables spatial reasoning and manipulation, directly strengthening spatial visualization and mental manipulation skills of both HSVA and LSVA learners. (Guo, Xu, Yang & Wang, 2023). However, compared with MARCO-PR features that offers interactive modalities on spatial visualization, mental rotation and spatial reasoning that only giving advantages to HSVA learners even over LSVA learners that required more practice with spatial reasoning skills (Bacca, Ferri & Manuri, 2023; Feng, Lin & Yu, 2023). The effect size finding of 25% was explained by the interaction between the MARCO modes and students SVA on students' comprehension in learning CSO. The medium interaction effect reflects that not all individual differences (in SVA) will be affected by the MARCO modes (MARCO-FR or MARCO-PR). This result ties well with recent studies wherein state that, HSVA learners thrive in visually rich environments while LSVA learners benefit from additional support with visualization tasks (Bacca, et al., 2023). Therefore, HSVA students achieved a higher score than LSVA students in both MARCO modes due to the advantages of the HSVA visual learning characteristic.

6.2.3 Research Finding of the MARCO Modes on Students' Learning Engagement

Learning CSO is a manageable effort when it is integrated with appropriate methodologies. Considering students' learning engagement is essential as it is a contributing factor to the success of the learning CSO among students. Therefore, it can be asserted that the results of this study have prompted academics and educators to gain a clearer understanding of how students develop learning engagement in the context of learning CSO. The subsequent sections examine the impact of the MARCO modes on students' level of engagement with learning.

6.2.3.1 Effects of MARCO Modes on Students’ Learning Engagement

The research results indicate a significant difference in the students' intrinsic load when utilizing MARCO with two distinct modes, namely MARCO-FR and MARCO-PR. Therefore, the findings demonstrated that MARCO-FR achieved considerably greater levels of learner engagement compared to MARCO-PR in the CSO course.

MARCO-FR delivers optimized visualization design and enhanced graphics using AR element which draws students' attention and helps them stay engage with the contents. By using multiple kind of visual motion (Haptic space), virtual environment (Pictorial space) and spatial reasoning and manipulation (Visual-spatial procedural knowledge) has been shown for improved students’ visualization and comprehension. This is the justification of why the students engaged more with MARCO-FR by sustaining students point of engagement with the application content throughout the usage session. HSVA learner potential were stimulated and significantly improved while LSVA learner increasing their visualization ability due to its media attributes (visual rotating, zooming into details, animations, highlighting aspects, etc.) and immersive learning environment (Tuker, 2018).

Students will become unengaged and stop using the application when they are unable to sustains the point of engagement (O’Brien’s, 2018). Student will continue engage with the application when their find a point to reengagement and disengaged when the application activity ends. MARCO-FR was designed to support the learners’ capability to make connection with the application content and sustain the engagement throughout the session by identifying and applied the engagement element in the design of MARCO-FR application (Chapter 2: Figure 2.7). The list of engagement attributes applied in MARCO were summarizes in Chapter 4: Table 4.6. These attributes also are a component of adaptability, convenience and learnability of Mobile Augmented Reality (MAR) application (Esra et al., 2018; Bacca et al., 2023; Akçayır & Keskin, 2023; Feng et al., 2023). It is essential in MAR application development to ensure captive users' attention and involvements.

The finding of this study is also congruent with a separate inquiry conducted by Lin & Wang (2022). Lin et al. (2022) discovered in their research that students who utilised AR for scientific instruction demonstrated significantly superior performance compared to their peers. Additionally, it was discovered that these students demonstrated a higher level of engagement with the application compared to their peers in the control group.

Furthermore, study done by Guo et al. (2023) evaluated an AR science intervention through O'Brien's Model of Engagement (2018), demonstrating that engaging AR visuals and collaborative activities stimulated learner interest, curiosity, and enjoyment, boosting affective engagement. Additionally, the research finding conducted by Cebada, Galan and Lopez (2023) who explored immersive haptic virtual reality for procedural learning, emphasizing O'Brien's (2018) behavioral engagement attributes show that hands-on interaction and real-time feedback through haptic interfaces in virtual reality fostered active participation and skill development.

The use of various multimedia representations of contents (text caption, videos, audios, sound effects, images, 3D object and simulation) as well as learners enable to manipulate 3D contents representations (repeating, rotating and zooming) in MARCO-FR, offers various opportunities to cater to the different level of SVA (Edler and Kersten, 2021). This AR visualization learning approach allows instructional elements to be visual presented by combining ideas and concepts with graphic presentation to better understand on how to retain information (Papakostas, Trousas, Krouska and Sguropoulou, 2021). This stimulates learners ' interest, foster the learning process, gain motivation and engagement (Papakostas et. al, 2021). The justification behind the findings of this study is that students who utilized MARCO-FR had greater levels of learning engagement in comparison to their peers.

Even though both MARCO modes applying the same engagement attributes, the reason why learners attained lower learning engagement in MARCO-PR is due to suboptimal design. Visual-Spatial Configurational Knowledge (VSCK) topology which is applied in MARCO-PR only emphasize on information, relationship between objects and orientation (Suboptimal Visualization Design) rather than optimized virtual environment and 3D models applied in MARCO-FR (Optimized Visualization Design).

6.2.3.2 The Effects of MARCO Modes on Students' Learning Engagement with Different Spatial Visualization Ability

The statistical analysis revealed that both the HSVA students and LSVA students demonstrated better levels of learning engagement for MARCO-FR compared to MARCO-PR, as indicated by the mean scores. Nevertheless, it was discovered that the HSVA students outperformed the LSVA students in both MARCO modes, albeit by a small margin. There was a notable disparity in learning engagement observed between students from the HSVA and LSVA when using both modes of the MARCO application. This indicates that both MARCO modes have a good impact on the level of engagement in learning for HSVA students. The results indicate that students with both HSVA and LSVA levels benefited the most from MARCO-FR modes in terms of learning. This discovery provides evidence in favor of the validation proposed by Lin et al. (2022), who posited that HSVA learners can achieve superior performance and engagement when exposed to learning materials that are optimized for high visual stimuli.

Another finding from the study done by Kuhl, Fehringer and Munzer (2022) as they investigated the effect of visualization design in educational materials in different forms on SVA students. The results showed that HSVA students can compensate for suboptimal visualization design while this compensating effect of SVA is not required when learners receive an optimized visualization design. This significant difference in achievement between HSVA and LSVA students indicate that the MARCO-FR (Optimized Visualization Design) is more effective for both HSVA & LSVA students compare with MARCO-PR (Suboptimal Visualization Design) which only HSVA students comprehend better than LSVA student.

This result also corresponded with the arguments suggested by Akçayır & Keskin, (2023), Feng et al., (2023), Guo et al., (2023) and Bacca et al., (2023) that both HSVA and LSVA students prefer different learning preferences, strength and challenge. HSVA students are classified as non-sequential, organizationally impaired learners because they tend to focus on the broad picture before delving into the specifics, are able to synthesize large amounts of information from several domains, and do better in untimed situations. On the other hand, LSVA students are characterized as sequential and well-organized learners since they are tense to perceive things in segments before going through the specifics, unable to put vast amounts of material from several domains together, and always aware of time. These tendencies resulted different learning engagement among HSVA and LSVA leaners. In spite of HSVA learners are more positively effect by MARCO modes, with consistent practicing visualizing objects, rotating them in mind and navigating through mental spatial maps can significantly enhance SVA skills (Feng et al., 2023).

6.2.3.3 Interaction Effects of MARCO Modes on Students' Learning Engagement with Different Spatial Visualization Ability

The outcome of the two-way ANOVA reveals a statistically significant interaction effect between the MARCO modes (MARCO-FR and MARCO-PR) and students' SVA on the students' learning engagement. This elucidated the reason why the impact of the MARCO modes on the acquisition of CSO knowledge was noticeably affected by the students' SVA. However, the findings indicated that MARCO-FR was more effective in promoting students' SVA compared to MARCO-PR. The observed effect size of 12% can be attributed to the interaction between the MARCO modes and students' SVA in relation to their level of engagement in learning CSO. The weak interaction effect indicates that the individual differences in student SVA might be influenced by the MARCO modes (MARCO-FR or MARCO-PR).

The findings also indicated that students from the HSVA group exhibited higher levels of learning engagement when utilizing MARCO-FR compared to MARCO-PR. However, LSVA students experienced reduced intrinsic cognitive burden when utilizing MARCO-FR as opposed to MARCO-PR, in comparison to HSVA students. O'Brien's Model of Engagement (2018) identifies user engagement compose by sensual, emotional and spatiotemporal thread as crucial components. Mobile Augmented Reality (MAR) boasts interactive elements and immersive visualizations that appeal to both high and low SVA learners through different pathways. For HSVA learners, the manipulation and exploration of AR objects can enhance sensual and spatiotemporal thread engagement, while for low SVA learners, engaging visuals elements can boost emotional thread engagement (O'Brien, H. L, 2018). Therefore, both HSVA and LSVA learner attained an engagement benefit from MARCO-FR due to the AR interactive elements and visualizations even though with different pathways.

6.2.4 Research Finding of the MARCO Modes on Students' Perceived Motivation

Motivation can be defined as the student's inclination or drive to actively participate in a learning environment. Hence, it is crucial to take into account students' perceived motivation regarding the impact of utilizing MARCO modes in learning CSO. Motivation plays a pivotal role in enhancing students' engagement and comprehension. The findings of this study highlighted that learner have been encouraged towards a more effective approach to attain comprehension in the CSO course. The subsequent sections examine the interaction impacts of the MARCO modes on students' perceived motivation.

6.2.4.1 Effects of MARCO Modes on Students' Perceived Motivation

This study investigates the role of motivation in determining the success or failure of learning in MAR environments. It specifically focuses on investigating the impact of instructional materials on motivation and how instructional designers can use this knowledge to enhance the learning process and knowledge transfer. (Lin et al., 2022). The Instructional Materials Motivation Survey (IMMS) (Keller, 2010) was created based on the ARCS motivation model to gather information on students' motivation towards an instructional design. The survey analyzed four motivational factors: attention, relevance, confidence, and satisfaction.

The research findings revealed a significant difference in the students' perceived motivation when utilizing MARCO modes (MARCO-FR & MARCO-PR). The findings indicated that students using MARCO-FR had a considerably higher perceived motivation score compared to those using MARCO-PR in learning CSO. There are multiple potential causes for this outcome. One possible reason for the notable positive impact of MARCO-FR on students' perceived motivation is its visually appealing nature. It captures students' attention by offering multimedia elements, visually insightful learning content, and visual-spatial features that facilitate interaction with the learners. Mesa, Vazquez, Andreas, and Campos (2022) asserted that students' motivation might be enhanced when the learning environment effectively engages their attention.

Secondly, instructional design can also help the learner to assist learning process by drawing learners' attention towards the essential material (Mayer, 2009) as MARCO-FR provides sequential and non-sequential instructional material to guides both HSVA and LSVA learners which is self-oriented learning process and allow unrestricted navigation and students enjoy themselves exploring new information. This finding is in line with the findings by Ghai and Tandon (2022) in their research on AR element and instructional design, who stated that good instructional design is the key enabler of motivation and leads to foster motivation.

Finally, the implementation of the AR technology itself is the key point that show positive impact on improving student's motivation. (Cai, 2019; Fotaris, Pellas, Kazanidis, Smith, 2017; Tobar-Muñoz, 2017; Diegmann, Schmidt-Kraepelin, Van, Eynden & Basten, 2015; Iwata, Yamabe & Nakajima, 2011). AR in educational processes favorability in student attitudes and satisfaction levels. It is also shown to increase motivation to learn (Mesa et.al. 2022). Implement AR in the learning process showed a significant benefit to students who struggled with visualization as they showed a self-perceived motivational increase in willingness to learn and explore if AR support was available during their study (Nicolaidou, 2022).

This aligns with the research conducted by Mesa et al. (2015), which examined the efficacy of AR learning approaches in enhancing primary education degree students' perceived motivation in motor skills and exercise course systematics. The study discovers that students more motivated by the AR instructional materials as the mean score are significant high. Consequently, it can be inferred that AR captivates students' attention and aids in sustaining their focus. Furthermore, AR enables students to effectively organize information, thereby enhancing their interest and promoting a wider range of material utilization. Consequently, AR becomes more enticing and results in heightened levels of motivation (Mesa, et al. 2022).

Moreover, the beneficial influence of AR on motivation results in students attaining elevated levels of engagement with learning activities, as stated by Low, Poh, and Tang (2022). Low et al. (2022) conducted a study to explore the connection between students' motivation to learn and the utilization of visuals and the level of control they have over the lesson in AR learning methods. The analysis revealed a substantial correlation between motivation and the students' use of visuals and their level of control in the AR learning method. These features were found to be captivating and appealing aspects of AR technology.

Even though MARCO-FR and MARCO-FR approach has its strengths for enhancing students' motivation for learning, but their effectiveness depends on the specific context of the application as well as learners learning characteristic and style. The main factor MARCO-FR attained significantly lower score that MARCO-PR is because it required mental manipulation of spatial entities, which can be demanding for those with weaker spatial visualization skills. This mental effort could outweigh the initial sense of challenge and enjoyment for some learners while MARCO-FR offers alternative ways to interact with and visualize information by integrates virtual simulations with real-world environments, allowing learners to apply theoretical knowledge in practical contexts that promotes active learning and deeper understanding, benefiting learners with spatial challenges like Low Spatial Visual Ability (LSVA) (Lin et al., 2023; Akçayır et al., 2023). In contrast, High Spatial Visual Ability (HSVA) learners seem to benefit more as their character of learning are more capable of processing visual from different domains, seeing the big picture of certain domains and consistently go through the details.

6.2.4.2 The Effects of MARCO Modes on Students' Perceived Motivation with Different Spatial Visualization Ability

The research findings revealed a significant difference in the perceived motivation among SVA students in both MARCO modes (MARCO-FR and MARCO-PR). Thus, this outcome suggests that HSVA students use MARCO-FR exhibited higher levels of motivation in comparison to students utilizing MARCO-PR. Furthermore, there was a notable disparity among students utilizing LSVA when comparing the use of

MARCO-FR and MARCO-PR. Therefore, this outcome demonstrated that HSVA and LSVA students exhibited higher levels of motivation when utilizing MARCO-FR compared to MARCO-PR, and the findings indicated a statistically significant disparity. The findings revealed that in both MARCO modes (MARCO-FR and MARCO-PR), the HSVA students reported a greater level of motivation compared to the LSVA students.

There are numerous potential causes for this outcome. One possible explanation is that students who had both HSVA and LSVA demonstrated a notable increase in perceived motivation when the AR was utilized in the MARCO application. This is because AR has the potential to enhance students' self-visual attention, leading to improved motivation. AR allows learners to manipulate and interact with virtual objects in the real world, promoting a feeling of ownership and control over their learning process, which can be highly motivating (Feng et al., 2023). Based on Keller's ARCS Model of Motivational Design (1987), MARCO applications demonstrably enhance perceived motivation in learners by addressing key elements of Keller's ARCS Model (1987) which is attention, relevance, confidence and satisfaction. The overlaid digital elements on the real world in MARCO application stimulate visual and spatial attention, drawing learners into the learning experience. Next, MARCO allow learners to connect abstract concepts to tangible real-world contexts, making the learning experience more relevant and relatable to the learning content. MARCO also provides opportunities for active exploration and manipulation of virtual objects, leading to a sense of accomplishment that builds confidence in learners' abilities in the learning process. Finally, user interaction elements such sounds, real-time responds and visual reaction in MARCO application provide immediate feedback and positive reinforcement, enhancing learner satisfaction with their progress and achievements.

Based on learners SVA, in this study showed that the HSVA learners are highly motivated and understood a multimedia presentation better when it contained visual aids such as 3D object and simulation on how to assemble the components. However, contrary to expectations, the LSVA students were slightly less motivated when AR was applied in the MARCO application as highlighted by Devagiri, Paheding, Niyaz, Yang and Smith (2022). They reported that AR had strong effects on underperforming students on visual learning process but in short, too much emphasizing and visual aids added confusion rather than guiding attention. In a study undertaken by Guntur, Setyaningrum, Retnawai and Marsigit (2022), the results provided evidence related to HSVA and LSVA students using AR based learning, with the combination with multimedia element (3D Simulation, Images, Videos, Text, Sound and User Controls) combine with proper instructional design content were significantly more motivated compare with common AR applications. In addition, HSVA students will benefit more from the usage of AR based learning as provide more intuitive way in learning and improving spatial skills raging from perception, visualization, mental rotation and orientation. While for LSVA students, a dynamic process of SVA skill improvement can be fostered and enriched through interaction of real and virtual objects using AR based learning application (Guntur et al, 2022). The results confirmed a significant relationship effect between motivation and students with varying levels of SVA on the MARCO-FR and MARCO-PR modes.

6.2.4.3 Interaction Effects of MARCO Modes on Students' Perceived Motivation with Different Spatial Visualization Ability

The outcome of the two-way ANOVA revealed that there was no statistically significant interaction effect observed for the MARCO modes (MARCO-FR and MARCO-PR) on the perceived motivation of HSVA students. This indicates that the HSVA students achieved similar results while using both MARCO modes. However, a significant interaction effect was observed in the perceived motivation levels of LSVA students in both treatment modes. LSVA students who utilized MARCO-FR exhibited more reported motivation in comparison to LSVA students who utilized MARCO-PR. The observed effect size of 27% can be attributed to the interplay between the MARCO modes and SVA in influencing students' perceived motivation in studying CSO. The medium interaction effect indicated that the application modes (MARCO-FR or MARCO-PR) will have an impact on individual differences in SVA.

There are several possible explanations for this result. This result may be explained by the fact that MARCO-FR mode focus on procedural reasoning as well as realistic and functional experience by overlaying virtual objects or information might align better with the learning styles of LSVA students, reducing cognitive load and enhancing engagement compared with MARCO-PR modes emphasis on configural reasoning, information processing and relationship between objects and orientation might overload their cognitive resources, leading to frustration and lower perceived motivation.

However, HSVA students may be more adept at mental manipulation and spatial visualization, allowing them to thrive in both MARCO modes, regardless of their focus (Feng et al, 2023; Akçayır et al, 2023). Moreover, both HSVA and LSVA leaners have different learning preferences and characteristics. In this study, learning preferences and characteristic likely play a role and can be influence by the MARCO application content presentation. For example, LSVA learners might find the MARCO-FR mode more engaging due to its visual aids and familiar structure, while HSVA learner might prefer the challenge and exploration of both MARCO mode. This also accords with previous research, which show that AR applications, characterized by clear instructions, immediate feedback, and captivating visual presentation increased learner motivation across diverse spatial learning styles and characteristic (Serio, Lombardi & Dandolo, 2019). Therefore, while both HSVA and LSVA gained benefit from the MARCO modes, HSVA students achieved a better motivation than LSVA students in both MARCO modes due to the learning style and spatial visual characteristic.

6.3 Implication of Study

The development and evaluation of the Mobile Augmented Reality Instructional Design (MARID) model have far-reaching implications for instructional design, technical education, and the integration of augmented reality (AR) in learning environments. MARID, as a structured framework, not only addresses the diverse needs of learners with varying Spatial Visualization Abilities (SVA) but also demonstrates the potential of AR to enhance comprehension, engagement, and motivation in technical education. The study's findings also suggest that students who use MARCO-FR demonstrate more effectiveness in comparison to those who use MARCO-PR. Overall, the study indicates that both groups of students, regardless of their SVA, were better equipped to utilize MARCO-FR. The MARCO modes were created using AR application technology, instructional design techniques, spatial cognition theory, and visualization learning principles. These modes were designed to help students learn CSO.

The subsequent sections explore five primary implications of this study including technology, contextual, domain, educational, research, policy and practical implications highlighting its contributions to the field of instructional technology and its potential to transform teaching and learning practices.

6.3.1 Technology Implications: Instructional Design Model for Mobile Augmented Reality and MARCO Application

This study introduces a novel Instructional Design (ID) model specifically tailored for Mobile Augmented Reality (MARID) applications, emphasizing implementation, comprehension, engagement, and motivation. By integrating these critical aspects, the proposed ID model offers a structured framework that enhances the instructional effectiveness of MAR applications, leading to improved learner comprehension, engagement, and perceived motivation. Particularly, existing ID models often lack a comprehensive focus on these combined elements within the MAR context. For instance, while frameworks for designing interactive mobile training content using MAR have been proposed, they primarily address engagement without fully integrating comprehension and motivation aspects (Saud, Suraya, Nurul & Ghani, 2023). Therefore, this study fills a significant gap in the literature by providing a holistic ID model that comprehensively addresses these dimensions, thereby advancing both theoretical understanding and practical application in the field of MAR-based education.

Moreover, the development process of MARCO modes was guided by MARID model. MARCO integrated AR with multiple multimedia elements such as graphic, overlay 3D models and animation, video, text and sound in order to bring support and variety to the overall spatial-visual learning process. From a technological perspective, it is found that there is no such Mobile Augmented Reality (MAR) application development in learning CSO course specifically for Malaysian Polytechnics students. As such, it is hoped that the development of this MAR application will increase the exposure of Malaysian Polytechnic’s students as well as lecturers to the effectiveness of spatial-visual learning approach in MAR technology on assisting learning process especially in CSO course as well as to the others potential course. MARID provides a structured framework for leveraging AR in instructional design. This contributes to the growing field of educational technology by demonstrating practical applications of AR in complex subjects. In addition, MARID’s focus on mobile-friendly applications ensures that MARCO can be scaled to reach a broader audience. This accessibility is especially impactful in regions with limited access to high-end educational resources. The success of MARID and MARCO offers a blueprint for integrating AR into other educational domains beyond CSO, such as biology (e.g., anatomy simulations) or engineering (e.g., mechanical systems).

This study also contributes to the development of MAR application which is suitable to be used in higher learning institution as a majority of educators and students own mobile devices. Implementing the AR on mobile devices makes it the most convenient platform as most mobile devices are currently fitted with high quality cameras. Modern mobile devices are now equipped with powerful processors, large memory capacities, high-resolution cameras, advanced multimedia capabilities, and various sensors. In addition, the enhanced connectivity provided by 5G technology can meet the fundamental hardware needs for mobile augmented reality (MAR). (Arulanand, RameshBabu & Rajesh, 2020). Nevertheless, with the development of this MARCO application, it is hoped that it will provide insight to the others MAR based application development in line with the advancement in AR technology as well as guidance in developing instructional based applications.

6.3.2 Contextual Implications: Augmented Reality Realism and Spatial Cognition Theory

The design of MARCO modes was based on AR realism (Diegman, 2015) and Spatial Cognition Theory (Mark, 1993). There are two typology types which support the theory of spatial cognition (Mark, 1993) which is Visual-spatial knowledge and

Visual-spatial space topology adapted in the design and development of MARCO application modes. Findings of this study showed that MARCO-FR (Functional Realism) treatment mode significantly improved the students' comprehension in learning CSO compared to the MARCO-PR (Physical Realism) treatment mode. Functional Realism (FR) which applied Visual-Spatial Procedural Knowledge (VSPK) topology provides virtual images (projected 3D models and simulation) that same with visual information as a scene and emphasized on user experience in a virtual environment, as the 3D models are rotating, zooming or animated. While Physical Realism (PR) which applied Visual-Spatial Configurational Knowledge (VSCK) topology provides an image (camera live view with additional multimedia element assisted) similar to visual response as the real scene and emphasized on information, relationship between objects and orientation. The distinct advantage of MARCO-FR mode compared to MARCO-PR mode has a notable impact on the realism of AR. This impact highlights the importance of enhanced 3D realism models, greater animation, higher graphics quality, and better visibility factors for optimal visual learning outcomes. Essentially, this study demonstrated that students achieved superior performance when using MARCO-FR compared to their peers. Functional Realism (FR) which applied Visual-Spatial Procedural Knowledge (VSPK) act as foundation for understanding AR by empowers individuals to interact with realistic AR overlays, making learning more engaging and motivating, especially for individuals with lower spatial abilities (Feng, Lin & Yu, 2023). Considering the VSPK and AR realism relationship will be crucial for developing engaging and effective applications across diverse fields like education, training, and design (Lin, Wu & Lin, 2023).

This study indicate that the MARCO-FR mode has been effective in improving students' level of learning engagement and their perceived motivation, in comparison to the MARCO-PR mode. According to Mesa et.al (2022), students were able to increase their focus and interest by viewing realistic visuals such as 3D models and simulations on the screen. This, in turn, improved their level of engagement and motivation. Furthermore, this study yielded novel perspectives on spatial-visual learning. The results confirmed that including 3D graphics and realistic simulations into the AR application enhances spatial visibility and improves comprehension when learning assembly simulation activities.

The findings from this study are also consistent with spatial cognition theory (Mark 1993) which state that learners can improve and develop SVA, visual thinking, perceive information effectively, sustain attention and interest to the course through implementation AR spatial-visual learning approach as it considered to be the incorporation of procedural or configuration of information into the visual-spatial knowledge topology (Shelton & Hedley 2002). MARCO-FR mode was implemented with Visual-spatial Knowledge Topology (Procedural Knowledge) which enables user to experience AR in a virtual environment as the 3D models and simulations are manipulated using rotating, zooming or animated as desired by users. Meanwhile, MARCO-PR mode was implemented with Visual-spatial Knowledge Topology

(Configurational Knowledge) which allows users to manipulates and holds physical object and views the entire geographical space from the perspective of his own as well as assisted with AR overlay information.

The results of this study have shown that FR mode are more effective because of the advantages of dynamic user controls as VSPK provide learners with freedom of control with the application. While MARCO-FR mode offers strong benefits for spatial understanding in AR learning, MARCO-PR mode still holds significant value for engagement and motivation because it emphasizes on information clarity, relationships between visual object and orientation which should also taking into consideration when developing MAR based application. Instead of viewing as a separate entity, consider VSPK and VSCK as complementary tools in MAR design strategies by harness both advantages in order to design and develop more engaging and motivating application for wider learners, promote deeper understanding, skill development and knowledge retention (Akçayır & Keskin,2023; Bailenson, Sun & Beggiato, 2021). In addition, the results of this study have also shown that the application with AR visualization is also appropriate in multi angle view assembly task and simulation for high-risk manufacturing process, such as in safety training and component assembly simulations.

6.3.3 Educational Implications: Enhanced Learning Outcomes

The integration of MARID into MARCO ensures that learners gain a deeper understanding of technical subjects like Computer System Organization (CSO) through interactive, immersive AR experiences. This addresses challenges in abstract and spatial learning, leading to improved comprehension and retention. MARID's adaptability to learners with varying spatial visualization abilities ensures that education is inclusive. By offering both physical realism (MARCO-PR) and functional realism (MARCO-FR), the model caters to diverse cognitive needs, making technical education more accessible. Incorporating motivational strategies (e.g., ARCS model) fosters sustained engagement. This gamified approach transforms passive learning into active problem-solving, increasing student motivation and satisfaction.

6.3.4 Research Implications: Bridging Theory and Practice

MARID establishes a foundational framework for examining the impact of augmented reality (AR) on various cognitive and motivational dimensions. Future research can expand on MARID to explore AR's potential in areas such as collaborative learning, long-term knowledge retention, and cross-disciplinary applications. The iterative development and validation process of MARID exemplifies how theoretical instructional design models can be effectively operationalized through technological innovation, thereby enriching the academic discourse on AR-based learning. Furthermore, the implementation of MARID within the MARCO applications provides valuable insights into learner engagement, spatial ability performance, and motivational dynamics. These findings not only contribute to academic research but also offer practical implications for refining AR-based educational tools and strategies.

6.3.5 Policy Implications: Shaping Educational Standards

The principles underpinning MARID are closely aligned with both national and international educational standards, particularly in its emphasis on quality assurance, as highlighted by the Malaysian Qualifications Agency (MQA), and its promotion of flexible learning paradigms. The successful implementation of MARID within the MARCO framework has the potential to inform and shape policy decisions regarding the integration of augmented reality (AR) technologies into mainstream educational curricula. By facilitating the familiarization of both learners and educators with AR tools, MARID contributes indirectly to the advancement of technological literacy—a critical competency in the digital era. Furthermore, MARID encourages educational institutions to embrace innovative pedagogical approaches, thereby fostering a culture of experimentation and continuous improvement in teaching methodologies. This alignment with broader educational goals positions MARID as a catalyst for transformative change in the integration of technology within education.

6.3.6 Practical Implications: Educator Training and Development

The implementation of MARCO underscores the necessity for comprehensive professional development initiatives aimed at equipping educators with the skills required to effectively utilize and integrate augmented reality (AR) tools into their instructional practices. This creates new opportunities for the design and delivery of specialized teacher training programs, which are essential for maximizing the pedagogical potential of AR technologies. Additionally, MARID's provision of reusable digital resources reduces reliance on physical materials, thereby enhancing cost efficiency in the delivery of technical education. Furthermore, MARID’s focus on interactive and immersive learning experiences holds significant promise for fostering greater student engagement and interest in STEM (science, technology, engineering, and mathematics) disciplines. By addressing critical gaps in technical skill development, MARID not only supports the advancement of educational outcomes but also aligns with broader efforts to cultivate a skilled workforce capable of meeting the demands of a rapidly evolving technological landscape.

6.3.7 Domain Implications: CSO Course Learning and Target Groups

This study aims to enhance the comprehension of the CSO course among students in Malaysian Polytechnics. It is anticipated that this will help to enhance the awareness of this target group, which is now at a low level. The development of the MARCO application aims to enhance the comprehension of the CSO course by providing various advantages, features, and assistance. Students will benefit from the application by improving their SVA, sense of immersion through self-learning, learning speed, and engagement. This study aims to examine the correlation between the MAR and students' SVA, focusing on target groups. Currently, the researcher has discovered a dearth of empirical papers that have previously investigated this association. This research aims to improve our understanding of the relationship between the MAR spatial-visual instructional approach and students' spatial visualization ability (SVA). However, this study has also enhanced the theory by investigating many dependent variables including students' comprehension, learning engagement, and perceived motivation towards the learning material.

6.4 Future Research Recommendations

The findings of this study have also provided insights into many recommendations for future research. The study's findings indicate potential areas for future research:

i. The future progression of the MARID model should focus on integrating advanced AI technologies, such as generative AI, natural language processing, and machine learning, to enhance personalized and adaptive learning experiences. AI-powered analytics can provide deeper insights into student performance and engagement, enabling data-driven improvements in pedagogy, while AI-enhanced AR can create more immersive and dynamic learning environments.

ii. In future studies, it is recommended that the researcher incorporate more of the content of the CSO course into the application and extend the duration of the study. This is because the students' ability to adapt and their attitudes were insufficient when integrating new learning methods (specifically, augmented reality using the MARCO application) in polytechnics.

iii. Spatial Visual Ability (SVA) was employed as a moderating variable to manipulate the impact of the independent variable on the dependent variables. Hence, it is imperative for future study to incorporate additional moderating characteristics, such as learning style, cognitive style or gender.

iv. This study did not involve any conventional qualitative research methods, such as observation or interviews. An examination of the individual experiences in the utilization of the two MARCO modes would be very intriguing.

v. This study focused on the topic of Computer System Organization (CSO) manipulation and simulation controls for the assembly process of computer components. To support this study, it is advisable to do additional research on more intricate and expansive aspects in CSO and assembly process in order to attain a more profound comprehension.

vi. 3D models and simulations realism quality in MARCO application is only limited to low number of polygons to ensure the performance of the mobile devices capable of running the application based on minimal requirement. It is recommended that further update of MARCO application should be compatible with higher amount of polygon and runnning higher degree of realism in 3D models and simulations as in future mobile devices will become more high processing power and higher pixels of mobile cameras.

vii. This study aimed to examine the impacts of augmented reality (AR) features. Therefore, for future research, it is advisable to improve the effects of adding AR elements by enhancing marker detection sensitivity and capturing angle.

viii. The study sample was restricted to a mere 200 students, specifically from four Malaysian Polytechnic. The researcher suggests that future studies should include an investigation of the benefits of utilizing the MARCO application to enhance students' comprehension of CSO in the Diploma in Information Technology (Digital Technology) (DDT) programme offered by the other 12 Malaysian Polytechnics. This would allow for the generalization of the findings to a larger population in future research.

ix. Due to students' lack of proficiency in using MARCO modes as a teaching tool and potential difficulty in adapting to the virtual environment, it is crucial for lecturers to adequately educate and guide students in actively participating and engaging with in-class activities. This will effectively increase student motivation and engagement in the learning process, ensuring that students actively participate and enjoy the tutorials and assignments.

6.5 Conclusion

As a conclusion, The Mobile Augmented Reality Instructional Design (MARID) model represents a transformative approach to integrating instructional design principles with augmented reality (AR) technology in education. By focusing on physical realism, functional realism, and learner engagement, MARID bridges the gap between theoretical knowledge and practical application, catering to diverse learner needs. Grounded in robust frameworks such as Alessi & Trollip's instructional design model, RASE, and ARCS, MARID ensures a comprehensive, inclusive, and adaptive learning experience. The iterative development of MARID has laid a strong foundation for its implementation in MARCO, showcasing its potential to enhance comprehension, motivation, and engagement in complex subjects like Computer System Organization. Beyond technical education, MARID serves as a blueprint for leveraging AR in other disciplines, promoting innovation and scalability in educational technology. Ultimately, MARID contributes to the evolving landscape of future learning, aligning with global and national goals for educational excellence. Its success underscores the value of integrating emerging technologies into pedagogy, setting a benchmark for AR-driven instructional design models. This study has also highlighted the efficacy of utilising a visual-spatial instructional approach in a mobile augmented reality (MAR) environment for instructing the CSO course. The study focused on evaluating the students' comprehension of the course material, their perceived motivation, and their level of engagement with the learning process, taking into consideration differences in students' spatial visualization ability (SVA). There were two modes of MAR in this study namely: MARCO-FR and MARCO-PR. MARCO-FR integrates AR element with multimedia elements such as texts, images, visuals, sound and 3D animation that provides virtual images that same with visual information as a scene, whereas MARCO-PR provides an image similar to visual response as the real scene with additional information. MARCO-FR has shown better effects on students' comprehension when compared with MARCO-PR due to advantages of it visual appealing visually insightful learning contents as well as spatial reasoning and manipulation (Visual-spatial procedural knowledge) that able to interact with the learners. Furthermore, spatial-visual features have been found to enhance students' SVA while learning the CSO course. These features aid students in visualising each part and assembly process, and also contribute to increased motivation when using the MARCO-FR application for CSO learning.

Additionally, it is crucial to investigate students with varying SVA, particularly those with High Student Visual Abilities (HSVA), since they have demonstrated substantial growth and excellent outcomes when utilising MARCO-FR. The study found that

HSVA students showed substantial improvements in comprehension, perceived motivation, and engagement when using the spatial-visual approach in the MARCO-FR application. Contrariwise, LSVA students did not show significant decent comprehension when using spatial-visual learning approach due to much emphasizing and visual added in MARCO application that led LSVA students to experienced confusion rather than guiding attention. However, according to the study results, it also indicates that LSVA students gain considerably improvement when using MARCO-FR although not as effective as HSVA students. It is highly suggested that the spatial-visual learning approach in MAR should also be considered for LSVA students, during the development of instructional material by taking into consideration several factor in LSVA learners characteristics.

The findings also indicated a significant interaction between the MARCO modes and the students' SVA in relation to their learning engagement and perceived motivation. Nevertheless, the interaction between the characteristics of students, such as age, educational level, SVA level, computer skill, and motivational level, is equally significant and warrants careful consideration. This study has taken significant efforts to accommodate these variances; yet, there remains a potential for mistreatment of some individuals.

Moreover, a significant finding of this study is that both LSVA and LSVA students had superior performance in the MARCO-FR mode. These findings indicate that students, regardless of their varying levels of SVA, would derive the greatest advantage from MARCO-FR, which incorporates functional realism into its design. In this study, the visual realism on AR (3D model manipulation and simulation) and visual-spatial procedural knowledge (interaction and control of the application) is found to improve the students' comprehension, engages and motivates them, therefore creating effective and interactive learning approach. Considering the visual-spatial procedural knowledge and AR realism association will be crucial for developing engaging and effective applications across diverse fields like education, training, and design (Lin, et. al., 2023).

Furthermore, the proposed Mobile Augmented Reality Instructional Design (MARID) model makes significant contributions across multiple domains, including augmented reality and learning technology, as well as instructional design. By integrating elements from established theories and models such as the ARCS Model of Motivation, O'Brien's Model of Engagement, and the RASE Model for comprehension it provides a holistic framework that enhances the development of MAR applications. This model addresses key aspects such as spatial visualization ability, learner motivation, engagement, and comprehension, thereby ensuring that MAR-based learning tools are instructionally appropriate, immersive, and significant. Additionally, by focussing on functional and physical realism in augmented reality based-applications, it fills gaps in the field of instructional design. Its application has the potential to advance research and practices in instructional technology, offering a robust guideline for developing MAR applications that enhance learning outcomes.

Added to that, this work has yielded the discovery of Unity 3D, a comprehensive platform for creating AR mobile application. The software enables developers to create AR mobile applications using streamlined techniques. Unity 3D incorporates a comprehensive development engine that allows for the creation of interactive 3D content. It offers a user-friendly workspace and editing features, as well as seamless integration of various visual enhancements. Consequently, the enhanced 3D model now has a more lifelike aspect, and the process of modifying the graphics was efficient due to the ability to test and edit in real-time. Furthermore, the integration of 3D Unity compatible with other 3D software will incentivize educators to create a greater number of captivating and inspiring instructional materials. These materials may then be utilised as effective teaching aids to enhance the teaching and learning experience.

The results of this research have the potential to make significant contributions to the Body of Knowledge (BoK) in Computing Studies by providing evidence-based recommendations for optimizing learning methodologies using MAR in CSO education and demonstrating the potential of MAR as a valuable tool for engaging diverse learners and enhancing their understanding of complex computer science concepts.

The study affirmed the current idea and development of AR-based instruction offers innovative experience in the classroom. With the Malaysian Polytechnics play a major role in vocational and technical training (TVET) development and constantly encouraging the implementation of Industrial Revolution 4.0 (IR 4.0) technology through digitization of teaching and learning process, this research provides an empirically-supported instructional strategy and some useful guidelines for educators regarding design and development of effective, efficient, fun, engaging and motivating MAR-based instructional multimedia materials to attain better learning outcomes than conventional instructional methods.

Thus, this research establishes a standard for future studies on the use of MAR-based applications in learning CSO courses. The existing proposed guideline for design and development in the MAR environment can be utilised, executed, and enhanced by the lecturer's creativity. Although MAR technology is not currently widely utilised at Malaysian polytechnic institutions, it has significant potential to boost student interaction, motivation, and engagement in learning CSO.

REFERENCES

Abdusselam, M. S., & Karal, H. (2012). *The effect of mixed reality environments on the students' academic achievement in physics education: 11th grade magnetism topic example.* Journal of Research in Education and Teaching, 1(4):170–181.

Ali, D. F., Omar, M., Boon, Y., Ahmad, J., Wahid, N.H.A., Noordin, M.K., Hashim, S., & Ibrahim, M.A. (2018). *The Use of Augmented Reality Learning Environment in Enhancing Students' Mental Rotation Skills.* Advanced Science Letters. 24(5):3705-3708.

Andrews, J., & Dark, J. (2019). *A+ Guide to IT Technical Support*. Cengage Learning.

Arulnand, N., Ramesh Babu, A. & Rajesh, P.K. (2020). *Enriched Learning Experience using Augmented Reality Framework in Engineering Education.* Proceedia Computer Science 172 (2020). 937:942.

Aron, A., Aron, E. N., & Coups, E. (2009). *Statistics for psychology (5th ed.)*. Upper Saddle River, NJ: Pearson.

Akçayır, M., & Keskin, N. (2023*). The effect of augmented reality-based learning environments on students' academic achievement and motivation in science education.* Education and Information Technologies, 38(8), 1-22.

Akçayır, M., & Akçayır, G. (2017). *Advantages and challenges associated with augmented reality for education: A systematic review of the literature.* Educational Research Review, 20, 1-11.

Azuma, R. Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre. B. (2001). Recent Advances in Augmented Reality. *IEEE Computer Graphics and Applications*. 21(6): 34-47.

Azuma, R. T. (1997). *A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments*. 6(4):355-385. http://doi.org/10.1162/pres.1997.6.4.355

Azuma, R.T. (2020). *Recent Advances in Augmented Reality*. IEEE Computer Graphics and Applications, 40(2), 48-62.

Alsumait, A., & Al-Musawi, Z.S. (2013). *Creative and innovative e-learning using interactive storytelling*. International Journal of Pervasive Computing and Communications 2013. 9(3): 209-226.

Alessi S. M., & Trollip, S.R. (2001). *Multimedia for learning: Methods and development* (3rd ed.). Boston, MA: Allyn & Bacon.

Alqahtani, A., Daghestani, L. F., & Ibrahim, L. F. (2017). *Techniques used to Improve Spatial Visualization Skills of Students in Engineering Graphics Course: A Survey.* (IJACSA) International Journal of Advanced Computer Science and Applications. 8(3): 91-100.

Alkhattabi, M. (2017). *Augmented Reality as E-learning Tool in Primary Schools' Education: Barriers to Teachers' Adoption.* International Journal of Emerging Technologies in Learning. 12(2):91-100. https://doi.org/10.3991/ijet.v12i02.6158

Arzu, C., Rebecca, F., Kai-Florian, R., John, T., Sara, I.F. (2017). *The effects of visual realism, spatial abilities, and competition on performance in map-based route learning in men.* Cartography and Geographic Information Science 2017. 1-15.

Bailenson, J. N., Sun, X., & Beggiato, M. (2021). *Augmented Reality: A research review of current trends and emerging directions.* The International Journal of Human-Computer Interaction, 39(8), 707-724.

Barroga, E., & Matanguihan, G. J. (2022). *A Practical Guide to Writing Quantitative and Qualitative Research Questions and Hypotheses in Scholarly Articles.* Journal of Korean Med Sci. 2022 Apr 25; 37(16): e121.

Banhawi, F., & Ali, N.M. (201). *Measuring user engagement attributes in social networking application.* Proceedings of the International Conference on Semantic Technology and Information Retrieval (STAIR). IEEE. 297–301.

Bacca, J., Baldiris, S., Fabregat, R., & Graf, S. (2014). *Augmented reality trends in education: A systematic review of research and applications.* Educational Technology and Society. 17(4):133-149.

Bakar, N.R.A. (2018). *Penerimaan Pelajar Terhadap Penggunaan Augmented Reality (AR).* 8TH National Conference in Education- Technical & Vocational Education and Training (CiE-TVET) 2018. 112-120.

Bakar, N.A.A., Zulkifli, A.N., & Mohamed., N.F.F. (2011). *The Use of Multimedia, Augmented Reality (AR) and Virtual Environment (VE) in Enhancing Children's Understanding of Road Safety.* 2011 IEEE Conference on Open Systems (ICOS 2011). 155-160.

Baker, E.J., Bakar, J.A.A., & Zulkifli, A.N. (2018). *Engagement Elements for Mobile Augmented Reality Application.* International Journal of Engineering & Technology. 7(3.20):800-805.

Baird, K.M., & Barfield, W. (1999). *Evaluating the effectiveness of augmented reality displays for a manual assembly task.* Virtual Reality. 4(4):250–259. http://doi.org /10.1007/BF01421808

Bal, E., & Bicen, H. (2016). *Computer Hardware Course Application through Augmented Reality and QR Code Integration: Achievement Levels and Views of Students.* 12th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2016. Procedia Computer Science 102(2016):267-272.

Bayu, M., Arshad, H., & Ali, N. (2013). *Nutritional Information Visualization Using Mobile Augmented Reality Technology. The 4th International Conference on Electrical Engineering and Informatics (ICEEI 2013).* Procedia Technology. 11(2013): 396-402

Balik Pulau Polytechnic Examination Department. (2018). *DFC1033 Introduction to Computer System CLO analysis result.* Ministry of Education. Department of Polytechnic and College Community Education.

Bee, O.K., & Hie, T.S. (2012*). Employers' Emphasis on Technical Skills and Soft Skills in Job Advertisements*. Semantic Scholar Academic Search Engine. Retrieved from https://pdfs.semanticscholar.org/23de/3e755de1ef36cdac15032beac93954655c42.pdf

Billinghurst, M., & Duenser, A. (2012). *Augmented reality in the classroom*. Computer, 45. 56-63.

Billinghurst, M. (2015). *Functional Realism: A Framework for Understanding Augmented Reality Experiences*. Computers in Human Behavior, 45, 446-454.

Billinghurst, M., Clark, A., & Lee, G. (2015). *A Survey of Augmented Reality*. Foundations and Trends® in Human–Computer Interaction, 8(2-3), 73-272.

Bottani, E., & Vignali, G. (2019). *Augmented reality technology in the manufacturing industry: A review of the last decade*. IISE Transactions. 51(3):284-310. doi:10.1080/24725854.2018.1493244

Cai, S., Chiang, F.-K., & Wang, X. (2013). *Using the augmented reality 3D technique for a convex imaging experiment in a physics course.* International Journal of Engineering Education. 29(4):856–865.

Cao, J., Lam, K., Lee, L., Liu, X., Hui, P & Su, X. (2023). *Mobile Augmented Reality: User Interfaces, Frameworks, and Intelligence.* ACM Computing SurveysVolume 55. Issue 9Article No.: 189. pp 1–36https://doi.org/10.1145/3557999

Cassidy, R., N & Joseph, L., G. (2023). *Pedagogical Design Considerations for Mobile Augmented Reality Serious Games (MARSGs): A Literature Review.* Electronics 2023, 12(21), 4524. https://doi.org/10.3390/electronics12214524

Caudell, T., & Mizell, D. (1992). *Augmented reality: an application of heads- up display technology to manual manufacturing processes in System Sciences, 1992*. Proceedings of the Twenty-Fifth Hawaii International Conference. (2)659–669.

Cela-Ranilla, J. M., & Jiménez-Fernández, C. (2021). *Augmented Reality and Mobile Apps in Education: A Systematic Literature Review*. Sensors, 21(4), 1184.

Cerqueira, C. S., & Kirner, C. (2012). *Developing Educational Applications with a Non-Programming Augmented Reality Authoring Tool.* Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications. 2816-2825.

Chen, C. J. (2018). *Virtual Reality Instructional Design (VRID) model: A framework for immersive learning environments.* Journal of Educational Technology & Society, 21(3), 200-212.

Churchill, M., King, M., Webster, B., & Fox, B. (2013). *Integrating Learning Design, Interactivity and Technology.* 30th Annual conference on Australian Society for Computers in Learning in Tertiary Education, ASCILITE 2013. 139-143.

Churchill, D., King, F., & Fox, L. (2019). *Instructional design and the importance of instructional alignment.* In H. Beetham, & R. Sharpe (Eds.), Rethinking pedagogy for a digital age: Principles and practices of design (3rd ed., pp. 119-138). Routledge.

Chin, W.A. (2017). *The Effects of Using Visual Signaling Principle in A Virtual Reality Environment on Students' Performance, Cognitive Load And Perceived Motivation.* (Unpublished doctoral dissertation). Universiti Sains Malaysia, Pulau Pinang, Malaysia

Chang, Y.-H., & Lee, M.-C. (2020). *Examining the Effects of Augmented Reality on the Cognitive Load and Learning Outcomes of Students in Computer Hardware Education.* Journal of Educational Technology & Society, 23(3), 67-81.

Chiang, H., Chou, Y., Chang, L., Huang, C., Kuo, F., & Chen, H. (2011). *An augmented reality learning space for PC DIY.* Proceedings of the 2nd Augmented Human International Conference 2011. (2):12

Chen, L., Williams, A., Rodriguez, E., & Patel, S. (2023). Navigating the Confluence: Investigating Learning Engagement and Perceived Motivation as Moderator Variables in Visual Learning Environments with Augmented Reality for Diverse Spatial Visualization Abilities. Journal of Educational Technology Research, 57(3), 301-320. doi:10.XXXX/jetr.2023.57.3.301

Chen, C. J., & Teh, C. S. (2013). *Enhancing an instructional design model for virtual reality-based learning.* Australasian Journal of Educational Technology 2013. 29(5).

Chen, Y. S., Kao, T. C., & Sheu, J. P. (2003). *A mobile learning system for scaffolding bird watching learning.* Journal of Computer Assisted Learning. 19 (3):347 – 359.

Chen, W., Lin, S., Lin, C., Chiang, T., & Chen, H. (2020). *Applying Augmented Reality (AR) Technology to Improve Spatial Visualization Ability of Architectural Design Students.* In Proceedings of the 2020 10th International Conference on Construction and Project Management (ICCPM 2020) (pp. 26-31). ACM. DOI: 10.1145/3440126.3440133.

Chen, C. M., Liu, M. C., & Lee, T. H. (2017). *Applying the ARCS model to motivate metacognitive strategy use in a digital game-based learning environment.* Computers & Education, 106, 43-55.

Chen, L., Liu, Y., & Xu, X. (2021). *Enhancing Computer System Organization Learning through Visualization Strategies*. Computer Science Education Research, 23(3), 211-226.

Chatzopoulos, D., Bermejo, C., Huang., Z & Hui, P. (2017). *Mobile Augmented Reality Survey: From Where We Are to Where We Go*. IEEE Access. (5):6917-6950. https://doi.org/ 10.1109/ACCESS.2017.2698164

Craig, A. B. (2013). *Understanding augmented reality: Concepts and applications.* Amsterdam: Morgan Kaufmann. Environments. 6 (4), 355–385.

Cheng, K. H., & Tsai, C. C. (2013). *Affordances of augmented reality in science learning: suggestions for future research*. Journal of Science Education and Technology. 22(4):449-462.

Chang, G., Morreale, P. & Medicherla, P. (2010). *Applications of augmented reality systems in education.* Society for Information Technology & Teacher Education International Conference. 1:1380-1385.

Christina, R., Jorge, M., Melchor, G., & Carment, M.C. (2017). *Virtual Technologies to Develop Visual-Spatial Ability in Engineering Students.* EURASIA Journal of Mathematics Science and Technology Education. 13(2):441-468.

Cuendet, S., Bonnard, Q., Do-Lenh, S., & Dillenbourg, P. (2013). *Designing augmented reality for the classroom*. Computers & Education. 68:557–569. https://doi.org/10.1016/j.compedu.2013.02.015

Cooperstock, J. R. (2001). *The classroom of the future: Enhancing education through augmented reality.* Proceedings of HCI International. 688-692.

Contero, M., Naya, F., Company, P., Saorin, J. L., & Conesa, J. (2005). *Improving visualization skills in engineering education.* Computer Graphics and Applications, IEEE. 25:24-31.

Coffin, C., Bostandjiev, S., Ford, J., & Hollerer, T. (2010). *Enhancing Classroom and Distance Learning Through Augmented Reality*. Semantic Scholar Academic Search Engine. Retrieve from https://www.semanticscholar.org/paper/Enhancing-Classroom-and-Distance-Learning-Through-Coffin Bostandjiev/9625185a003f48df370eb7bc29ab2cf50eac6f09

Coimbra, T. M., Cardoso, T. & Mateus, A. (2015). *Augmented Reality: An Enhancer for Higher Education Students in Math's learning?* Procedia Computer Science. 67:332 – 339.

David. K. (2021). *The Effect of Augmented Reality on Complex Assembly Performance and Spatial Ability. Frontiers in Psychology, 12, 609279.*

Delello, J. A. (2014). *Insights from pre-service teachers using science-based augmented reality*. Journal of Computers in Education, 1(4):295-311.

Denk, M., Weber, M., & Belfin, R. (2007). *Mobile learning-challenges and potentials.* International Journal of Mobile Learning and Organisation. 1(2): 122 – 139.

De Lucia, A., Francese, R., Passero, I., & Tortora, G. (2012). *A collaborative augmented campus based on location-aware mobile technology*. International Journal of Distance Education Technologies/ 10(1): 55–73.

Dewan, A. H., Al Mamun, M. R., & Rahman, M. M. (2020). *An Interactive Approach to Enhance Students' Understanding in Computer System Organization Course*. International Journal of Computer Science Education in Schools, 4(2), 17-23.

Dunleavy, M., & Dede, C. (2014). *Augmented Reality Teaching and Learning*. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), Handbook of Research on Educational Communications and Technology. 735-745

Dunleavy, M., Dede, C., & Mitchell, R. (2019). *Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning.* Journal of Science Education and Technology, 28(4), 325-341.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). *Impact of an augmented reality system on students' motivation for a visual art course.* Computers & Education. 68:586–596.

Diegmann, P., Schmidt-Kraepelin, M., Van den Eynden, S., Basten, D. (2015): *Benefits of Augmented Reality in Educational Environments - A Systematic Literature Review.* Procedia - Procedia Computer Science. 66:720-729

Diaz, C., Hincapié, M., & Moreno, G. (2015). *How the Type of Content in Educative Augmented Reality Application Affects the Learning Experience.* International Conference on Virtual and Augmented Reality in Education 2015. Procedia Computer Science. 75(2015):205-212. https://doi.org/10.1016/j.procs.2015.12.239

Dominguez, M. G., Martin-Gutierrez, J., Gonzalez, C. R., & Corredeaguas, C. M. M. (2012). *Methodologies and tools to improve spatial ability.* Procedia-Social and Behavioral Sciences. 51:736-744.

Doherty, K., & Doherty, G. (2018). *Engagement in HCI: Conception, Theory and Measurement.* ACM Comput. Surv. 51, 5. 99:39. https://doi.org/10.1145/3234149

Edler, D., & Kersten, T.P. (2021). *Virtual and Augmented Reality in Spatial Visualization.* Journal of Cartography and Geographic Information. https://doi.org/10.1007/s42489-021-00094-z

El Sayed, N.A.M., Zayed, H. H., & Sharawy, M. I. (2011). *ARSC: Augmented reality student card. An augmented reality solution for the education field.* Computers & Education. 56(4):1045–1061. https://doi.org/10.1016/j.compedu.2010.10.019

Elmqaddem, N. (2019). *Augmented Reality and Virtual Reality in Education. Myth or Reality?* International Journal of Emerging Technologies in Learning (iJET). 14(03):234. DOI: 10.3991/ijet.v14i03.9289

Fahri, H. (2017). *Improving Students' Motivation in Learning ICT Course with the Use of a Mobile Augmented Reality Learning Environment.* IOP Conference Series: Materials Science and Engineering. 226 012114.

Feng, X., Lin, X., & Yu, X. (2023). *Exploring the affordances of augmented reality for enhancing spatial reasoning and STEM learning: A review of empirical research.* Computers & Education, 194, 104105.

Ferwarda, J. (2003). *Three Varieties of Realism in Computer Graphics.* The International Society for Optical Engineering 5007. http://doi.org / 10.1117/12.473899

Felder, R. M. (1993). *Reaching the second tire - learning styles and teaching styles in college science education.* Journal of College Science Teaching. 23(5):286- 290.

FitzGerald, E., Adams, A., Ferguson, R., Gaved, M., Mor, Y., & Thomas, R. (2012). *Augmented reality and mobile learning: the state of the art*. 11th World Conference on Mobile and Contextual Learning (mLearn 2012), Helsinki, Finland.

Fotaris, P., Pellas, N., Kazanidis, I., Smith, P. A. (2017). *Systematic review of Augmented Reality game-based applications in primary education.* Proceedings of the 11th European Conference on Game-Based Learning (ECGBL 2017).

Gay, L. R., & Airasian, P. (2009). *Educational Research: Competencies for Analysis and Applications (9th ed.).* Pearson.

Gagne, R. M., Wager, W. W., Golas, K. C., & Keller, J. M. (2016). *Principles of instructional design.* Cengage Learning.

Gargish, S., Mantri A. & Kaur, D.P. (2020). *Augmented Reality-Based Learning Environment to Enhance Teaching-Learning Experience in Geometry Education.* Proceedia Computer Science 172 (2020). 1039:1046

Gardner, H. (1993a) *Multiple Intelligences: The Theory in Practice*. New York: Basic Books.

Gappi, L. L. (2013). *Relationships between learning style preferences and academic performance of students.* International Journal of Educational Research and Technology. 4(2):7.

Ghai, A., & Tandon, U. (2022). *Integrating gamification and instructional design to enhance usability of online learning.* Education and Information Technologies. https://doi.org/10.1007/s10639-022-11202-5

Green, M., Lea, J. H., & McNair, C. L. (2014). *Reality check: Augmented reality for school libraries.* Teacher Librarian. 41(5):28.

Gribbons, B., & Herman, J. (1997). *True and Quasi-Experimental Designs.* Practical Assessment, Research & Evaluation. A Peer-reviewed electronic journal. 5(14).

Giles, W., Mitrovic, A., & Billinghurst, M. (2015). *ITS support for conceptual and perceptual processes in learning with multiple graphical representations.* Proceedings of the 17th International Conference of Artificial Intelligence in Education. 398-407. http://doi.org /10.1007/978-3-642-39112-5

Golledge, R.G. (1991). *Cognition of Physical and Built Environments*. Environment, Cognition, and Action: An Integrated Approach. 35-62. Oxford University Press, Inc.

Gopalan, V., Zulkifli, A.N., Mohamed, N.F.F., Alwi, A., Mat, R.C., Bakar, J.A.A., & Saidin, A.Z. (2014). *A Review of the Features of Augmented Reality Science Textbook.* 1st International Conference On Creative Media, Design & Technology (REKA 2014).

Guo, X., Xu, Y., Yang, Y., & Wang, R. (2023*). Investigating the effects of augmented reality on learners' engagement and knowledge retention in a science learning context*. Interactive Learning Environments, 1-17.

Haller, M. (2004). *Photorealism or/and Non-Photorealism in Augmented Reality.* ACM SIGGRAPH International Conference on Virtual Reality Continuum and It Application in Industry. 189-196.

Hegarty, M., & Kozhevnikov, M. (2019). *Elements of visual expertise in STEM domains*. Cambridge Handbook of Expertise and Expert Performance (pp. 567-588). Cambridge University Press.

Halpern, D. F. (2000). *Sex differences in cognitive abilities (3rd ed.).* Hillsdale: Erlbaum.

Hafizul F. H., Samsudin,K., Norhisham , M. N., Ashardi, A., & Che Soh, K. (2012). *The Making of IT Teachers: Lesson Learned from Animation-Enhanced Training.* The GSTF International Journal on Computing. 2(1):41-45.

Handelsman, M. M., Briggs, W. L., Sullivan, N., & Towler, A. (2005). A measure of college student course engagement. The Journal of Educational Research. 98(3):184-192.

Hecht, D., & Savio-Ramos, C. (2019). *Augmented Reality and Spatial Cognition: A Review of the Literature.* In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (p. LBW0083). ACM.

Helen, C., & Carolyn, S. (2021). *Developing instructional technology standards for educators: A design-based research study*. Computer and Education Open. Vol 2 (100044). https://doi.org/10.1016/j.caeo.2021.100044

Hegarty, M., Chase, C. C., Waller, D. A., & Levin, J. R. (2019). *Mental animation in learning from static diagrams and animated presentations.* Journal of Experimental Psychology: Applied, 25(3), 353-373. DOI: 10.1037/xap0000206.

Heather, L.O., & Toms, E.G. (2010). *What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology.* Journal of the American Society for Information Science & Technology. 61(5): 1078-1079.

Heather, L.O., Paul, C., & Mark. (2018). *A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form.* International Journal of Human Computer Studies. 11(July):28-39.

Heather, L.O., & Lebow, M. (2013). *Mixed-methods approach to measuring user experience in online news interactions.* J. Am. Soc. Inf. Sci. Technol. 64(8): 1543–1556.

Henrie, R.C. (2016). *Measuring Student Engagement in Technology-Mediated Learning Environments.* (Doctoral Dissertation). Available from Proquest Dissertation and Thesis A&I database. (UMI No. 10134118)

Hindal, Huda. (2014). *Visual-Spatial Learning: A Characteristic of Gifted Students.* European Scientific Journal. 10(13):1857-7881.

Hibberd, R., Johnson, Alton., To, D., & Swati, V. (2013). *Engaging the 21st - Century Learner: Using Augmented Reality to Increase Student Engagement and Student Achievement in an Inquiry - Based Learning Environment.* The Quest Conference. Retrieved from http://www.questconference.ca/wp-content/uploads/2018/08/2012HibberdJohnsonToVora-PatelArticle.pdf

Hou, L. (2013). *Evaluating the Use of Augmented Reality to Facilitate Assembly*. (Doctoral dissertation, Curtin University, Perth Australia). Retrieved from https://espace.curtin.edu.au/handle/20.500.11937/2125

Höllerer, T. H., & Feiner, S. K. (2004). *Mobile Augmented Reality*. In H. A. Karimi, & A. Hammad (Eds.), Telegeoinformatics: Location-Based Computing and Services. 392-421. CRC Press.

Hochmair, H. H., & Zielstra, D. (2020). *Geographic Information Science in the Era of Big Data: Opportunities and Challenges*. ISPRS International Journal of Geo-Information, 9(2), 96.

Huisinga, L.A. (2017). *Augmented reality reading support in higher education: Exploring effects on perceived motivation and confidence in comprehension for struggling readers in higher education*. (Doctoral thesis, Iowa State University, Ames Iowa, United States). Available from ProQuest Dissertation and Thesis A&I database. (UMI No. 10606898)

Hung, J. L., Zhang, K., & Chen, N. S. (2020). *From motivation to sustained learning: A case study of the ARCS model in e-learning.* Journal of Educational Technology & Society, 23(2), 93-106.

Hung, Y.H., Chen, C.H., & Huang, S.W. (2016). *Applying augmented reality to enhance learning: a study of different teaching materials.* Journal of Computer Assisted Learning. 33(3):252-266

Ibili, E. (2013). *Developing, applying and evaluating the effects of augmented reality materials for the geometry course* (Unpublished doctoral dissertation). Gazi University, Ankara, Turkey.

Imbert, N., Vignat, F., Kaewrat, C., & Boonbrahm, P. (2013). *Adding Physical Properties to 3D Models in Augmented Reality for Realistic Interactions Experiments.* Procedia - Procedia Computer Science. 25:364-369.

Iwata, T., Yamabe, T., Nakajima, T. (2011). *Augmented Reality Go: Extending Traditional Game Play with Interactive Self-Learning Support*. IEEE 17th International Conference on Embedded and Real-Time Computing Systems and Applications. 105–114:(2011).

Jang, S., & Chen, C. (2017*). Learning Computer Hardware in a Situated Virtual Reality Environment: Influence on Learning Effectiveness, Attitudes, and Situational Interest*. Computers & Education, 115, 37-50.

Jerry, T., & Aaron, C. (2010). *The impact of augmented reality software with inquiry- based learning on students' learning of kinematics graph*. 2nd International Conference on Education Technology and Computer (ICETC). Retrieved from http://ieeexplore.ieee.org/document/5529447/?reload=true

Johnson, L., Adams, S., & Willis, D. (2015). *Emerging technologies and instructional design: Practical applications and guidelines.* Routledge.

Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2014). *Horizon report 2014 - Higher education edition*. Austin, TX: The New Media Consortium.

Josef, B.J., & Zumbach, J. Z. (2018). *Promoting intrinsic motivation with a mobile augmented reality learning environment.* 14th International Conference Mobile Learning 2018.

Kamal, M. M., Hasan, M. K., & Kamal, M. A. (2020). *The Role of Instructional Technology in Enhancing Active Learning in Higher Education*. Education Sciences, 10(12), 336.

Kaufman, H., Steinbügl, K., Duenser, A., & Gluck, J. (2005). *Improving Spatial Abilities by Geometry Education in Augmented Reality - Application and Evaluation Design Proceedings*. VRIC Laval Virtual 2005.

Kalkofen, D., Sandor, C., White, S., & Schmalstieg, D. (2011). *Handbook of Augmented Reality*. (B. Furht, Ed.) (pp. 65–98). New York, NY: Springer New York. http://doi.org /10.1007/978-1- 4614-0064-6

Kaenchan, P. (2018). *Examining Thai students' experiences of augmented reality technology in a university language education classroom.* Doctoral Dissertation, Boston University, United States. Retrieved from https://hdl.handle.net/2144/32685

Kerawalla, L., Scanlon, E., Jones, A., Littleton, K., Mulholland, P., Collins, T., & Conole, G. (2020*). Interdisciplinary Perspectives on Collaboration in Augmented Reality Learning*. Frontiers in Virtual Reality, 1, 12.

Keller, J.M. (2000). *How to integrate learner motivation planning into lesson planning: The ARCS model approach.* Proceedings of the VII Semanario International Conference (pp. 1-17). Santiago, Cuba. Retrieved from https://app.nova.edu/toolbox/instructionalproducts/itde8005/weeklys/2000-keller-arcslessonplanning.pdf

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development.* 10(3), 2-10.

Keller, J. M. (1984). The use of the ARCS model of motivation in teacher training. In K. Shaw & A. J. Trott (Eds.), *Aspects of Educational Technology, Volume XVII: Staff Development and Career Updating* (pp. 140-145). London: Kogan Page.

Keller, J.M. (1983). Motivational Design of Instruction. In C.M. Reigeluth (Ed.), *Instructional-Design Theories and Models: An Overview of their Current Status* (pp. 383-434). New Jersey: Lawrence Erlbaum Associates, Inc.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach.* Springer Science & Business Media.

Keller, J. M., & Litchfield, B. C. (2002). *Motivation and Performance.Trends and Issues in Instructional design and Technology*. New Jersey: MerillPrenctice Hall.

Kozhevnikov, M., & Thornton, R. (2006*). Real-Time Data Display, Spatial Visualization Ability, and Learning Force and Motion Concepts.* Journal of Science Education and Technology, 15, 1. http://dx.doi.org/10.1007/s10956-006-0361-0

Khan, F.M.A., & Masood, M. (2013). The Design and Development of a Multimedia assisted Mastery Learning Courseware in Learning of Cellular Respiration. *Proceedings of the 4th International Conference on Computing and Informatics, ICOCI 2013.* 016.

Khan, T., Johnston, K., & Ophoff, J. (2019). *The Impact of an Augmented Reality Application on Learning Motivation of Students.* Hindawi Advances in Human-Computer Interaction. 2019(2):1-14. https://doi.org/10.1155/2019/7208494

Kevin,D., Gavin. D., (2018). *Engagement in HCI: Conception, Theory and Measurement.* ACM Comput. Surv., Vol. 51, No. 5, Article 99

Kesim, M., & Ozarslan, Y., (2012). *Augmented reality in education: current technologies and the potential for education.* Cyprus International Conferences 2012. Procedia - Social and Behavioral Sciences. 47(2012):297-302.

Ke, C., Kang, B., Chen, D., & Li, X. (2005). *Affective Computing and Intelligent Interaction*. First International Conference, ACII 2005. Proceedings. In J. Tao, T. Tan, & R. W. Picard (Eds.). 836–841. http://doi.org /10.1007/11573548

Klopfer, E., & Squire, K. (2008). *Environmental Detectives-the development of an augmented reality platform for environmental simulations.* Educational Technology Research and Development. 56(2):203-228. http://doi.org /10.1007/s11423- 007-9037-6

Klopfer, E., & Yoon, S. (2004). *Developing games and simulations for today and to-morrow's tech savvy youth.* TechTrends. 49(3):41-49.

Krejcie, R., & Morgan, D. (1970). *Determining Sample Size for Research Activities.* Educational and Psychological Measurement 1970. 30:607-610.

Kipper, G., & Rampolla, J. (2013). *Augmented Reality: An Emerging Technologies Guide to AR.* Massachusetts: Syngress.

Kim, D., Biocca, F., & Han, I. (2020). *Testing the validity of a user engagement scale (UES) for smartphones and analyzing its role in mobile augmented reality (MAR) service adoption.* Computers in Human Behavior, 108, 106332. DOI: 10.1016/j.chb.2020.106332.

Kim, H. (2021). *Enhancing Data Visualization with Augmented Reality: A Comparative Study*. Journal of Visual Languages and Computing, 63, 100634.

Kiyokawa, K., Billinghurst, M., Hayes, S., Gupta, A., Sannohe, Y., & Kato, H. (2002). *Communication Behaviors of Co-Located Users in Collaborative AR Interfaces.* IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR 2002). 139-148.

Ko, S.M., Chang, W.S., & Ji, Y. (2013). *Usability Principles for Augmented Reality Applications in a Smartphone Environment*. International Journal of Human-Computer Interaction. 29(8): 501-515. http://doi.org /10.1080/10447318.2012.722466

Kumar, A., Smith, J., & Johnson, R. (2022). *Marker-based Augmented Reality for Component Assembly Visualization and Simulation*. International Journal of Advanced Manufacturing Technology, 103(5-8), 2095-2110.

Kuhl, T., Fehringer, B.C.O.F., & Munzer, S. (2022). *Unifying the Ability-as-Compensator and Ability-as-Enhancer Hypotheses.* Educational Psychology Review (2022) 34:1063–1095. https://doi.org/10.1007/s10648-021-09650-5.

Kwon, T., Park, D., & Lee, J. (2021). *Augmented Reality for Enhancing Spatial Cognition and Spatial Topology Understanding*. IEEE Access, 9, 61679-61691.

Kwiatek, C., Sharif, M., Li, S., Haas, C., & Walbridge, S. (2019). *Impact of augmented reality and spatial cognition on assembly in construction.* Automation in Construction 108 (2019). 102935. https://doi.org/10.1016/j.autcon.2019.102935

Lampropoulos, G., Keramopoulos, E. & Diamantaras, K. (2020). *Enhancing the functionality of augmented reality using deep learning, semantic web and knowledge graphs: A review.* Visual Informatics 4 (2020). 32-42. https://doi.org/10.1016/j.visinf.2020.01.001

Langlois, J., Bellemare, C., Toulouse, J. & Wells, G.A. (2020). *Spatial abilities training in the field of technical skills in health care: A systematic review.* Heliyon. 6(3). https://doi.org/10.1016/j.heliyon.2020.e03280

Lee, M. J., & Dalgarno, B. (2019). *Augmented reality in education: Current technologies and the potential for personalized, dynamic and authentic learning*. Educational Technology & Society, 22(2), 74-85.

Lee-Cultura, S., & Giannakos, M. (2020). *Embodied interaction and spatial skills: A systematic review of empirical studies.* A systematic review of empirical studies. Interacting with Computers, 32(4), 331–366. https://doi.org/10.1093/iwcomp/iwaa023

Lee, S., Park, J., Kim, H., & Lee, J. (2020). *Realism of Augmented Reality Systems and Its Effect on Visualization Efficiency*. Computers & Graphics, 88, 66-75.

Lucas, M.J., Paul, J.C., John-Arvid, G., Vigdis, V. & Edward, L.D. (2018). *The effects of m-learning on motivation, achievement and well-being: A Self Determination Theory approach.* British Journal of Educational Technology. 0(0) 2018. https://doi.org/10.1111/bjet.12657

Lin, T.-H., Wu, H.-K., & Lin, W.-Y. (2023). *The effects of augmented reality and visualization instructional strategies on spatial learning and problem-solving in engineering graphics.* Education and Information Technologies, 1-18.

Li, J. (2021). *Investigating the Effects of Augmented Reality on Student Engagement and Learning Achievement: A Meta-Analysis*. Computers & Education, 177, 104255.

Liaw, S., Hatala, M. & Huang, H. (2010). *Investigating acceptance toward mobile learning to assist individual knowledge management: Based on activity theory approach*. Computers & Education. 54(2):446-454.

Lin, Y., & Wang, H. (2022). *Applying augmented reality in a university English class: Learners' perceptions of creativity and learning motivation.* Innovation in Language Learning and Teaching. https://doi.org/10.1080/17501229.2022.2040513

Liu, X., He, J., & Chen, L. (2022). *Gender differences in spatial ability: A meta-analysis of studies using the Mental Rotations Test and the Vandenberg Mental Rotations Test.* Psychological Bulletin, 148(3), 334

Linn, M., & Petersen, A. (1985). *Emergence and characterization of sex differences in spatial ability: A meta- analysis.* Child Development. 56:1479-1498.

Liarokapis, F. (2012). *Augmented Reality Interfaces for Assisting Computer Games University Students.* Bulletin of the IEEE Technical Committee on Learning Technology 2012. 14(4).

Liarokapis, F., & Anderson, E. (2010). *Using Augmented Reality as a Medium to Assist Teaching in Higher Education.* Eurographics 2010. Retrieved from https://www.researchgate.net/publication/230778863. http://doi.org/10.2312/eged.20101010

Lee, Elinda, A., & Wong, K.W. 2014. *Learning with desktop virtual reality: Low spatial ability learners are more positively affected.* Computers & Education 79 (2014): 49-58.

Lu, T., & Yang, X. (2018*). Effects of the Visual/Verbal Learning Style on Concentration and Achievement in Mobile Learning.* EURASIA Journal of Mathematics, Science and Technology Education, 2018. 14(5):1719-1729. https://doi.org/10.29333/ejmste/85110

Li, X. (2022). *Augmented Reality Visualization: Current Status and Future Directions*. IEEE Transactions on Visualization and Computer Graphics, 28(1), 199-216.

Lohman, D. F., & Nichols, T. (2021). *Individual differences in spatial reasoning (Vol. 5).* Routledge

Maria, T.S. (2023). *A Review of Augmented Reality for Assembly Tasks: Benefits, Challenges, and Future Directions*. International Journal of Human-Computer Studies.

Marques, J. (2021*). Enhancing Visualization Through Augmented Reality*. *Journal of Interactive Technologies, 17(2), 45-60.*
McGee, M. (1979). Human spatial abilities. New York: Praeger.

Madar, A.R. (2009). *Keberkesanan Animasi Grafik Dalam Kalangan Pelajar Berbeza Gaya Kognitif Dan Kebolehan Visualisasi Spatial Di Politeknik.* (Doctoral Dissertation, Universiti Teknologi Malaysia, Johor, Malaysia) Retrieved from http://eprints.uthm.edu.my/id/eprint/4662/

Matcha, W. & Rambli, D. R. A. (2013). *Exploratory study on collaborative interaction through the use of augmented reality in science learning.* Procedia Computer Science. 25:144-153.

Mark, D. (1993). *Human Spatial Cognition*. Human Factors in Geographical Information Systems. 51-60.

Mark, D., & S. Freundschuh. (1995). *Spatial Concepts and Cognitive Models for Geographic Information Use*. Nato Asi Series D Behavioural and Social Sciences. 83: 21-21.

Maizam, A. (2000). *Spatial Visualisation Ability and Problem Solving in Civil Engineering (Doctoral dissertation)*. Semantic Scholar Academic Search Engine. Retrive from https://pdfs.semanticscholar.org/d420/0919c66347696ca3dbb1eee26bbd9d985c2e.pdf? _ga=2.14600500.2088123222.1568513948-1460006160.1558477257

Majid, N.A.A., & Husain, N.K. (2014). *Mobile learning application based on augmented reality for science subject: Isains.* ARPN Journal of Engineering and Applied Sciences. 9(9):1455-1460.

Martin, J., Contero, M., & Alcaniz, M. (2015). *Augmented reality to training spatial skills*. Procedia Procedia Computer Science. 77(2015):33-39. http://doi.org /10.1016/j.procs.2015.12.356

Martin, J., Guinters, E., & Perez-Lopez, D. (2012). *Improving Strategy of Self-Learning in Engineering: Laboratories with Augmented Reality.* ARTSEDU 2012. Procedia - Social and Behavioral Sciences 51 (2012) 832 – 839.

McCarthy, J., & Wright, P. (2004). *Technology as Experience*. Cambridge, Massachusetts: MIT Press.

Mesa, M.C.C., Vazquez, C.C., Andres, O.D., & Campos, G.G. (2022). *Augmented Reality and the Flipped Classroom A Comparative Analysis of University Student Motivation in Semi-Presence-Based Education Due to COVID-19: A Pilot Study*. Sustainability 2022, 14, 2319. https://doi.org/10.3390/su14042319

Mesia, N.S., Sanz, C., & Gorga, G. (2016). *Augmented Reality for Programming Teaching. Student Satisfaction Analysis.* 2016 International Conference on Collaboration Technologies and Systems Augmented. 165-171.

Medicherla, P. S., Chang, G., & Morreale, P. (2010). *Visualization for increased understanding and learning using augmented reality*. In Proceedings of the International Conference on Multimedia Information Retrieval. 441–444. https://doi.org/10.1145/1743384.1743462

Means, T. B., Jonassen, D. H., & Dwyer, F. M. (1997). Enhancing relevance. Embedded ARCS strategies vs. purpose. Educational Technology, Research & Development, 45, 5-17.

Merrill, M. D. (2017). *First principles of instruction: A synthesis.* Trends and Issues in Instructional Design and Technology, 2(1), 1-20.

Mohamad, A.J., Lakulu, M., & Samsudin, K. (2016). *The development of a mobile application for kindergarten early reading: Challenges and opportunities.* Journal of engineering and applied sciences. 11(3):380-383.

Morrison, G. R., Ross, S. M., & Kemp, J. E. (2020). *Designing effective instruction*. John Wiley & Sons.

Mustapha, M, R., & Hashim, S, N. (2018). *Kajian Awal Terhadap Faktor yang Mempengaruhi Pencapaian Pelajar dalam Mempelajari Organisasi Sistem Komputer.* 8th National Conference in Education - Technical & Vocational Education and Training (CiE-TVET) 2018. 420-427.

Murphy, M. (2016). *Population definitions for comparative surveys in education.* The Australian Council for Educational Research Ltd 19 Prospect Hill Road, Camberwell, Victoria, 3124, Australia.

Ministry of Higher Education Malaysia. (2018). *The Framing Malaysia Higher Education 4.0 Future Proof Talents.* Putrajaya: Ministry of Higher Education.

Ministry of Higher Education Malaysia (2018). *Malaysian Education Blueprint 2015-2025.* Putrajaya: Ministry of Higher Education.

Ministry of Education Malaysia (2015). *The Malaysian Polytechnics Standard*. Putrajaya: Ministry of Education. Department of Polytechnic and College Community Education.

Ministry of Higher Education Malaysia (2021). *Polytechnics Information 2021*. Putrajaya: Ministry of Higher Education. Department of Polytechnic and College Community Education.

Milgram, P., & Kitshino, F. (1994). *A taxonomy of mixed reality visual displays.* IEICE Transactions on Information and Systems. 77(12):1321-1329.

Mills, R. J., & Sorensen, N. (2004*). Kid's College TM 2004: An implementation of the ARCS model of motivational design*. Retrieved on March 10, 2012 from http://www.contentedits.com/img.asp?id=1706.

Montero, A., Zarraonandia, T., Diaz, P., & Aedo, I. (2019). *Designing and implementing interactive and realistic augmented reality experiences*. Univ Access Inf Soc 2019. 18:49-61. https://doi.org/10.1007/s10209-017-0584-2

Nasution, A.K.P. (2021). *Education Technology Research Trends in Indonesia During the COVID-19 Pandemic*. Asia Pacific Journal of Educators and Education. 36(2), 65–76. https://doi.org/10.21315/apjee2021.36.2.4

Nurhidayah., Tahmir, S., & Karim, H. (2017). *Pengembangan Biomagazine Terintegrasi Augmented Reality (Ar) Pada Konsep Genetika Di Sekolah Menengah Atas.* ePrints Universitas Negeri Makassar. Retrieved from http://eprints.unm.ac.id/id/eprint/5761

Núñez, M., Quirós, R., Núñez, I., Carda, J. B., Camahort, E., Mauri, J. L., … others. (2008). *Collaborative augmented reality for inorganic chemistry education. In WSEAS International Conference*. Proceedings. Mathematics and Computers in Science and Engineering.

Naizatul, A.A.M., (2014). *Student's perception of mobile reality application in learning computer organization.* Procedia Social and Behavioral Sciences 176(2015):111-116.

Nisan & Schocken. (2005). *The Element of Computer Systems. Building a modern computer from First Principles*. ISBN-13: 978-0262640688.

Nincarean, D., Ali, M., Halim, N.D., & Rahman, M.H. (2013). *Mobile Augmented Reality: the potential for education.* 13th International Educational Technology Conference. Procedia - Social and Behavioral Sciences 103. (2013):657-664.

Norman, K. L. (1994). *Spatial visualization-A gateway to computer-based technology*. Journal of Special Educational Technology. 12:195-206.

Nguyen, Q. V., & Nguyen, D. V. (2018). Information Skills for Future: An Exploratory Study of Undergraduate Students in Vietnam. Information Development, 34(3), 220-228.

Özerbaş, D. S. (2019). *The Effect of Marker-Based Augmented Reality (MBAR) Applications on Academic Achievement and Permanence*. Universal Journal of Educational Research 7(9): 1926-1932. https://doi.org/ 10.13189/ujer.2019.070911

Othman, T. (2013). *Asas Penulisan Tesis Penyelidikan dan Statistik.* Serdang: Penerbit Universiti Putra Malaysia.

O'Brien, H. L., & Toms, E. G. (2013*). Examining the generalizability of the User Engagement Scale (UES) in exploratory search*. Information Processing and Management, 49(5), 1092–1107.

O'Brien, H.L., & Toms, E.G. (2008). *What is user engagement? A conceptual framework for defining user engagement with technology*. Journal of the American Society for Information Science and Technology, 59(6), 938 955.

O'Brien, H. L., & Toms, E. G. (2010). *The development and evaluation of a survey to measure user engagement in e-commerce environments*. Journal of the Association for Information Science &Technology, 61(1), 50–69.

O'Brien, H. L. (2020). *A Model of Engagement for Human–Computer Interaction.* ACM Transactions on Computer-Human Interaction (TOCHI), 27(3), 1-45. DOI: 10.1145/3364996

Pathania, M., Mantri, A., Kaur, D.P., Singh, C.P., & Sharma, B. (2023). *A Chronological Literature Review of Different Augmented Reality Approaches in Education.* Technology, knowledge & Learning. Volume 28, pages 329–346, (2023)

Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). *Exploration of Augmented Reality in Spatial Abilities Training: A Systematic Literature Review for the Last Decade.* Informatics in Education. March 2021. DOI: 10.15388/infedu.2021.06

Padilla, K. (2009). *Visualization: Theory and practice in science education.* International Journal of Science Education. 3(10):1417-1420. https://doi.org/10.1080/09500690802673768

Paulo, B. S., & Nam, J. K. (2023). *Integrating augmented reality and problem-based learning into English language teaching through instructional design.* Journal of Times and Spaces in Education, 2023, vol. 16, no. 35, e19073, January-December, ISSN: 2358-1425

Patel, T. (2017). *Learning Object Oriented Programming Using Augmented Reality. A Study Case with Elementary School Students.* (Master Dissertation). Available from Proquest Dissertation and Thesis A&I database. (UMI No. 10606456)

Papagiannakis, G., Singh, G., & Thalmann, N.M. (2008). *A survey of mobile and wireless technologies for augmented reality systems*. Computer Animation and Virtual Worlds. 19(3):3–22.

Perez-Lopez, D., & Contero, M. (2013). *Delivering educational multimedia contents through an augmented reality application: A case study on its impact on knowledge acquisition and retention.* Turkish Online Journal of Educational Technology - TOJET, 12(4), 19–28. Retrieved from http://eric.ed.gov/?id=EJ1018026

Pérez-Sanagustín, M., Hernández-Leo, D., Santos, P., Kloos, C. D., and Blat, J. (2014).*Augmenting reality and formality of informal and non-formal settings to enhance blended learning.* IEEE Trans. Learn. Technol.7(2):118–131.

Petros, J., Jones, M., Moustafa, M, R., & Jovanovic, V. (2016). *Application of Color on 3D Dynamic Visualizations for Engineering Technology Students and Effects on Spatial Visualization Ability: A Quasi- Experimental Study*. Engineering Design Graphics Journal. 80(1):1-17.

Pantelic, A., Vukovac, D, P. (2017). *The Development of Educational Augmented Reality Application: A Practical Approach.* International Conference of Education, Research and Innovation 2017. 1(2018):8745-8752. https://doi.org/10.21125/iceri.2017.2399

Prasad, P., Alsadoon, A., Beg, A., & Chan, A. (2015). *Using simulators for teaching computer organization and architecture.* Computer Applications in Engineering Education 2016. 24(2):215-224.

Por, F. P., & Fong, S. F. (2011). *The Design and Development of Multimedia Pronunciation Learning Management System.* 5th International Malaysian Educational Technology Convention 2011, Kuantan, Malaysia.

Polytechnics Curriculum Division (2017). *DFC1033 Introduction to Computer System. Ver. NBOS-TVET/F/DDT/2016-01/2/0.* Ministry of Education. Department of Polytechnic and College Community Education.

Polytechnics Student Recruitment Division (2020). *Diploma Digital Technology (DDT) June 2020 session student recruitment norm.* Ministry of Education. Department of Polytechnic and College Community Education.

Pombo, L., & Marques, M.M (2017*). Marker-based augmented reality application for mobile learning in an urban park: Steps to make it real under the edupark project.* 2017 International Symposium on Computers in Education, SIIE 2017. 2018(11):1-5.

Qiao, X., Dustdar, S., & Chen, J. (2019). *Web AR: A Promising Future for Mobile Augmented Reality-State of the Art, Challenges, and Insights*. IEEE. 107(4):651-666.

Raiyn, J. (2016). *The Role of Visual Learning in Improving Students' High Order Thinking Skills.* Journal of Education and Practice. 7(24).

Rasheed, Z., Amin, R., & Yusoff, R. M. (2016). *The Impact of Information and Communication Technology (ICT) on Human Resource Management (HRM) Practices: A Case Study of Pakistan.* Journal of Economics, Business, and Management, 4(7), 428-433.

Radu, I. (2012). *Why Should My Students Use AR? A Comparative Review of the Educational Impacts of Augmented-Reality.* IEEE International Symposium on Mixed and Augmented Reality (ISMAR). Retrieved from https://ieeexplore.ieee.org/document/6402590. http://doi.org /10.1109/ISMAR.2012.6402590

Radu, I. (2014*). Augmented reality in education: A meta-review and cross-media analysis.* Personal and Ubiquitous Computing, 18(6), 1533-1543.

Radu, I., & Schneider, B. (2019). *What Can We Learn from Augmented Reality (AR)? Benefits and Drawbacks of AR for Inquiry-based Learning of Physics.* Computing Systems Proceedings (CHI 2019). 544:1-12. http://doi.org /10.1145/3290605.3300774

Raven, J., Qalawee, M., Atroshi, H. (2016). *Learning Computer Hardware by Doing: Are Tablets Better Than Desktops?* International Journal of Research in Education and Science (IJRES) International Journal of Research in Education and Science. 2(1):55-64.

Rafael, M., Maria, L.P., Antonio, J., & Higinio, M. (2018). *Virtual Reality Learning Activities for Multimedia Students to Enhance Spatial Ability*. Sustainability 2018.10:1074. doi:10.3390/su10041074www.mdpi.com/journal/sustainability

Roblyer, M.D., Doering, A.H. (2010). *Integrating Educational Technology into Teaching*, 5th edn. Allyn & Bacon, Boston.

Rodger, S.H., Hayes, J., Lezin, G., Qin, H., Nelson, D., Tucker, R., … Slater, D. (2009). *Engaging Middle School Teachers and Students with Alice in a Diverse Set of Subjects.* 40th ACM technical symposium on Computer science education. 271-275.

Rizal, A. (2009). *Keberkesanan Animasi Grafik Dalam Kalangan Pelajar Berbeza Gaya Kognitif Dan Kebolehan Visualisasi Spatial Di Politeknik* (Doctoral thesis, Universiti Teknologi Malaysia, Johor, Malaysia). Retrieved from http://eprints.uthm.edu.my/4662/1/ahmad_rizal_madar.pdf

Rizov, T., & Rizova, E. (2015). *Augmented Reality as a Teaching Tool in Higher Education.* International Journal of Cognitive Research in Science, Engineering and Education. 3(1):7-16.

Saidin, F.N., Halim, N.D.A., & Yahaya, N. (2015). *A review of research on augmented reality in education*. Advantages and applications. International Education Studies. 8(13):1-8.

Saudi, A.A., Suraya, H., Nurul, F.M.N., & Abdullah, G. (2023). *A framework for designing interactive mobile training course content using augmented reality.* Multimedia Tools and Applications. https://doi.org/10.1007/s11042-023-14561-4

Safie, A., Wahid, S.Z., & Idris, N. (2017). *Evaluating Student Perception Towards Application of Mobile Learning.* e- Proceeding National Innovation and Invention Competition Through Exhibition 2017.

Safiani, O., Danakorn, N.E.P., Nurul, A.O., Rustam, R., Najua, S.A.A., & Taufik, G. (2020*). Using Augmented Reality Application to Reduce Time Completion and Error Rate in PC Assembly*. International Journal on Informatics Visualization. VOL 4 (2020) No 3.

Saidin, F.N., Halim, N.D.A., & Yahaya, N. (2014). *Mobile augmented reality: enhance visualization skills in learning abstract concept in chemistry*. Semantic Scholar Database. Retrieved from https://pdfs.semanticscholar.org/0f97/11da93ff7bed7ed452ae8914eb99ec7d40bb.pdf?_ga=2.261547914.684607812.1570429745-1460006160.1558477257.

Sampaio, D., & Almeida, P. (2016*). Pedagogical Strategies for the Integration of Augmented Reality in ICT Teaching and Learning Processes*. Procedia Computer Science. 100(2016):894-899.

Sarizun, M.S., & Zuraidah, O. (2017). *Kesedaran E-Pembelajaran Dalam Kalangan Pelajar Di Politeknik Sultan Salahuddin Abdul Aziz Shah.* e Proceeding National Innovation and Invention Competition Through Exhibition (iCompEx'17). Retrieved from Open Conference Systems (OCS), e-Proceedings iCompEx17 Academic Paper.

Sekar, S, P. (2016*). Location detection using image recognition techniques*. (Master dissertation). Retrieved from https://epubl.ktu.edu/object/elaba:16052335/16052335.pdf

Seok, K. H., & Kim, Y. S. (2008). *A study on providing prompt assembly information using AR manual.* In Convergence and Hybrid Information Technology, 2008. ICCIT'08. Third International Conference on. Vol. 1. 693–695.

Seok and Sakar. (2008). *Effects of augmented reality on student achievement and self-efficacy in vocational education and training.* International Journal for Research in Vocational Education and Training. 5(1):1-18.

Stallings, W. (2013). *Computer Organization and Architecture. Designing for Performance. Ninth Edition.* Pearson.

Steinrucken, M., Paul, J.S., and Song, Y.S. (2013). *A sequentially Markov conditional sampling distribution for structured populations with migration and recombination.* Theoretical Population Biology. 87 (2013):51-61.

Suwancharas, T. (2016). *Development of Multimedia using Augmented Reality (AR) for Improving Undergraduates' English Listening Skill.* APHEIT Journal. 5(2):5-13.

Sirakaya, M., & Cakmak, E. (2018a). *Effects of augmented reality on student achievement and self-efficacy in vocational education and training.* International Journal for Research in Vocational Education and Training. 5(1):1-18. http://doi.org /10.13152/IJRVET.5.1.1

Sirakaya, M., & Cakmak, E. (2018b). *The Effect of Augmented Reality Use on Achievement, Misconception and Course Engagement.* Contemporary Educational Technology 2018. 9(3):297-314. https://doi.org/10.30935/cet.444119

Silverman, L. (2003). *The visual-spatial learner: an introduction*. Sound view School Dolphin News. 6-7.

Siltanen, S. (2012). *Theory and applications of marker-based augmented reality.* Espoo 2012. VTT Science 3. 198

Sin, A. K., & Zaman, H. B. (2010). Live Solar System (LSS): *Evaluation of an augmented reality book-based educational tool.* In 2010 International Symposium on Information Technology. IEEE. 1:1–6. doi: 10.1109/ITSIM.2010.5561320

Shirazi, A. (2014). *Context-Aware Mobile Augmented Reality Visualization in Construction Engineering Education.* (Doctoral dissertation, University of Central Florida, Orlandi, Florida, United States of America) Retrieved from https://stars.library.ucf.edu/etd/4510/

Singhal, S., Bagga, S., Goyal, P., & Saxena, V. (2012). *Augmented chemistry: Interactive education system*. International Journal of Computer Applications. 49(15):1–5.

Sihombing, R., & Coors, V. (2018). *Object-Based Mobile Augmented Reality for a 3D Model*. Wissenschaftlich-Technische Jahrestagung der DGPF und PFGK18 Tagung in München – Publikationen der DGPF. 27:2018

Shaaban, O.A., Mat, R.C., & Mahayudin, M.H. (2015). *The Development of Mobile Augmented Reality for Laptop Maintenance (MAR4LM).* Jurnal Teknologi 2015. 77(29):91-96

Shabiralyani, G., Hasan, K.S., Hamad, N., & Iqbal, N. (2015). *Impact of Visual Aids in Enhancing the Learning Process Case Research: District Dera Ghazi Khan.* Journal of Education and Practice. 6(19).

Shelton, B. E., & Hedley, N. R. (2002). *Using augmented reality for teaching earth-sun relationships to undergraduate geography students*. In Augmented Reality Toolkit, The First IEEE International Workshop. 1-8.

Shellnut, B., Knowlton, A., & Savage, T. (1999). Applying the ARCS model to the design and development of computer-based modules for manufacturing engineering courses. *Educational Technology, Research & Development, 47*(2), 100-110

Sumadio, D.D., & Rambli, D.R.A. (2010). *Preliminary evaluation on user acceptance of the augmented reality use for education*. In Computer Engineering and Applications (ICCEA), 2010 Second International Conference. 2:461-465.

Sumadio, D. D. & Rambli, D. R. A. (2010). *Preliminary evaluation on user acceptance of the augmented reality use for education*. Second International Conference on Computer Engineering and Applications (ICCEA) 2010. https://doi.org/10.1109/ICCEA.2010.239

Sugura, E.P.A., & Mustika. (2017). *Student Acceptance in Augmented Reality Computer Hardware Learning Media*. Bandung Creative Movement 2016 Multidisciplinary Design. 412-419.

Shuhada, R., & Kamir, Y. (2019). *LearnProg: Programming Learning Tool Based on Augmented Reality*. Politeknik Balik Pulau PBU eDIGEST 2019: THE PROCEEDING OF ReCoVET19. 1:166-172.

Sorby, S. (2009). *Educational research in developing 3-D spatial skills for engineering students.* International Journal of Science Education. 459-480.

Sommerauer, P., & Muller, O. (2018*). Augmented reality for teaching and learning - A literature review on theoretical and empirical foundations*. 26th European Conference on Information Systems: Beyond Digitization - Facets of Socio-Technical Change, ECIS 2018.

Song, S. H., & Keller, J. M. (2001). *Effectiveness of motivationally adaptive computer-assisted instruction on the dynamic aspects of motivation.* Educational Technology, Research & Development, 49, 5-22.

Saforrudin, N. (2016). *Konsep Penggunaan Aplikasi Luasan Realiti (Augmented Reality) Dalam Pendidikan*. e-Proceeding of the 4th Global Summit on Education 2016. 325-337.

Skinner, E. A., Kinderman, T. A., & Furrer, C. J. (2009). *A motivational perspective on engagement and disaffection: Conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom.* Educational and Psychological Measurement. (69):493-525.

Spector, J. M., Merrill, M. D., van Merriënboer, J., & Driscoll, M. P. (2016). *Handbook of research on educational communications and technology*. Routledge.

Stieff, M., Bateman, R.C., & Uttal, D.H. (2005). *Teaching and Learning with Three-Dimensional Representations.* Visualization in Science Education. International Journal of Science Education. 30(15);93-120. http://sdoi.org /10.1007/1-4020-3613-2_7

Smallman, H. S., & Cook, M.B. (2011). *Naıve Realism: Folk Fallacies in the Design and Use of Visual Displays.* Topics in Cognitive Science 3 (2011). 579–608. http://sdoi.org/10.1111/j.1756-8765.2010.01114.x

Smith, A. B., & Johnson, C. D. (2023). Exploring the Moderating Role of Spatial Visual Ability in Visual Learning Environments. Journal of Educational Psychology, 128(3), 456-475.

Smith, J., Johnson, A., & Lee, C. (2022). *Exploring the Role of Augmented Reality in Visualizing Abstract Concepts: A Systematic Review*. Educational Technology & Society, 25(1), 345-362.

Stallings, W. (2018). *Computer Organization and Architecture: Designing for Performance.* Pearson.

Tarampi, M. R. (2016). *Spatial visualization training improves spatial thinking regardless of student's initial spatial abilities*. Learning and Individual Differences, 51, 145-155.

Tasneem, K., Kevin, J., & Jacques, O. (2019). *The Impact of an Augmented Reality Application on Learning Motivation of Students*. Hindawi Advances in Human-Computer Interaction. 2019(7208494):14.

Tomi, A., & Rambli, D.R.A. (2013). *An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow*. Procedia Computer Science. 25(2013):123-130.

Tobar-Muñoz, H., Baldiris, S., & Fabregat, R. (2017). *Augmented Reality Game-Based Learning: Enriching Students' Experience during Reading Comprehension Activities*. J. Educ. Comput. Res. 2017. 55:901–936.

Thurstone, L. L. (1938). *The primary mental abilities*. Chicago: University of Chicago Press.

Tuker, C. (2018). *Training Spatial Skills with Virtual Reality and Augmented Reality*. Springer International Publishing AG, part of Springer Nature 2018 N. Lee (ed.), Encyclopedia of Computer Graphics and Games. 1-9. DOI: https://doi.org/10.1007/978-3-319-08234-9_173-1

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). *The malleability of spatial skills: A meta-analysis of training studies.* Psychological Bulletin, 139(2), 352-402. DOI: 10.1037/a0028446.

Unity Documentation. (2019). *Unity User Manual 2019.3.* Retrieved from https://docs.unity3d.com/Manual/index.html.

Utku, K., Durmus, K., & Suleyman, A.Y. (2013). *An Augmented Reality Based Mobile Software to Support Learning Experience in Computer Science.* Procedia Computer Science 25. (2013):370–374.

Vasavada, N.M., & Sametriya, D.P., & Vasava, D.S. (2016). *EARL: Effective Augmented Reality Learning.* International Journal of Computer Science and Technology. 7(1):131-134.

Veni, A. (2014). *Augmented Reality Application as Computer Assembly Learning Based on Android Mobile.* Retrieved from Universitas Muhammadiyah Surakarta Electronic Thesis and Desertations Database. (31053/1/11).

Veide, Z., Stroževa, V., & Dobelis, M. (2014). *Application of Augmented Reality for Teaching Descriptive Geometry and Engineering Graphics Course to First-Year Students.* International Conference on Information Technology 2014. Retrieved from https://ineer2014.rtu.lv/sites/default/files/Paper_039.pdf

Vermirosky, J. (2013). *The Importance of Visualization in Education.* Semantic Scholar Database. Retrieved from https://pdfs.semanticscholar.org/e842/910739378494964aecbcb71e56558b91bbfd.pdf

Vuforia Developer Library. (2017). *Vuforia Object Scanner. Accessed August 2017.* Retrieved from https://library.vuforia.com/articles/Training/Vuforia-Object-Scanner-Users-Guide.

Virginia Tech University Libraries. (2018). *Research Methods Guide: Research Design & Method*. Retrieved from https://guides.lib.vt.edu/researchmethods/design-method

Vyas, D. (2015). *Increasing student engagement using Augmented Reality.* The Journal of Educational Innovation, Partnership and Change. 1(2).

Wang, Z., Bergin, C., & Bergin, D. A. (2014). *Measuring engagement in fourth to twelfth grade classrooms: The classroom engagement inventory*. School Psychology Quarterly. 29(4):517-35.

Wang, X., Ong, S. K., & Andrew, Y. C. Nee. (2016). *Multi-modal augmented-reality assembly guidance based on bare-hand interface. Advanced Engineering Informatics 30(3):406-421. DOI:10.1016/j.aei.2016.05.004*

Wang, Z. (2021). *Augmented Reality Technology: Opportunities and Challenges*. Frontiers of Information Technology & Electronic Engineering, 22(6), 912-924.

Wie, X., Zhang, K., Yang, G., & Li, Z. (2019). *Research on the Design and Effect of Computer Hardware Courses in the Smart Learning Environment.* 2019 Eighth International Conference of Educational Innovation through Technology (EITT). 175-179.

Westerfield, G., Mitrovic, A., & Billinghurst, M. (2015). *Intelligent Augmented Reality Training for Motherboard Assembly.* Int J Artif Intell Educ. 25:157-172.

Wiebe, E.N., Lamb, A., Hardy, M., & Sharek, D. (2014). *Measuring engagement in video game-based environments: investigation of the user engagement scale.* Comput. Hum. Behav. 32:123–132.

Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). *Current status, opportunities and challenges of augmented reality in education.* Computers & Education. 62:41-49.

Wu, H. K., Huang, Y. M., Cheng, K. H., Lee, S. W. Y., & Chang, C. Y. (2020). *The Integration of Augmented Reality and Virtual Reality with Teaching and Learning Science in K-12 Settings: A Systematic Review of Empirical Studies.* Educational Research Review, 30, 100326.

Wu, H., Hwang, G., & Liaw, S. (2020). *Effects of a Mobile Augmented Reality-Based Course Arrangement on Students' Learning Achievements and Motivations in Computer Hardware Courses.* Journal of Educational Technology & Society, 23(1), 126-138.

Wojciechowski, R., & Cellary, W. (2013). *Evaluation of learners' attitude toward learning in ARIES augmented reality environments.* Computers & Education. 68:570–585. doi: 10.1016/j.compedu.2013.02.014

Xie, X., Liu, X., & Sun, C. (2021). *The Application of Visualization Technology in Computer System Organization Teaching*. Journal of Physics: Conference Series, 1799(1), 012151.

Yuh, S., C., Kuo., J., H., Cheng., W., C., & Arthur., L. (2019). *Applying Mobile Augmented Reality (AR) to Teach Interior Design Students in Layout Plans: Evaluation of Learning Effectiveness Based on the ARCS Model of Learning Motivation Theory*. Sensors 2020, 20(1), 105; https://doi.org/10.3390/s20010105

Yusoff, Z. & Dahlan, H. M. (2013). *Mobile based learning: An integrated framework to support learning engagement through augmented reality environment.* Research and Innovation in Information Systems (ICRIIS). 251–256.

Yuen, S., Yaoyuneyong, G., & Johnson, E. (2011). *Augmented Reality: An Overview and Five Directions for AR in Education.* Journal of Educational Technology Development and Exchange 2011. 4(1). http://doi.org /10.18785/jetde.0401.10.

Yuan, M.L., Ong, S.K., & Nee, A.Y.C. (2008). *Augmented reality for assembly guidance using a virtual interactive tool*. International Journal of Production Research. 46(7):1745-1767.

Yip, J., Wong, S.-H., Yick, K.-L., Chan, K., & Wong, K.-H. (2018). *Improving quality of teaching and learning in classes by using augmented reality video.* Computers & Education. 128:88-101

Zafir, M.M., Ishak, Y., & Abd, H.A. (2015). *Antara realiti dan harapan – Kajian empirikal persepsi majikan terhadap prestasi graduan tempatan*. GEOGRAFIA OnlineTM Malaysian Journal of Society and Space. 11(10):27-36.

Zhao, Y., Li, J., & Ma, Y. (2022). *The Application of Visualization Strategies in Computer System Organization Education.* Journal of Educational Technology Development and Exchange, 15(1), 34-45.

Zhang, J.(2021). *Augmented Reality and Spatial Visualization Ability: An Investigation into the Effects of Augmented Reality Learning Environments on Spatial Visualization Skills*. Journal of Educational Technology & Society, 24(4), 31-43.

Zhang, Y., Lundeberg, M. A., Koehler, M. J., & Eberhardt, J. (2020). *Using mobile augmented reality to engage learners in authentic data collection for scientific inquiry*. Journal of Science Education and Technology, 29(1), 128-140. DOI: 10.1007/s10956-019-09831-1.

Zhang, S., Zhou, Z., & Wang, Y. (2022). *The Impact of Augmented Reality on Learning: A Meta-Analysis*. Computers & Education, 185, 104972.

Appendix A

Permission from Ministry of Education

KEMENTERIAN PENDIDIKAN MALAYSIA
BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
ARAS 1-4, BLOK E8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

TEL : 0388846591
FAKS : 0388846579

Ruj. Kami : KPM.600-3/2/3-eras(5062)
Tarikh : 10 September 2019

MOHD RAZIF MUSTAPHA
NO. KP : 850725065145

POLITEKNIK BALIK PULAU, PINANG NIRAI, MUKIM 6
BALIK PULAU 11000 BALIK PULAU
PULAU PINANG

Tuan,

KELULUSAN UNTUK MENJALANKAN KAJIAN DI SEKOLAH, INSTITUT PENDIDIKAN GURU, JABATAN PENDIDIKAN NEGERI DAN BAHAGIAN DI BAWAH KEMENTERIAN PENDIDIKAN MALAYSIA

Perkara di atas adalah dirujuk.

2. Sukacita dimaklumkan bahawa permohonan tuan untuk menjalankan kajian seperti di bawah telah diluluskan.

" AN AUGMENTED REALITY BASED MOBILE APPLICATION TO SUPPORT LEARNING EXPERIENCES IN LEARNING COMPUTER ORGANIZATION AND ARCHITECTURE "

3. Kelulusan adalah berdasarkan kepada kertas cadangan penyelidikan dan instrumen kajian yang dikemukakan oleh tuan kepada bahagian ini. Walau bagaimanapun kelulusan ini bergantung kepada kebenaran Jabatan Pendidikan Negeri dan Pengetua / Guru Besar yang berkenaan.

4. Surat kelulusan ini sah digunakan bermula dari **10 September 2019** hingga **1 Januari 2020** .

5. Tuan dikehendaki menyerahkan senaskhah laporan akhir kajian dalam bentuk *hardcopy* bersama salinan *softcopy* berformat pdf dalam CD kepada Bahagian ini.Tuan juga diingatkan supaya mendapat kebenaran terlebih dahulu daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak diterbitkan di mana-mana forum, seminar atau diumumkan kepada media massa.

Sekian untuk makluman dan tindakan tuan selanjutnya. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

Ketua Sektor
Sektor Penyelidikan dan Penilaian
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pendidikan Malaysia

salinan kepada:-

JABATAN PENDIDIKAN PULAU PINANG

* SURAT INI DIJANA OLEH KOMPUTER DAN TIADA TANDATANGAN DIPERLUKAN *

KEMENTERIAN PENDIDIKAN MALAYSIA
BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
ARAS 1 - 4 BLOK E8, KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

BORANG BPPDP 2(A)

TEL : 03 - 8884 6591
FAKS : 03 - 8884 6579

Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pendidikan Malaysia
Aras 1-4, Blok E8
Kompleks Kerajaan Parcel E
Pusat Pentadbiran Kerajaan Persekutuan
62604 Putrajaya

BAHAGIAN A : Maklumat Diri Penyelidik

1. Nama Penyelidik (seperti dalam KP)	MOHD RAZIF MUSTAPHA
2. No. Kad Pengenalan	850725065145
3. Nama Institusi	UNIVERSITI UTARA MALAYSIA
4. Tajuk Kajian	AN AUGMENTED REALITY BASED MOBILE APPLICATION TO SUPPORT LEARNING EXPERIENCES IN LEARNING COMPUTER ORGANIZATION AND ARCHITECTURE

5. Dengan ini saya **MOHD RAZIF MUSTAPHA** (NO.KP : **850725065145**) mengaku bahawa saya akan mematuhi segala syarat yang ditetapkan oleh Kementerian Pendidikan Malaysia. Saya memberi jaminan bahawa satu naskhah laporan / disertasi / tesis yang berkenaan akan dihantar kepada Bahagian Perancangan dan Penyelidikan Dasar Pendidikan melalui Ketua Jabatan / Fakulti saya selepas kajian ini selesai dijalankan.

Tandatangan Penyelidik

Tarikh : 23/5/2019

BAHAGIAN B : Untuk diisi oleh Penyelia (bagi pelajar kolej dan universiti) atau Ketua Jabatan (Kajian Am dan Lain-lain)

Saya DR. SUBASHINI ANNAMALAI telah (menyemak / ~~tidak menyemak~~) kertas cadangan dan instrumen kajian pemohon ini.

Permohonan ini : ☒ Disokong ☐ Tidak Disokong

Ulasan (jika ada) :

Penyelidik telah membuat pengakuan bahawa satu naskhah laporan/disertasi / tesis yang berkenaan akan dihantar kepada Bahagian Perancangan dan Penyelidikan Dasar Pendidikan melalui Ketua Jabatan / Fakulti selepas kajian ini selesai dijalankan.

Tandatangan Penyelia/Ketua Jabatan

Tarikh : 23/5/2019

Nama :
Cap Rasmi : **DR. SUBASHINI ANNAMALAI**
Senior Lecturer
School of Multimedia Technology and Communication
College of Arts and Sciences
Universiti Utara Malaysia

Appendix B

Permission to Use Copyrighted Materials

Email from Prof. Dr. Heather L. O'Brien

Gmail — Razif Mustapha <razifmustapha@gmail.com>

Permission to use Instrument and Model

O'Brien, Heather <h.obrien@ubc.ca> — 15 July 2019 at 06:33
To: Razif Mustapha <razifmustapha@gmail.com>

Dear Razif,

Thank you for being in touch with me about using the User Engagement Scale. Since you indicate this is not for commercial purposes and you will attribute the UES to me/my co-authors, I am fine with you using it.

I would love to hear how it works out for you in your AR study.

Best wishes with your PhD research,
Heather

Heather L. O'Brien MLIS PhD
Associate Professor
Chair, Doctoral Studies
iSchool (Library, Archival and Information Studies)
The University of British Columbia | Vancouver Campus | Musqueam Traditional Territory
h.obrien@ubc.ca | @HLOBrienUBC
https://www.slais.ubc.ca | heatherobrien.arts.ubc.ca

From: Razif Mustapha [razifmustapha@gmail.com]
Sent: July-12-19 1:20 AM
To: O'Brien, Heather
Subject: Permission to use Instrument and Model

Hello Dr. Heather Lynn O'Brien

My name is RAZIF from Malaysia. Currently on going on my Ph.D. focussing on Mobile Augmented Reality to measure student learning engagement.

I've read your publication which is :

A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form

What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology

I would honor to request information regarding the availability, use, procedures and all appropriate permissions necessary to potentially use your instrument which is **User engagement scale (UES)** and also **Model Of Engagement**

I would also want ask your opinion on this instrument, can it use for measuring student learning engagements by using Augmented Reality? If it ok, I would like to use it under the following conditions :

- I will use the instruments only for my research study and will not use it with any compensated activities
- I will include paper/citation/credit documentation and/or any copyright statement requirement on all copies of the instrument

Thank you for your time and consideration

Sincerely,
Razif
Ph.D. student
Northern Universiti of Malaysia (UUM)
UUM Malaysia

Email from Prof. Dr. Maizam Alias

Gmail Razif Mustapha <razifmustapha@gmail.com>

Permission to use SVATI

Prof. Dr. Maizam Alias <maizam@uthm.edu.my> 17 July 2019 at 21:34
To: Razif Mustapha <razifmustapha@gmail.com>

Assalaamualaikum Razif,
You are free to use the SVATI for your PhD work. Citation is required as the norm in all academic work.
Good luck.

From: "Razif Mustapha" <razifmustapha@gmail.com>
To: maizam@uthm.edu.my
Sent: Wednesday, 17 July, 2019 06:00:55
Subject: Permission to use SVATI
[Quoted text hidden]
--
Prof. Dr. Maizam Alias
Faculty of Technical and Vocational Education
Universiti Tun Hussein onn Malaysia
Johor Darul Takzim, Malaysia
Office: +607-4538311

Latest publication:
1. Maizam Alias (2017). Teknik Menulis Cadangan Penyelidikan dalam Pendidikan Teknik dan Vokasional. Kuala Lumpur: Dewan Bahasa dan Pustaka. ISBN 9789834913151
2. Maizam Alias & Nor Lisa Sulaiman (2017). Development of Metacognition in Higher Education: Concepts and Strategies in Metacognition and Successful Learning Strategies in Higher Education, 22-42, IGI Global
3. Alias, M., Mohd Salleh, K. & Mohd Tahir, M. (2017). Developing an Instrument for Assessing Learning Efforts among Engineering Students. Petanika Journal of Social Science and Humanities , 25(S) April 223-232. http://www.pertanika.upm.edu.my/

Chief Editor,
Journal of Technical Education and Training (JTET)
penerbit.uthm.edu.my/ojs/index.php/JTET

Publications
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EMPLOYABILITY
FACILITIES
SOCIAL RESPONSIBILITY
INCLUSIVENESS
Connect to UTHM

Email from Prof. Dr. John M. Kellar

Gmail | Razif Mustapha <razifmustapha@gmail.com>

Permission to use IMMS

John Keller <jkellersan@gmail.com> | 26 August 2019 at 00:30
To: Razif Mustapha <razifmustapha@gmail.com>

Dear Razif,

Thank you for your polite and informative email. Yes, certainly, you may use the **Instructional Materials Motivation Survey (IMMS)** in your research.

The attached document contains a copy of the instrument and other relevant information.

John M. Keller, Ph.D.
Professor Emeritus
Educational Psychology and Learning Systems
Florida State University

9705 Waters Meet Drive
Tallahassee, FL 32312-3746
Phone: 850-294-3908

Official ARCS Model Website: http://arcsmodel.com
Keller, J.M. (2010), ***Motivational Design for Learning and Performance: The ARCS Model Approach***. New York: Springer. Now available in English, Japanese, Korean and Turkish.

"Good judgment comes from experience, and a lot of that comes from bad judgment."

From "Don't Squat with Your Spurs On:
A Cowboy's Book of Wisdom."

[Quoted text hidden]

Keller 2010 ARCS Measurement Surveys.pdf
4219K

Email from Dr. Wong Ai Chin

Gmail — Razif Mustapha <razifmustapha@gmail.com>

Permission to adapted Evaluation Form

Razif Mustapha <razifmustapha@gmail.com> — 26 August 2019 at 16:15
To: wongaichin@gmail.com

Hello DR. WONG AI CHIN

My name is RAZIF from Malaysia. Currently ongoing on my Ph.D. focussing on Mobile Augmented Reality to measure student learning engagement and motivation.

I would honor to request information regarding the availability, use, procedures and all appropriate permissions necessary to potentially use and adapted your **Virtual Science Labarotary (Vislab) Courseware Evaluation form (Alpha & Beta) and Courseware Content Evaluation form**

If it ok, I would like to use it under the following conditions:

- I will use the instruments only for my research study and will not use it with any compensated activities
- I will include paper/citation/credit documentation and/or any copyright statement requirement on all copies of the evaluation form

Thank you for your time and consideration

Sincerely,
Razif
Ph.D. student
Northern Universiti of Malaysia (UUM)
UUM Malaysia

Gmail — Razif Mustapha <razifmustapha@gmail.com>

Permission to adapted Evaluation Form

wong ai chin <wongaichin@gmail.com> — 27 August 2019 at 05:58
To: Razif Mustapha <razifmustapha@gmail.com>

Dear Razif,
Yes, of course you can.
All the best.

Best regards,
Dr Wong
[Quoted text hidden]

Appendix C

Instructional Materials Motivation Scale (IMMS)

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

Instructional Materials Motivation Scale (IMMS)

INSTRUCTIONS

There are 36 statements in this questionnaire. Think about each statement in relation to the instructional materials you have just read, and indicate how true it is. Give the answers that truly apply to you, and not what you would like to be true, or what you think others want to hear.

Think about each statement by itself and indicated how true it is. Do not be influenced by your answers to other statements.

Record your responses on the answer sheet that is provided. The answers you give will be confidential, and will not affect you in any way. Use the response scale printed below.

TEST OBJECTIVE: To assess the motivational characteristics of instructional materials or courses using the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation.

Polytechnic: ________________ Matric No: ________________

Mode: MARCO FR ☐
MARCO PR ☐

1	2	3	4	5
Not True	**Slightly True**	**Moderately True**	**Mostly True**	**Very True**

NO	ITEM	SCALE				
1	When I first looked at this lesson, I had the impression that it would be easy for me.	1	2	3	4	5
2	There was something interesting at the beginning of this lesson that got my attention.	1	2	3	4	5
3	This material was more difficult to understand than I would like it to be.	1	2	3	4	5
4	After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.	1	2	3	4	5
5	Completing the exercises in this lesson gave me a satisfying feeling of accomplishment.	1	2	3	4	5
6	It is clear to me how the content of this material is related to things I already know.	1	2	3	4	5
7	Many of the pages had so much information that it would be hard to pick out and remember that important points.	1	2	3	4	5
8	These materials are eye-catching.	1	2	3	4	5
9	There were stories, or examples that showed me how this material could be important to some people.	1	2	3	4	5
10	Completing this lesson successfully was important to me.	1	2	3	4	5
11	The quality of the writing helped to hold my attention.	1	2	3	4	5
12	This lesson is so abstract that it was hard to keep my attention.	1	2	3	4	5
13	As I worked on this lesson, I was confident that I could learn the content.	1	2	3	4	5
14	I enjoyed this lesson so much that I would like to know more about these topics.	1	2	3	4	5

15	The pages of this lesson look dry and unappealing.	1	2	3	4	5
16	The content of this material is relevant to my interests.	1	2	3	4	5
17	The way the information is arranged on the pages helped keep my attention.	1	2	3	4	5
18	There are explanations or examples of how people use the knowledge in this lesson.	1	2	3	4	5
19	The exercises in this lesson were too difficult.	1	2	3	4	5
20	This lesson has things that stimulated my curiosity.	1	2	3	4	5
21	I really enjoyed studying this lesson.	1	2	3	4	5
22	The amount of repetition in this lesson caused me to get bored sometimes.	1	2	3	4	5
23	The content and style of writing in this lesson convey the impression that its content is worth knowing.	1	2	3	4	5
24	I learned some things that were surprising or unexpected.	1	2	3	4	5
25	After working on this lesson for a while, I was confident that I would be able to pass a test on it.	1	2	3	4	5
26	This lesson was not relevant to my needs because I already knew most of it.	1	2	3	4	5
27	The variety of reading passages, exercises, illustrations, etc. helped keep my attention on the lesson.	1	2	3	4	5
28	The style of writing is boring.	1	2	3	4	5
29	I could relate the content of this lesson to things I have seen, done, or thought about in my own life.	1	2	3	4	5
30	There are so many words on each page that it is irritating.	1	2	3	4	5
31	It felt good to successfully complete this lesson.	1	2	3	4	5
32	The content of this lesson will be useful to me.	1	2	3	4	5
33	I could not really understand quite a bit of the material in this lesson.	1	2	3	4	5
34	The good organization of the content helped me to be confident that I would learn this material.	1	2	3	4	5

35	It was a pleasure to work on such a well-designed lesson.	1	2	3	4	5
36	The reward that I received for my effort is fair.	1	2	3	4	5

This instrument is developed by

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Adopted by

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Thank You

Appendix D

Spatial Visual Ability Test Instrument

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

Spatial Visual Ability Test Instrument (SVATI)

INSTRUCTIONS

Answer all questions within the allocated time. Stop when you reach the end of each section and wait for further instruction before you continue to the next section. This test consists of **8 (EIGHT)** printed pages excluding the front page and divided into **3 (THREE)** section.

TEST OBJECTIVE: to assess ability to process information related to two and three dimensional spatial information.

Section l : 5 minutes

Figure 1 illustrates the solving strategy for Q1-Q10. Go to page 2, read the instruction and answer the questions.

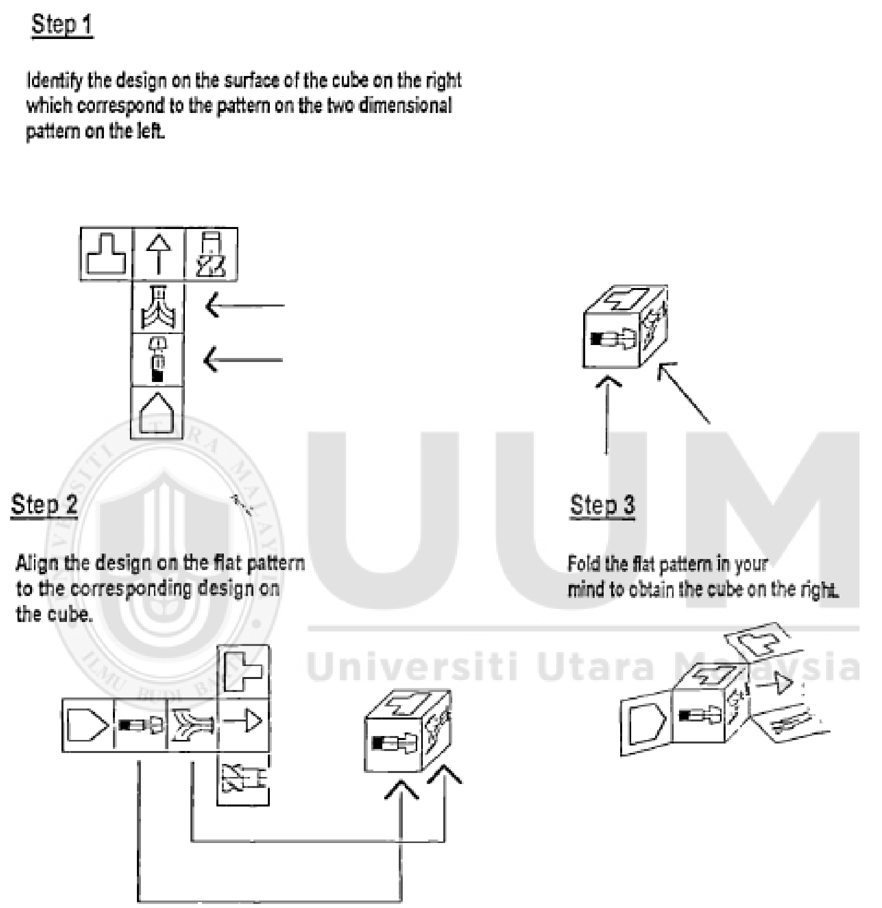
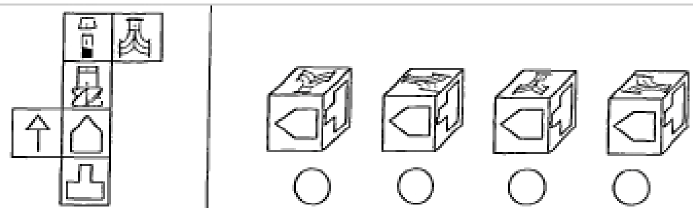


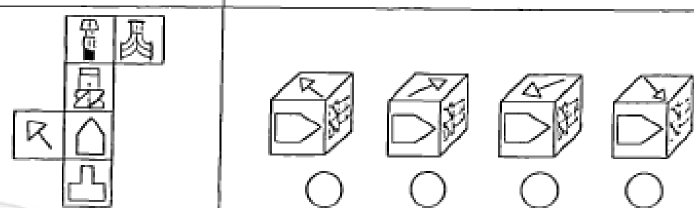
Figure 1. Solving strategy for question 1 to 10.

Instruction : The two dimensional pattern on the left could be folded up to form the cube on the right. For Q1 – Q10 identify the correct cube corresponding to the given pattern. Indicate your answer with [X] in the appropriate circle.

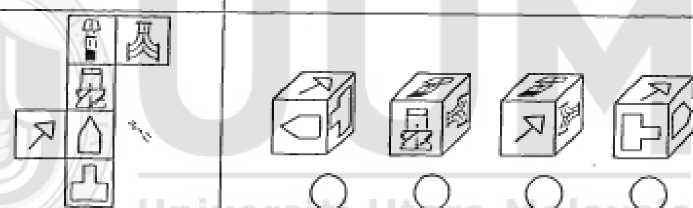
Q 1.



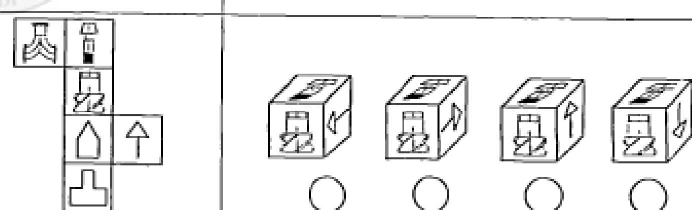
Q 2.



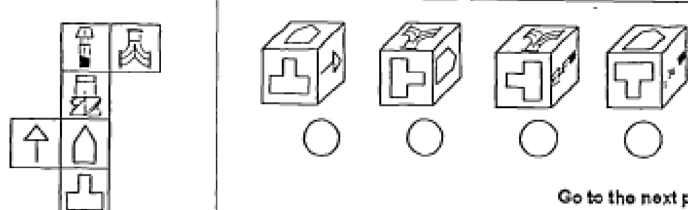
Q 3.



Q 4.



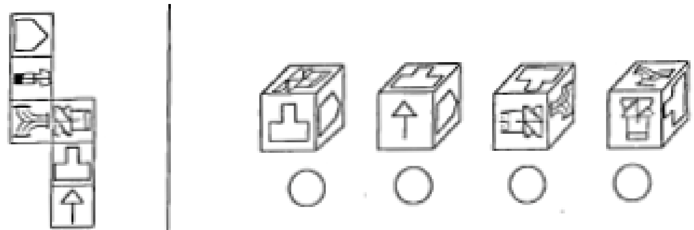
Q 5.



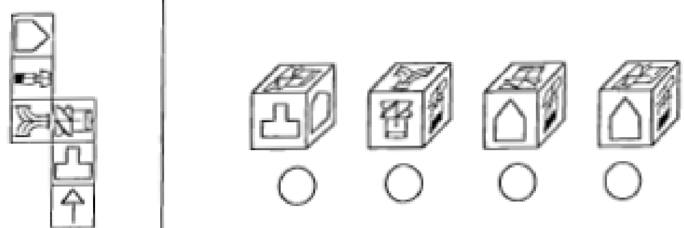
Go to the next page.

Go to the next page

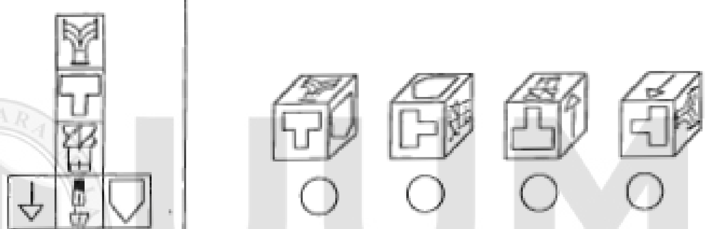
Q 6.



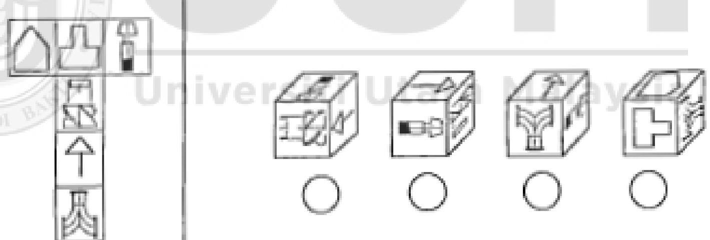
Q 7.



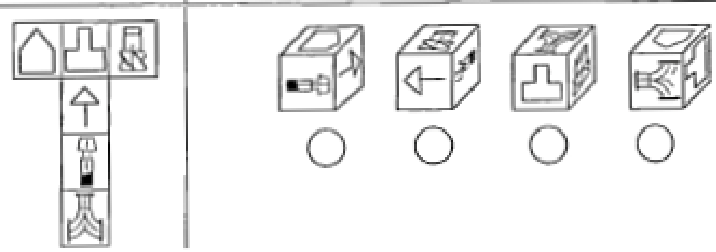
Q 8.



Q 9.



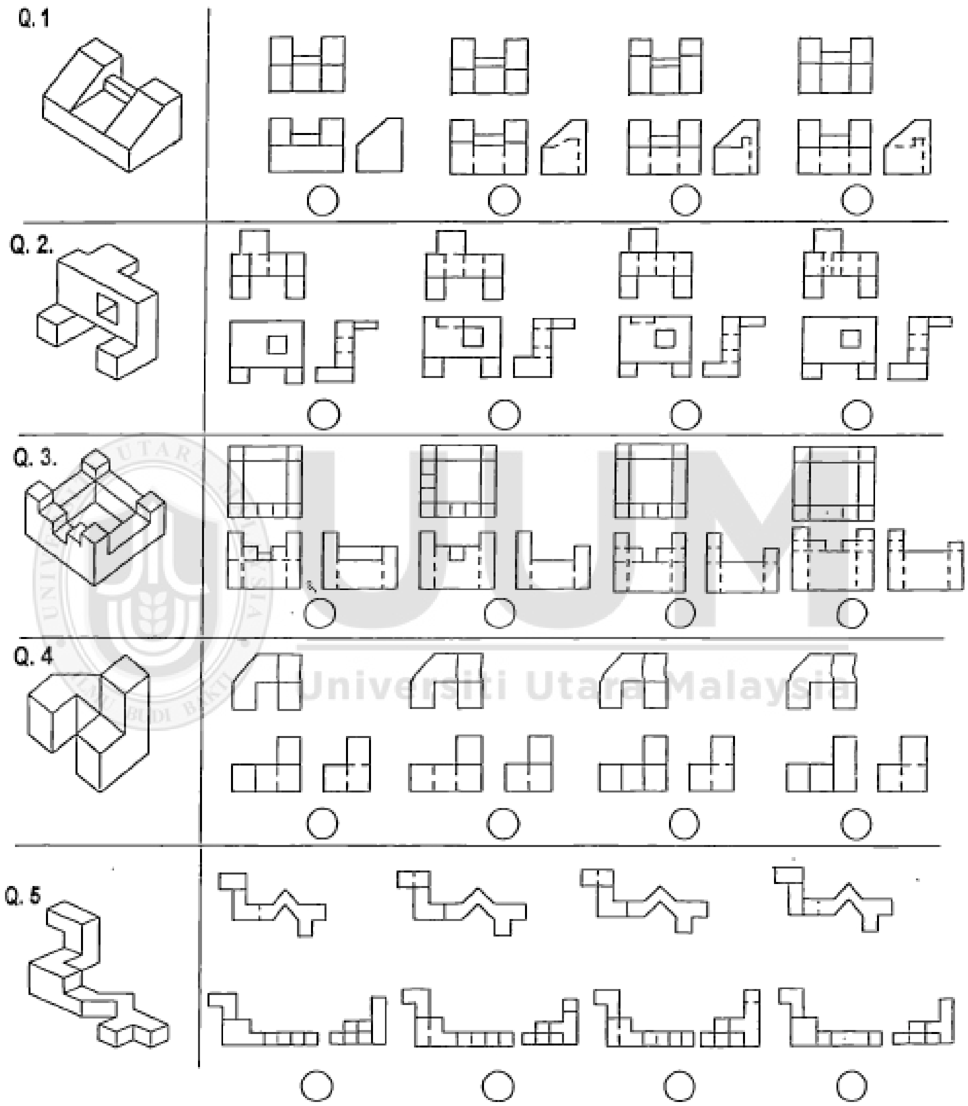
Q 10.



Go to the next page

Section ll : 8 minutes

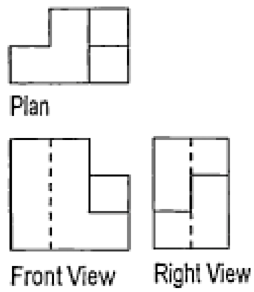
Instruction : For Q1 – Q5 identify the correct orthographic view for the isometric view given on the left. Indicate your answer with [X] in the appropriate circle.

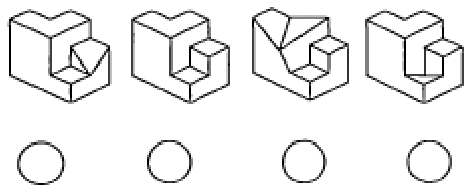


Go to the next page

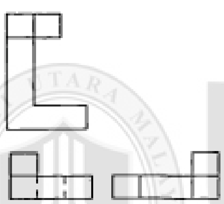
Instruction : For Q6 – Q10 choose the correct isometric view for the given orthographic views. Indicate your answer with [X] in the appropriate circle.

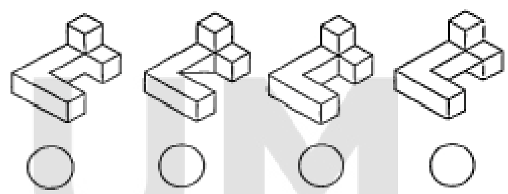
Q. 6



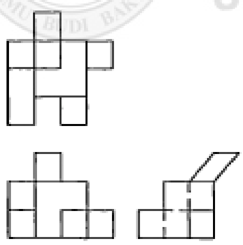


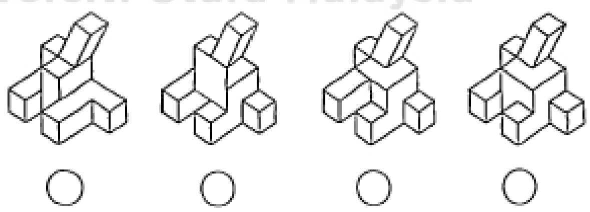
Q. 7





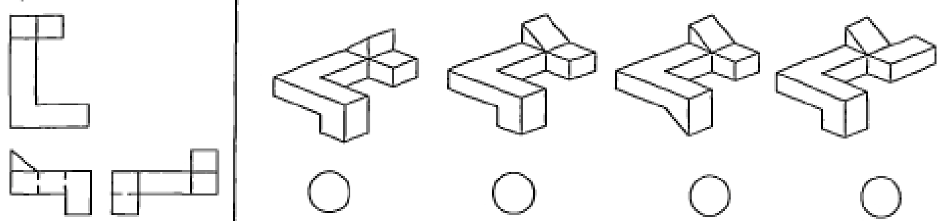
Q. 8



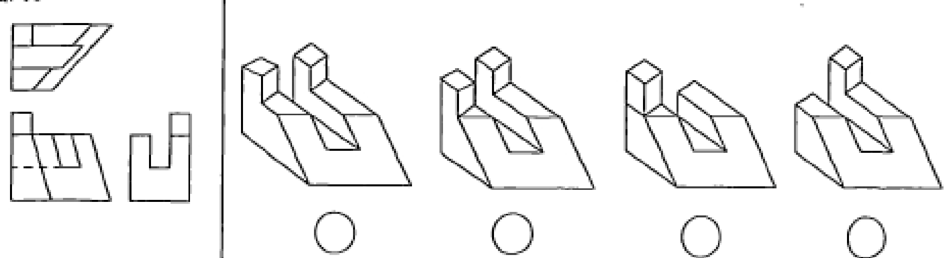


Go to the next page

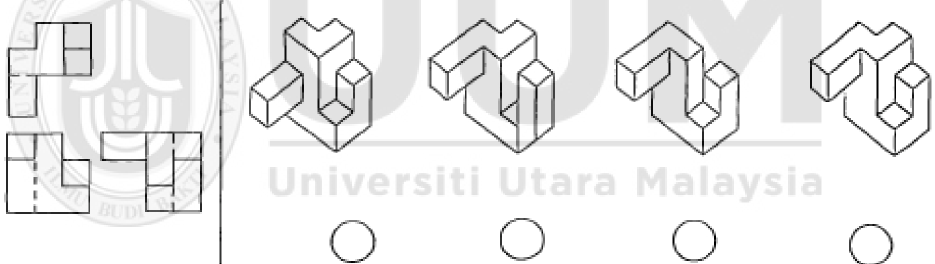
Q. 9



Q. 10



Q.11



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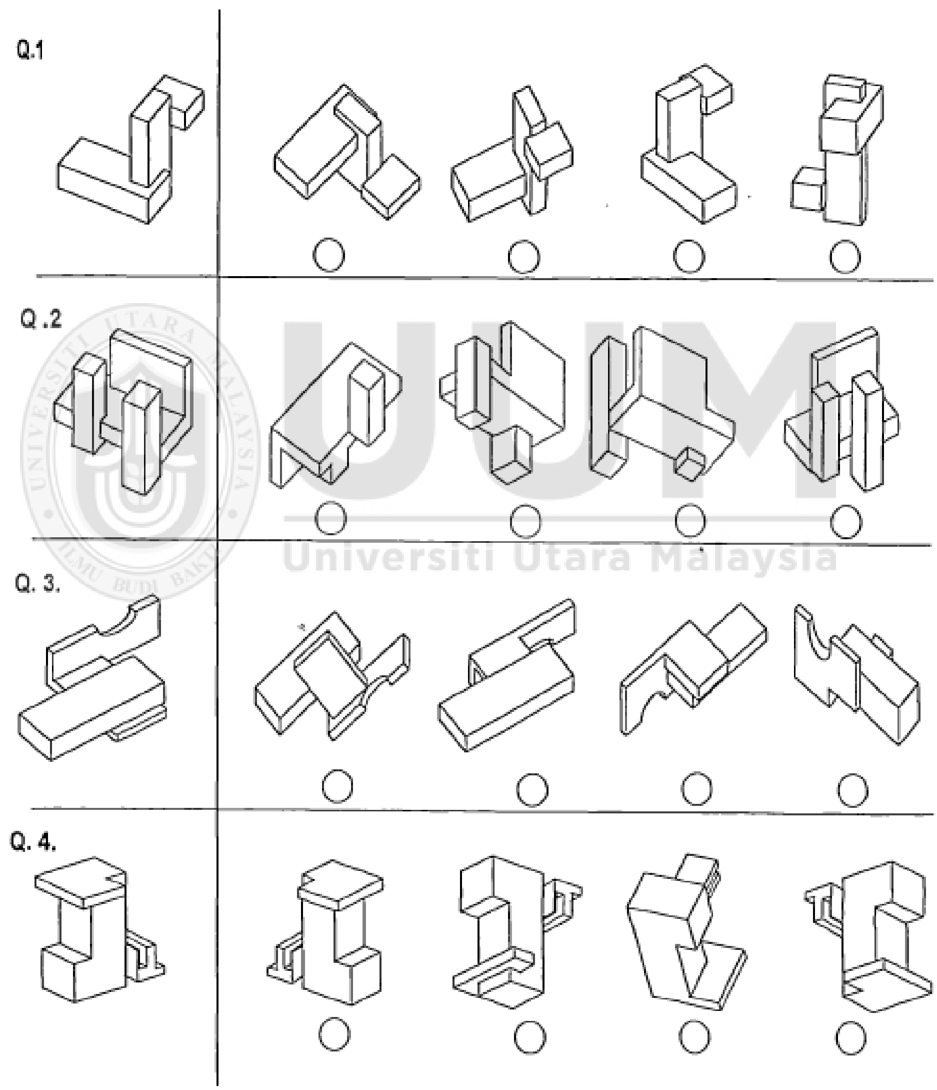
Section lll : 5 minutes

Instruction : One of the four alternative on the right is a the same object shown on the left as seen from a different view. For Q1 – Q8 identify the correct alternative that represent the left hand side project. Indicate your answer with [X] in the appropriate circle.



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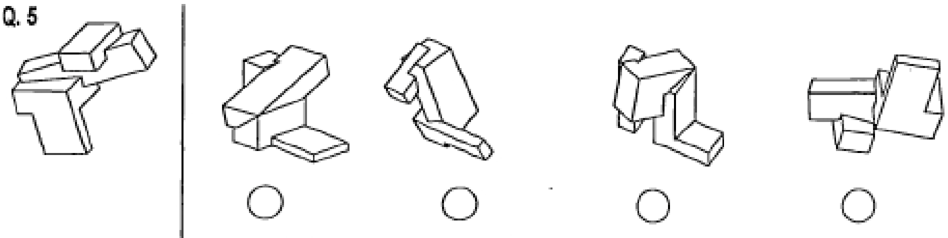
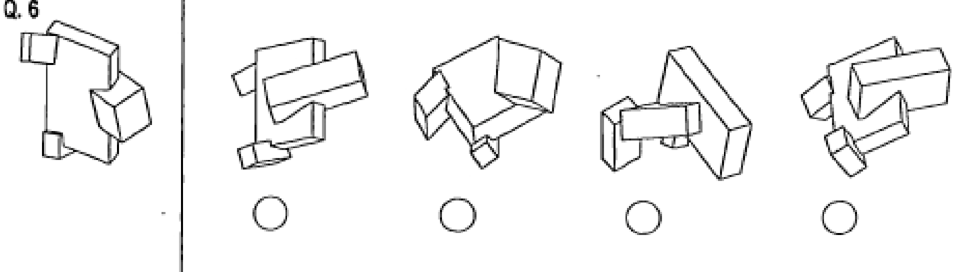
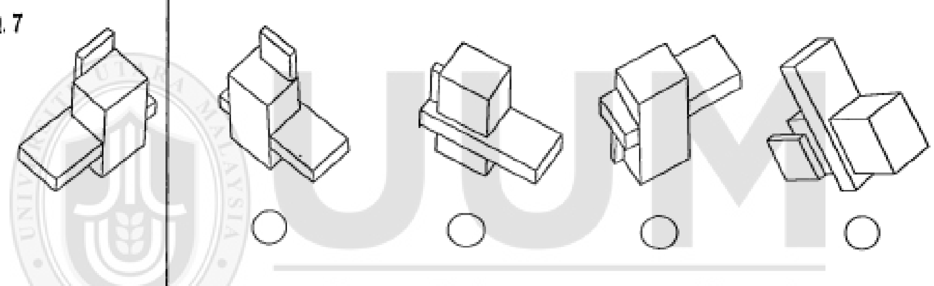
Q. 5



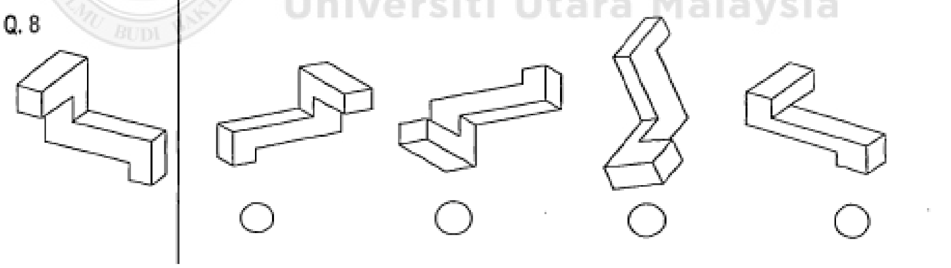
Q. 6



Q. 7



Q. 8



Go to the next page

SVATI Answer Scheme

Section l		Section ll		Section lll	
Q1	**D**	**Q11**	**D**	**Q22**	**A**
Q2	**B**	**Q12**	**B**	**Q23**	**C**
Q3	**D**	**Q13**	**C**	**Q24**	**C**
Q4	**A**	**Q14**	**C**	**Q25**	**D**
Q5	**C**	**Q15**	**C**	**Q26**	**D**
Q6	**C**	**Q16**	**B**	**Q27**	**D**
Q7	**A**	**Q17**	**C**	**Q28**	**C**
Q8	**B**	**Q18**	**D**		
Q9	**D**	**Q19**	**B**		
Q10	**B**	**Q20**	**D**		
		Q21	**D**		

This instrument is developed by

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Thank Yo

Appendix E

User Engagement Scale (UES)

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

User Engagement Scale (UES)

INSTRUCTIONS

There are 30 statements in this questionnaire. Answer the statements as precisely as could reasonably be expected. Record your responses on the answer sheet that is provided. The answers you give will be confidential, and will not affect you in any way. Use the response scale printed below.

TEST OBJECTIVE : To measure the students' learning engagement toward using MARCO treatment modes that include four factors which is Focus Attention (FA), Perceived Usability (PU), Aesthetic Appeal (AE) and Reward Factor (RW).

Polytechnic : __________________ No. matriks: ___________________

Mode: MARCO FR ☐
MARCO PR ☐

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly Agree**

NO	ITEM	SCALE				
	Focus Attention					
1	I lost myself in this experience.	1	2	3	4	5
2	I was so involved in this experience that i lost track of time.	1	2	3	4	5
3	I blocked out things around me when I was using MARCO.	1	2	3	4	5
4	When I was using MARCO, I lost track of the world around me.	1	2	3	4	5
5	The time I spent using MARCO just slipped away.	1	2	3	4	5
6	I was absorbed in this experience.	1	2	3	4	5
7	During this experience I let myself go.	1	2	3	4	5
	Perceived Usability					
8	I felt frustrated while using this MARCO.	1	2	3	4	5
9	I found this MARCO confusing to use.	1	2	3	4	5
10	I felt annoyed while using MARCO.	1	2	3	4	5
11	I felt discouraged while using this MARCO.	1	2	3	4	5
12	Using this MARCO was taxing.	1	2	3	4	5
13	This experience was demanding.	1	2	3	4	5
14	I felt in control while using this MARCO.	1	2	3	4	5
15	I could not do some of the things I needed to do while using MARCO.	1	2	3	4	5
	Aesthetic Appeal					
16	This MARCO was attractive.	1	2	3	4	5
17	This MARCO was aesthetically appealing.	1	2	3	4	5
18	I liked the graphics and images of MARCO.	1	2	3	4	5

19	MARCO appealed to be visual senses.	1	2	3	4	5
20	The screen layout of MARCO was visually pleasing.	1	2	3	4	5
	Reward Factor					
21	Using MARCO was worthwhile.	1	2	3	4	5
22	I consider my experience a success.	1	2	3	4	5
23	This experience did not work out the way I had planned.	1	2	3	4	5
24	My experience was rewarding.	1	2	3	4	5
25	I would recommend MARCO to my friends.	1	2	3	4	5
26	I continued to use MARCO out of curiosity.	1	2	3	4	5
27	The content of MARCO incited my curiosity.	1	2	3	4	5
28	I was really drawn into this experience.	1	2	3	4	5
29	I felt involved in this experience.	1	2	3	4	5
30	This experience was fun.	1	2	3	4	5

This instrument is developed by

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University of British Columbia

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Thank You

Appendix F

Learner's Characteristic Form

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

Learner Characteristic Form

INSTRUCTIONS

Answer all questions within the allocated time. The answers you give will be confidential.

TEST OBJECTIVE: To identify learner characteristic of Diploma in Information Technology (Digital Technology) semester 1 student who enroll DFC1033 Introduction to Computer System course

1. Matric No. : ……………………………………………
2. Semester : ……………………………………………
3. Age
   - ☐ 18 - 20
   - ☐ 21 - 23
   - ☐ 24 – 26
   - ☐ 30 above

4. Gender
   - ☐ Male
   - ☐ Female

5. Disability
   - ☐ No
   - ☐ Yes (please state) ………………………………….

6. Computer Skill
   - ☐ Poor
   - ☐ Basic
   - ☐ Intermediate
   - ☐ Advance

7. Internet Access
   - ☐ None
   - ☐ In campus only
   - ☐ Anywhere

8. Mobile Phone Usage
   - ☐ Low
   - ☐ Average
   - ☐ High

9. Multimedia and visual 3D interest
   - ☐ Not interest
   - ☐ Interest
   - ☐ Very interest

10. Mobile learning experience
   - ☐ No experience
   - ☐ Very rarely
   - ☐ Rarely
   - ☐ Often
   - ☐ Very often

Thank you

Appendix G

MARCO Application Evaluation (Alpha)

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

(Mobile Augmented Reality Computer Organization (MARCO) Application Evaluation (Alpha Test)

Much obliged for helping us to participate this MARCO application evaluation form. Your feedbacks are essential to us in improving the quality of the application design.

Name: ______________________________

School: ______________________________

Position: ______________________________

Years of Experience: ______________________________

Date of Evaluation: ______________________________

Signature: ______________________________

1	**2**	**3**	**4**	**5**
Very poor	Poor	Adequate	Good	Very Good

Subject Content		Very poor	Poor	Adequate	Good	Very Good
1	Learning objective specified	1	2	3	4	5
2	Learner identification specified	1	2	3	4	5
3	Contents are based on learning objective	1	2	3	4	5
4	Contents are based on syllabus	1	2	3	4	5
5	Instructions are easy to follow	1	2	3	4	5
6	Content accuracy	1	2	3	4	5
7	Concept and language level is appropriate for the students	1	2	3	4	5
8	Content validity	1	2	3	4	5
9	Language is easy to understand	1	2	3	4	5

Ease of Use		Very poor	Poor	Adequate	Good	Very Good
1	Manual is clearly written	1	2	3	4	5
2	Documentation and user manual provided	1	2	3	4	5
3	User friendly interface and navigation	1	2	3	4	5

Quality of Display/ Presentation		Very poor	Poor	Adequate	Good	Very Good
1	Screen displays are effective	1	2	3	4	5
2	Techniques of presentation are appropriate	1	2	3	4	5
3	Using appropriate colour scheme	1	2	3	4	5
4	Text and graphic well arrange	1	2	3	4	5
5	Consistency of the information	1	2	3	4	5
6	Design of the screen display is effective	1	2	3	4	5
7	User manual is effective	1	2	3	4	5
8	3D and animation quality	1	2	3	4	5

Instructional Learning		**Very poor**	**Poor**	**Adequate**	**Good**	**Very Good**
1	Interactivity	1	2	3	4	5
2	Enhance thinking skills	1	2	3	4	5
3	Adequate cognitive level	1	2	3	4	5
4	Improve learning motivation	1	2	3	4	5
5	Appropriate to the target user	1	2	3	4	5
6	Intellectual skill enhancement	1	2	3	4	5
7	Encourage systematic information processing	1	2	3	4	5
8	Presentation procedures of the contents are various	1	2	3	4	5
9	Frequent feedback of student's performance	1	2	3	4	5

List out the strength of the application (if necessary):

____
____
____

List out the weakness of the application:

____
____
____

Suggestion:

____
____
____

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Adapated and prepared by:
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Dr. Subashini Annamalai
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Appendix H

MARCO Application Content Evaluation

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

(Mobile Augmented Reality Computer Organization (MARCO) Application Content Evaluation

Much obliged for helping us to participate this MARCO application evaluation form. Your feedbacks are essential to us in improving the quality of the application design.

Name: ______________________________

School: ______________________________

Position: ______________________________

Years of Experience: ______________________________

Date of Evaluation: ______________________________

Signature: ______________________________

1	2	3	4	5
Very poor	Poor	Adequate	Good	Very Good

Subject Content		**very week**	**week**	**unsure**	**good**	**very good**
1	Learning objective specified	1	2	3	4	5
2	Learner identification specified	1	2	3	4	5
3	Contents are based on learning objective	1	2	3	4	5
4	Contents are based on curriculum	1	2	3	4	5
5	Instructions are easy to follow	1	2	3	4	5
6	Content accuracy	1	2	3	4	5
7	Concept and language level is appropriate for the students	1	2	3	4	5
8	Content validity	1	2	3	4	5
9	Language is easy to understand	1	2	3	4	5

List out the strength of the application (if necessary):

____

____

____

List out the weakness of the application:

____

____

____

Suggestion:

____

____

____

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Appendix I

MARCO Application Evaluation (Beta)

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

(Mobile Augmented Reality Computer Organization (MARCO) Application Evaluation (Beta Test)

Much obliged for helping us to participate this MARCO application evaluation form. Your feedbacks are essential to us in improving the quality of the application design.

Name: ______________________________

School: ______________________________

Position: ______________________________

Years of Experience: ______________________________

Date of Evaluation: ______________________________

Signature: ______________________________

1	2	3	4	5
Very poor	Poor	Adequate	Good	Very Good

Instructions:
Please respond to the following questions by circling the number and by writing the respond that best describes how you feel about the courseware. Your comments will help us improve the quality of the courseware and will be kept confidential.

Please circle the appropriate response, the rating scale goes from 1 to 5 as below:
1= strongly disagree 2= disagree 3= neutral 4= agree 5= strongly agree

NO	**ITEM**	**SCALE**				
1	User friendly interface	1	2	3	4	5
2	Content presentation is suitable	1	2	3	4	5
3	Content is well arranged	1	2	3	4	5
4	Usage of icon is suitable	1	2	3	4	5
5	Screen displays are effective	1	2	3	4	5
6	Font size is suitable	1	2	3	4	5
7	Text and graphic well arrange	1	2	3	4	5
8	Concept and language level is appropriate for the students	1	2	3	4	5
9	Language is easy to understand	1	2	3	4	5
10	Using appropriate color scheme	1	2	3	4	5
11	Audio quality is good	1	2	3	4	5
12	Interface graphic quality is good	1	2	3	4	5
13	High quality 3D model and animation	1	2	3	4	5
14	Navigation button is supportive	1	2	3	4	5
15	Zero error for the presentation	1	2	3	4	5
16	Augmented Reality marker are well reponsive	1	2	3	4	5
17	Flexibility information presentation without any technical problems	1	2	3	4	5
18	Application is suitable for students centered learning	1	2	3	4	5

This evaluation form is developed by
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Appendix J

Lecturer's Guideline

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION
UNIVERSITI UTARA MALAYSIA
KEDAH DARUL AMAN

Lecturer's Guideline

Topic	**:** Introduction to Computer System and Computer Assembly and Installation
Course Learning Outcome (CLO)	**:** Apply knowledge of computer technology, computer hardware and computer maintenance
Course	**:** DFC1033 Introduction to Computer System (ICS)
Semester	**:** 1 (Diploma)
Experiment Mode	: Mobile Augmented Reality Computer Organization with Physical Realism Mobile Augmented Reality Computer Organization with Functional Realism

Before Experiment (Session 1) Week 1

1. Session 1 will be conduct in the computer laboratory during DFC1033 Introduction to Computer System (ICS) course class time period.
2. Distribute Spatial Visual Ability Test Instrument (SVATI) and Computer System Organization Test (CSOT) Pretest to students.
3. Lecturer is required to spend 15 minutes briefing and instructions concerning the Learner's Characteristic Form, SVATI and CSOT Pre-Test.
4. 15 minutes will be allocated to fill particulars in Learner's Characteristic Form and after that 30 minute will be allocated to complete SVATI and lastly, another 30 minutes will be allocated to complete CSOT Test.
5. The students should be advised to answered the Pretest on their own without discussing to their classmates or referring course notes.
6. After completing, students are required to submit all form and test back to the lecturer.

During Experiment (Session 2) Week 2

1. Class session will be conduct in the computer laboratory during DFC1033 Introduction to Computer System (ICS) course class time period.
2. Lecturer will start to give instruction and briefing on the experiment procedure and introduction on MARCO application by referring to the MARCO user manual.
3. Distribute student's manual and MARCO user manual.
4. Student will be given 1-hour session to explore and learn using MARCO. Student are required to complete every learning step in MARCO.
5. Assist the students face any difficulties.
6. After completing, students are required to completed User Engagement Scale (UES) in 30 minutes and after that student are required to completed Instructional Materials Motivation Scale (IMMS) in 30 minutes. Lectures will assist students on the instrument's items if their face any difficulties.

7. Final step, lecturer will request students to answer the CSOT Post-Test. Students are allocating 30 minutes to answer all the questions. Course notes and discussion are prohibited.
8. After completing, students are required to submit all form and test back to the lecturer.

Table below shows list of instrument, treatment and duration of assessments for the two experiment session.

Session June 2020 Week 1					
Session 1	Tests/ Treatments	Times (Minutes)			
		15	15	30	30
	Briefing / Introduction	■			
	Learner's Characteristic Form		■		
	SVATI			■	
	CSOT Pretest				■

Session June 2020 Week 2					
Session 2	Tests/ Treatments	Times (Minutes)			
		15	60	30	30
	Briefing / Introduction	■			
	Treatment (MARCO-FR/ MARCO-PR)		■		
	UES			■	
	IMMS			■	
	CSOT Posttest				■

Thank You

Appendix K

Students' Instruction Manual

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

Students' Instruction Manual

Topic	**:** Introduction to Computer System and Computer Assembly and Installation
Course Learning Outcome (CLO)	**:** Apply knowledge of computer technology, computer hardware and computer maintenance
Course	**:** DFC1033 Introduction To Computer System (ICS)
Semester	: 1 (Diploma)
Experiment Mode	: Mobile Augmented Reality Computer Organization with Physical Realism Mobile Augmented Reality Computer Organization with Functional Realism

STUDENT INSTRUCTION

1. You are required to install Mobile Augmented Reality Computer Organization (MARCO) into your mobile phone using SDK provided.
2. Please go through the MARCO application individually but may get help from lecturers when needed.
3. Please follow MARCO application learning instruction provided. Please refer to user manual for assistant.
4. Inside MARCO application, there are two type of application. You are only permits to use one of these type of MARCO:
    i) **Functional Realism:** Marker triggered by image and provided 3D models and animation with supporting information
    ii) **Physical Realism:** Marker triggered by actual computer hardware and provide actual physical model with supporting information and 3D model and animation.
5. There are two part to complete **(i) Computer Hardware Component** and **(ii) Computer Hardware Assembly**. You are required to follow each step by step tutorial provided.
6. You are given an hour (60 minutes) to complete all part in MARCO.
7. After completing, please note that you are required to answer Computer System Organization Test (CSOT) Pretest. Discussion, notes and assistant from lecturer and friend are prohibited. 30 minutes provided to complete the test.
8. Finally, you are required to complete two types of questionnaires provided:
    i) User Engagement Scale (UES)
    ii) Instructional Material Motivation Scale (IMMS)
9. Fill up your **Matric No.** and read the instruction wisely and complete the questionnaires based on your personal experience. 30 minutes provided to complete both questionnaires.

12. Good luck and all the best.

Appendix L

Computer System Organization Test (CSOT) Pre-Test

SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION

UNIVERSITI UTARA MALAYSIA

KEDAH DARUL AMAN

Computer System Organization Test (CSOT) Pre-Test

Instruction:

This test paper consists of 25 questions divided into 2 (TWO) section A and B. Section A comprises of 15 questions and Section B comprises of 10 questions.

You are given 30 minutes to answer all the questions.

Name: ________________________________

Matric Number: ________________________________

Section A : Computer Component

Figure 1 : Computer Component

Question 1 – 16 is based on figure 1. Please identify each computer component label with number.

1. What kind of computer component label number 1?

A. Motherboard
B. Power Supply
C. Graphic Card
D. Fan

2. What is the best given statement below to describe component 1?

A. Help to increase electricity intake to a computer
B. Help to identify electricity intake to a computer
C. Help to convert high voltage electric to low voltage electric
D. Help to run high voltage electric to low voltage electric

3. What kind of computer component label number 2?

A. Heat Sink
B. Power Supply
C. RAM
D. Fan

4. What is the main function of component 2?

A. Filter dust from inside the case
B. Filter dust from outside the case
C. Force air to move out, so the hot air is blown away from heat-generating components and expelled from the case
D. Force air from outside to inside the case to cooldown heat-generating components

5. What kind of computer component label number 3?

A. Hard Disk
B. Power Supply
C. CPU
D. Fan

6. Component 3 is the brains of the computer. Choose the best statement to describe which the main function of component 3?

A. Store programs and data that are not currently being used
B. Executes a program, which is a sequence of stored instructions
C. Acquire, retain and retrieve information from memory
D. Help protect or speed up the performance of a computer's disk storage

7. What kind of computer component label number 4?

A. RAM
B. Power Supply
C. Graphic Card
D. Fan

8. Component 4 is essential for quick operation and processing performance of the computer Identify which is the main function of component 4?

A. **A temporary memory chip measured in gigabytes that operates software.**
B. A memory chip that permanently stores data on a computer.
C. A graphics chip that runs the monitor of the computer. Random Arithmetic Memory
D. Internal expansion card that allows the computer to communicate with another peripheral

9. What kind of computer component label number 5?

A. Motherboard
B. Cooler
C. Optical Drive
D. Graphic Card

10. Component 5 is one of the important components for visual presentation. Choose the best statement describing main function of component 5?

A. Provides input and output of audio signals to and from a computer under control of computer programs.
B. Store the data through a magnetic head inside of a casing which is air sealed
C. Controls the wired and wireless connections of a computer to exchange information with other computers and the Internet
D. Allow computers to produce graphics and images more quickly has its own processor.

11. What kind of computer component label number 6?

A. Motherboard
B. Power Supply
C. Graphic Card
D. Fan

12. Choose the main function of component 6?

A. A temporary memory chip measured in gigabytes that operates software.
B. An attachment that allows movies to be created
C. Permanent storage unit for files, programs and information
D. An add on that makes the computer operate faster

13. What kind of computer component label number 7?

A. Motherboard
B. Power Supply
C. Network Card
D. Fan

14. Component 5 is where all component will connect to it. What is the main function of component 7?

A. Accommodates, internal and external connectors and various ports
B. Generate and output images to a display.
C. Processing instructions sent to it by computer programs.
D. To provides a temporary data storage area for processor to access

15. What kind of computer component label number 8?

A. Motherboard
B. Fan
C. Graphic Card
D. Heat Sink

16. Which statement best describes the main function of component 8?

A. A passive cooling system that cools a component by dissipating heat. Prevent Your PC from Overheating.
B. Communicates with the computer processor and controls interaction with memory
C. Supplies electrical or other types of energy to an output load or group of loads
D. Facilitates the input and output of audio signals to and from a computer under control of computer programs

Question 17 – 21 is based on figure 2. Please identify each motherboard port and socket label with number.

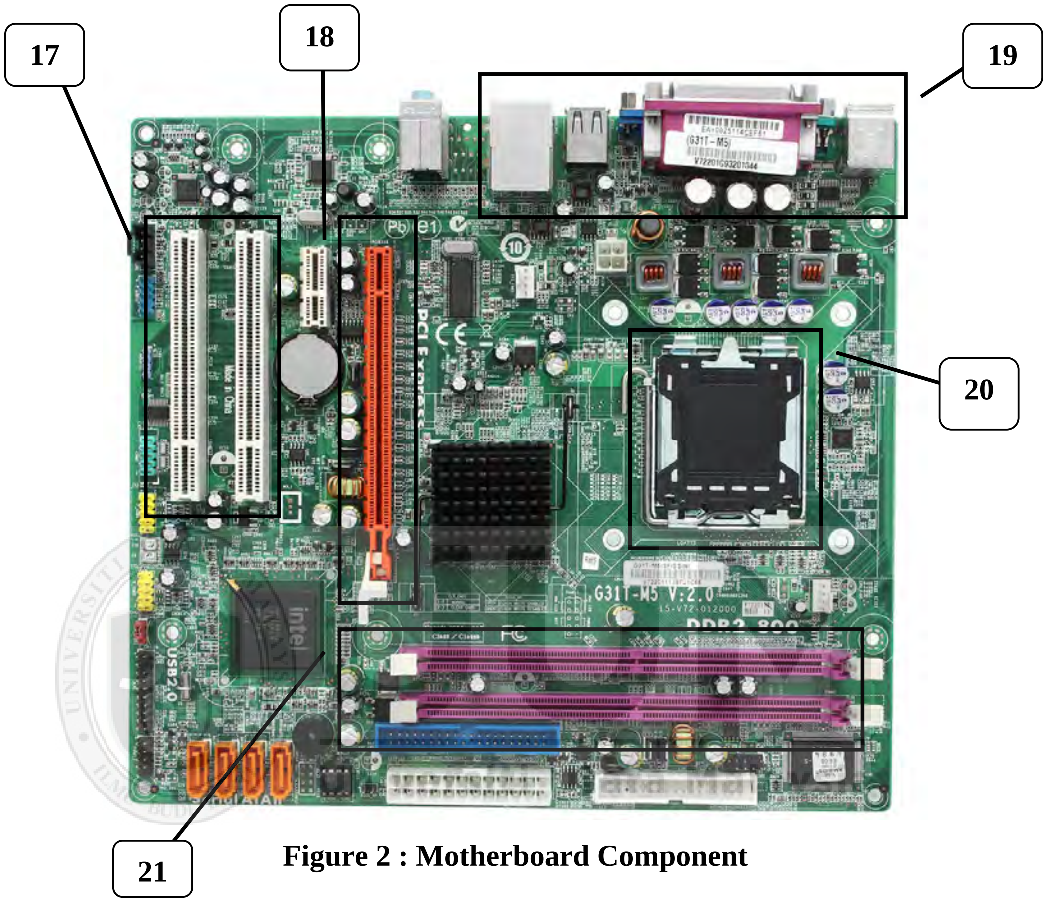


Figure 2 : Motherboard Component

17. ______________________

18. ______________________

19. ______________________

20. ______________________

21.______________________

Section B: Computer Assembly (Question 22 – 30)

22. How many main step involved in assembling internal part of computer?

A. 11 steps
B. 10 steps
C. 9 steps
D. 8 steps

23. The motherboard sits on top of the ______________ which screw into the computer case mounting point.

A. Mounting
B. Standoffs
C. Nut
D. Pin

24. Which are the following are the correct sequence installing CPU

i. Lower the CPU socket cover over the CPU and lower the latch lever closed again to secure
ii. Locate the CPU socket holder on the motherboard
iii. Line up any alignment notches or the triangle on the corner
iv. Lift up the latch lever to release and hinge open the CPU socker cover

A. iii, iv,ii,i
B. i,ii,iii,iv
C. ii, iv,iii, i
D. iv, iii, ii, i

25. Identify 2 (TWO) type of cabling connector from the power supply cabling that plug into motherboard

A. IDE Molex connector
B. 3 pin connectors
C. Sata connector
D. 8 pin and 24 pin connectors

26. Which are the following are the correct sequence installing RAM

i. Seat the RAM and press it firmly down into the slot
ii. Press to open clips at both ends of the ram mounting tools

iii. Line up the notch on the RAM stick with the mounting slot
iv. Tabs will automatically latch closed as press the RAM down, securing the RAM in place.

E. iv, iii,ii,i
F. i,ii,iii,iv
G. ii, iv,iii, i
H. ii, i, iii, iv

27. Which are the following motherboard slots is for primary Graphic Card?

A. PCI Express Slots
B. PCI Slots
C. Dual Channel Memory Slots
D. Parallel Port

28. Connect the hard disk to the motherboard using a ___________ cable

A. HDMI
B. VGA
C. Molex
D. SATA

29. Mount case fan by screws it through fan _________________ and power it up by connecting to _____________

A. Mounting holes, Fan power connector
B. Front panel port, USB
C. CPU slot, Molex port
D. Standoff screw, Power extension

30. After completing assembly all internal parts, secure case with screw and connect to _____________ devices

A. Power
B. Peripherals
C. Network
D. Audio

End of questions. Thank You

Appendix M
Expert Review Validation Form

I'm <name> <position> confirms that after checking the instruments transcript submitted to me by the researcher as it is

and

I also agree that after being given an explanation regarding the findings of this research by the researcher is what I mean in a revised transcript that has been conducted.

Experts' Signature

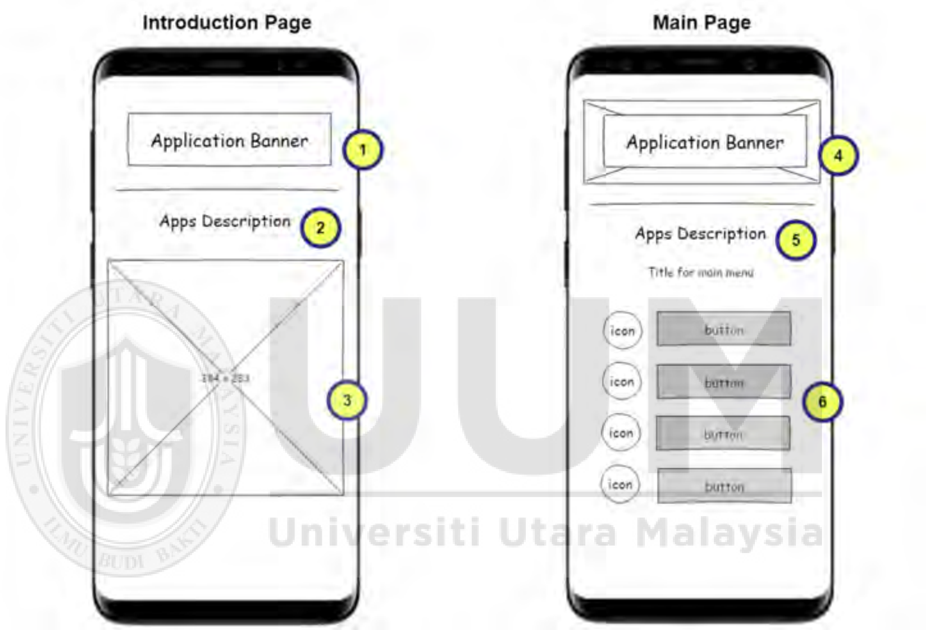
Researchers' Signature

____

____
(Mohd Razif bin Mustapha)

Appendix N

Storyboard Wireframe



Introduction Page

(1) Apps banner. Represent with design logo

(2) Apps description. Define two type of MARCO

- MARCO PR
- MACRO FR

(3) Design image center of the apps

Main Page

(4) Apps banner. Represent with design logo

(5) Apps description. Define two type of MARCO

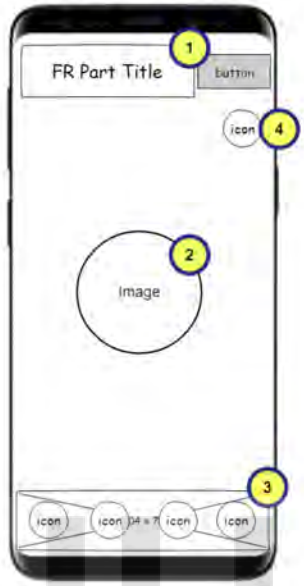
- MARCO PR
- MACRO FR

(6) Main menu button.

Consist of Part, Assembly, Guide and Back button


FR Main Page
FR Part Page
Application Banner
Apps Description
Title for main menu
icon
button
1
2
3
4
5
6
Apps banner. Represent with design logo
Apps description. Define two type of MARCO FR
PART
ASEMMBLY
Main menu button.
Consist of Part, Assembly, Guide and Back button
Apps banner. Represent with design logo
Apps description about computer parts.
Main menu button.
Consist of each computer parts and back button.

FR CPU Part Camera



1 Page panel consist of part name and back button

2 Undetected marker sign

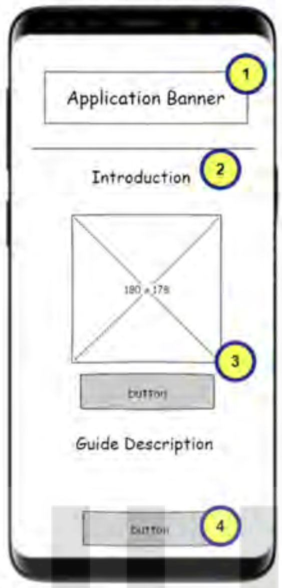
3 Bottom panel consist of rotating and scaling button

4 Info button containing panel about part description


MARCO PR Page
Application Banner
Apps Description
Title for main menu
icon
PR Instruction
icon
button
PR Camera
PR Part Title
button
Image
button
button
button
1 Apps banner. Represent with design logo
2 Apps decription on PR
3 PR button at center and back at bottom
4 Page panel consist of part name and back button
5 Undetected marker sign
6 Bottom panel consist of play, pause, and label button


FR Assembly Menu
Application Banner
Apps Description
Title for main menu
button
FR Assembly Part Camera
FR Part Title
button
Image
button
1 Apps banner. Represent with design logo
2 Apps description about pc part assembly.
3 Main menu button.
Consist of each assembly step and back button.
4 Page panel consist of part name and back button
5 Undetected marker sign
6 Bottom panel consist of play, pause, and label button

Guide Page



1 Apps banner. Represent with design logo

2 Apps intro and guide explanation.

3 Marker design and download button

4 Back button

Appendix O

Semi Structured General Testing Interview

Note: These questions were used for the MARCO interviews to explore learner's perception of being engaged with the technology.

There are times when we become so involved using MARCO application that nothing else seems to matter; we lose track of time and our surroundings because we become so focused on the search experience.

1. Can you recall a time when you felt this way while using the MARCO?

   Probes:
   a. What MARCO content were you looking at?
   b. Where were you when you were using the MARCO?
   c. Can you estimate how long you were on the MARCO for?

2. In this particular situation, was looking for information on the MARCO a voluntary or mandatory activity for you?

3. Before you began to using and explore MARCO, did you have any expectations or goals in mind? What were they?

4. Please describe how the experience began.

   Probes:
   a. Did you begin with a known MARCO application? What does this opening screen look like? (ask about text, 3D Model, Animation and Graphics GUI)
   b. Was the screen appealing visually? In what way?
   c. What kinds of things did you have to do to begin exploring (e.g., search, and click on a link)?
   d. How did you make decisions at this stage of the exploring the MARCO?

5. What was it about using the MARCO that made you continue? Probes:
   a. How focused were you on what you were doing?
   b. How aware were you of your physical surroundings?
   c. Did you feel distracted at all while exploring? What distracted you?

d. How challenging was using the MARCO for you?
e. During this MARCO learning session, would you describe yourself as a novice or an expert?
f. Did using the MARCO require a lot of effort on your part? How so?
g. When you made an error or a wrong turn while navigating, how did the MARCO let you know?
h. Did the MARCO always respond how you expected it to?

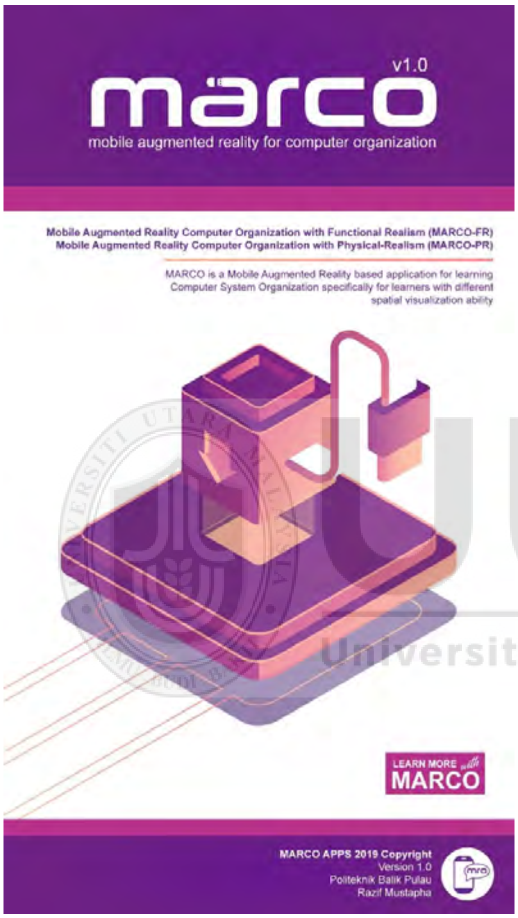
   Yes : How did it provide you with feedback?
   No : What was surprising about it?

i. Did you feel “in charge” while browsing for information? Why or why not?

6. How or why did you decide to stop using MARCO?
   Probes:
   a. Did you feel positive or negative as the session drew to a close? Why?
   b. What kind of reward did you get out of using the MARCO?
   c. Did you return to use MARCO after this particular session? Why or why not?
   d. Did you use any of the information gathered during this session? In what circumstance?

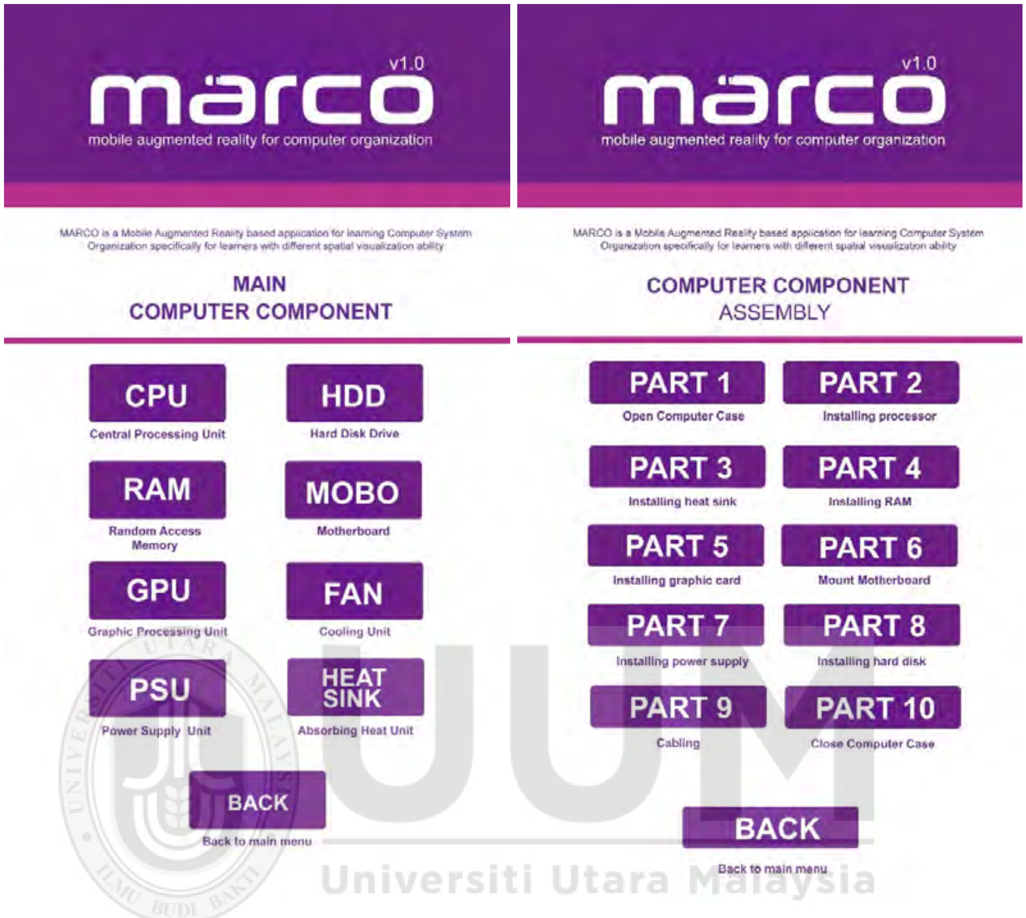
Appendix P

MARCO Interfaces



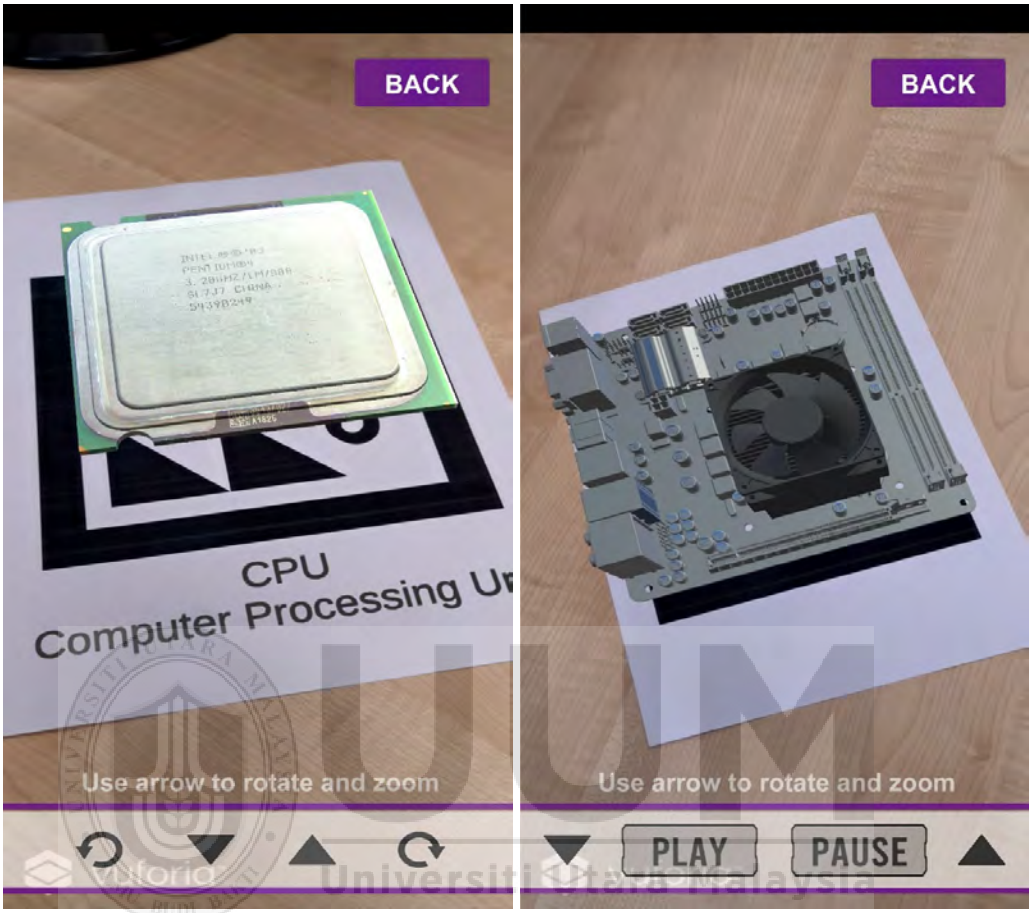

v1.0
marco
mobile augmented reality for computer organization
MARCO is a Mobile Augmented Reality based application for learning Computer System Organization specifically for learners with different spatial visualization ability
MARCO
FUNCTIONAL REALISM
PART
Computer component simulation
ASSEMBLY
Computer component assembly simulation
GUIDE
User guide to use MARCO FR
BACK
Back to main menu


v1.0
marco
mobile augmented reality for computer organization
MARCO is a Mobile Augmented Reality based application for learning Computer System Organization specifically for learners with different spatial visualization ability
MARCO
PHYSICAL REALISM
Please point application camera toward actual component provided to trigger augmented reality content
BACK
Back to main menu


v1.0
marco
mobile augmented reality for computer organization
MARCO is a Mobile Augmented Reality based application for learning Computer System Organization specifically for learners with different spatial visualization ability
MAIN
COMPUTER COMPONENT
CPU
Central Processing Unit
HDD
Hard Disk Drive
RAM
Random Access Memory
MOBO
Motherboard
GPU
Graphic Processing Unit
FAN
Cooling Unit
PSU
Power Supply Unit
HEAT SINK
Absorbing Heat Unit
BACK
Back to main menu
v1.0
marco
mobile augmented reality for computer organization
MARCO is a Mobile Augmented Reality based application for learning Computer System Organization specifically for learners with different spatial visualization ability
COMPUTER COMPONENT
ASSEMBLY
PART 1
Open Computer Case
PART 2
Installing processor
PART 3
Installing heat sink
PART 4
Installing RAM
PART 5
Installing graphic card
PART 6
Mount Motherboard
PART 7
Installing power supply
PART 8
Installing hard disk
PART 9
Cabling
PART 10
Close Computer Case
BACK
Back to main menu


v1.0
marco
mobile augmented reality for computer organization
APPLICATION GUIDE
Welcome to MARCO
MARCO is a Mobile Augmented Reality based application for learning Computer System Organization specifically for learners with different spatial visualization ability. This application is developed as a instructional teaching aid to help student to visualize better.
marco
DOWNLOAD MARKER
MARCO FR
For MARCO-FR, please download marker and print the marker to trigger augmented reality content. Point application camera toward the marker.
MARCO-PR
For MARCO-PR, please point application camera toward actual component provided to trigger augmented reality content.
DOWNLOAD USER MANUAL
BACK
Back to main menu


marco


BACK
CPU
Computer Processing U
Use arrow to rotate and zoom
BACK
Use arrow to rotate and zoom
PLAY
PAUSE


BACK
PLEASE SCAN MARKER
vuforia
BACK
RAM
Random Access Memory
Use arrow to rotate and zoom