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# THE EFFECT OF AUGMENTED REALITY MODULE ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT AND MOTIVATION IN LEARNING PROGRAMMING

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DISSERTATION PRESENTED TO QUALITY FOR A MASTER OF EDUCATION (RESEARCH MODE)

FACULTY OF COMPUTING AND META-TECHNOLOGY

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## ABSTRACT

The computer science subject poses significant challenges to learners, including cognitive overload due to abstract concepts, low motivation, and a lack of adequate visualization and learning materials. Thus, this study addressed these challenges by designing and developing an interactive Augmented Reality (AR) module (SmartAR Module) for programming. In particular, this study aimed to design, develop, and evaluate the SmartAR Module by examining its usability and effect on student achievement and motivation in learning computer science among secondary school students. Employing a one-group pre-test-post-test research design, this study utilized the ADDIE instructional design framework and Jonassen's (1977) problem-solving learning strategy to develop the module. Accordingly, the development process began with a needs analysis through semi-structured interviews with five computer science students and two teachers, followed by validation from seven experts. The experts agreed that the SmartAR Module is valid, robust, and aligned with Malaysia's computer science curriculum. As such, the module was implemented in a classroom setting with 30 Form 4 students over nine weeks, including the pre-test and post-test phases. Results indicated a significant increase in students' achievement scores after using the module. Specifically, mean scores improved markedly from the pre-test ($M = 43.27$, $SD = 1.78$) to the post-test ($M=81.80$, $SD=11.05$). Meanwhile, a paired-sample t-test confirmed that this difference was statistically significant, $t(29) = 20.16$, $p<.001$. Moreover, usability ratings for the module were high overall ($M = 4.89$, $SD = 0.30$), with particularly strong ratings observed in cognitive usability ($M = 4.97$, $SD=0.18$). Simultaneously, student motivation measurements across attention, relevance, satisfaction, and confidence dimensions averaged 4.57, indicating excellent motivation. Concurrently, this study contributes to educational technology by demonstrating the effectiveness of AR integration in computer science subjects. In essence, the findings suggest that interactive AR experiences significantly enhance learning and maintain students' attention while developing essential problem-solving capabilities.

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# KESAN MODUL REALITI TERIMBUH TERHADAP PENCAPAIAN DAN MOTIVASI PELAJAR SEKOLAH MENENGAH DALAM PEMBELAJARAN PENGATURCARAAN

## ABSTRAK

Mata pelajaran Sains Komputer memberikan cabaran besar kepada pelajar, termasuk beban kognitif disebabkan konsep abstrak, motivasi yang rendah, serta kekurangan visualisasi dan bahan pembelajaran yang mencukupi. Kajian ini menangani cabaran-cabaran tersebut dengan mereka bentuk dan membangunkan modul Realiti Terimbuh (AR) interaktif SmartAR Module untuk sains komputer. Kajian ini bertujuan untuk mengkaji kebolehgunaan modul, kesan terhadap pencapaian pelajar, dan motivasi pelajar dalam pembelajaran sains komputer selepas menggunakan SmartAR Module dalam kalangan pelajar sekolah menengah. Kajian ini menggunakan reka bentuk satu kumpulan dengan praujian dan pascaujian serta mengaplikasikan rangka kerja reka bentuk pengajaran ADDIE dan strategi pembelajaran berasaskan penyelesaian masalah oleh Jonassen (1977) dalam pembangunan modul tersebut. Proses pembangunan dimulakan dengan analisis keperluan melalui temu bual separa berstruktur dengan lima orang pelajar Sains Komputer dan dua orang guru serta diikuti dengan pengesahan daripada tujuh orang pakar. Para pakar bersetuju bahawa Modul SmartAR adalah sah, teguh, dan selaras dengan kurikulum sains komputer Malaysia. Modul ini dilaksanakan dalam suasana bilik darjah dan melibatkan 30 orang pelajar Tingkatan 4 selama sembilan minggu, termasuk fasa praujian dan pascaujian. Keputusan kajian menunjukkan peningkatan yang ketara dalam skor pencapaian pelajar selepas menggunakan modul. Skor min meningkat dengan ketara daripada ujian pra ($M = 43.27$, $SD = 1.78$) kepada ujian pasca ($M = 81.80$, $SD = 11.05$). Ujian-t sampel berpasangan mengesahkan bahawa perbezaan ini adalah signifikan secara statistik, $t(29) = 20.16$, $p < .001$. Selain itu, penilaian kebolehgunaan untuk modul adalah tinggi secara keseluruhan ($M = 4.89$, $SD = 0.30$), dengan penilaian yang sangat kukuh diperhatikan dalam kebolehgunaan kognitif ($M = 4.97$, $SD = 0.18$). Pengukuran motivasi pelajar merentasi dimensi perhatian, relevansi, kepuasan, dan keyakinan mencapai purata 4.57, menunjukkan tahap penglibatan yang tinggi.Kajian ini membuktikan keberkesanan integrasi AR dalam mata pelajaran Sains Komputer, sekali gus menyumbang kepada pengayaan teknologi pendidikan. Implikasi kajian ini menunjukkan bahawa pengalaman AR interaktif berpotensi meningkatkan pembelajaran pelajar melalui visualisasi konsep abstrak dan pengukuhan kemahiran menyelesaikan masalah.

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# CHAPTER 1

# INTRODUCTION

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## 1.1 Introduction

The integration of Computer Science (CS) subject into Malaysia's secondary curriculum (KPM, 2016) reflects programming's growing importance in developing computational thinking skills (Jacob & Warschauer, 2024; Zainil, Kenedi, Rahmatina, & Handrianto, 2022). In the computer science syllabus, students learnt basic principles of programming, the functioning of various digital systems, and the application of this knowledge in programming (Almdahem, 2024). Feurzeig et al. (1970) introduced programming as a way for students to understand mathematical concepts like variables, functions, and problem-solving techniques. Learning programming requires an understanding of language rules and the semantics of various constructs (Vinnervik,

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2023). This foundation has changed greatly in recent years where several nations are now encouraging learners to partake in programming as a way to prepare for a digitalized world (Scherer, Siddiq & Viveros, 2019). Fostering 21st century skills is required to respond effectively to the sophisticated demands of today's society (Satori, Komariah, & Suryana, 2019).

Although learning programming is critically important, students face significant challenges that negatively affect their academic achievements. The most profound challenge is the deep complexity of programming concepts and algorithms. Cheah (2020) emphasis students struggle with understanding abstract concepts like control structures, loops, and algorithms. This cognitive overload leads to confusion and hampers students' ability to apply their knowledge effectively (Cheah, 2020; Vinnervik, 2023; Chen, Zhang, & Zhang, 2022). Chen et al., (2022) highlights Students often fail to internalize algorithmic thinking due to the disconnect between abstract problem decomposition and their limited computational literacy. Furthermore, a lack of higher-order algorithmic thinking and lower-order computational thinking results in a lack of understanding to break down tasks into smaller sub-tasks (Durak et al., 2018; Dolgopolovas et al., 2018; Kadar et al., 2021).

In addition, students' achievement is also affected by lack of confidence in programming. These notions of self-inefficacy cause students to become anxious, avoidant, and withdraw from certain learning tasks (Günbatar & Karalar, 2018; Tsai et al., 2019). Furthermore, students frequently have difficulty visualising abstracts in programming concepts includes loops, functions and variables and thus fail to comprehend how these parts combine to form a program (Thompson & Lee, 2023).

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These issues are derived from traditional programming learning environments that lack in providing instant reflection or feedback. This process making difficult for students to recognize and remedy errors once it happened (Garcia & Brown, 2021). Ineffective teaching methods and limited instructional support more hinder students learning achievement as relying on passive learning (Patel & Wilson, 2022). Patel and Wilson, (2022) emphasis lecture-based approaches that fail to engage students or address individual learning needs.

Moreover, insufficient scaffolding, lack of prerequisite knowledge, and poorly structured guidance further prevent the development of fundamental programming foundation (Qian & Lehman, 2017; Zingaro et al., 2018; Margulieux et al., 2021). Cheah (2020) emphasis, static materials such as books fails to convey the dynamic nature of programming and leads to inadequate for teaching object-oriented programming. The negative perception of programming difficulties and inadequate teaching material directly affect students' intrinsic motivation (Cheah, 2020). Student motivation emerges as a critical factor in overcoming these programming challenges. Research demonstrates that motivation significantly influences students' persistence (Tsai & Lai, 2022), engagement with complex problem-solving (Medeiros et al., 2019), and the effective application of computational thinking (Puganesri & Puteh, 2019). Students without prior programming experience shows lower levels of motivation and face greater difficulty in satisfying their psychological needs for autonomy and competence (Yong & Tiong, 2022). A study by Olipas (2022) further highlights specific obstacles faced by IT students, including difficulties with programming syntax, debugging, and comprehending core concepts such as loops and decision statements.

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These findings underscore the need for innovative approaches that can enhance both achievement and motivation simultaneously.

In address these challenges, Malaysia curriculum has used multiple learning resources and hands on tools to make computer science subject significantly programming interestingly to improve students' achievement and motivation. Firstly, the staple textbooks for Form 4 and Form 5 aligned with Malaysian National Curriculum (KSSM) emphasizes *Kemahiran Berfikir Aras Tinggi* (KBAT) and 21st century skills. Next, Malaysian Ministry of Education's curriculum updates, secondary school students learning programming using Microsoft Visual Basic, JavaScript, MySQL and HTML. Additionally, Malaysia curriculum used Arduino Micro: Bit and Scratch free sources for hands-on programming and robotics to teach algorithmic thinking and AI concepts (Razak, Ismail, Mahadzir, Idrus, & Ramli, 2024). Furthermore, Razak et al., (2024) highlighted government allocated 38 million in Budget 2023 for teaching aids to address proficiency gaps and professional development programs.

Additionally, in general ClassCode (Suzuki, Kato, Yatani, 2020) provides a web-based interactive environment that allows students to learn at their own pace and engage with coding exercises embedded within tutorials. Similarly, Computer-Supported Collaborative Learning (CSCL) by Ludvigsen & Morch (2010) provides platforms integrate collaborative and competitive elements to facilitate social interaction among learners, often through web-based digital learning environments and e-learning media. Although numerous tools exist to support the teaching and learning of programming, many challenges persist. From the students' perspective, a significant

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issue is their lack of problem-solving skills (Bosse & Gerosa, 2017; Gomes & Mendes, 2007; Robins, 2019; Savage & Piwek, 2019). Next, the existing Malaysia curriculums are tools, however lack of innovative teaching aids to support the tools. Bacia (2024) emphasizes that well-designed learning materials are critical to complement technological tools, improving student engagement, comprehension, and academic performance.

Furthermore, both previous innovations are web-based, which may limit their accessibility and engagement potential. According to Osembe and Khomo (2024), mobile learning technologies provide more flexibility and promote active participation in the learning process. Chen and Lee (2015) emphasised mobile application learning significantly improved students' academic motivation, self-directed learning readiness, and learner-interface interaction compared to web-based learning on computers. Previous study, Chen et al. (2022) demonstrate that Augmented Reality AR technology further enhances programming education by transforming abstract logic into interactive, visual experiences that boost motivation and understanding. Consequently, these studies show integrating advanced technologies such as mobile apps and AR to address challenges in programming education and improve student outcomes.

Previous studies emphasize that AR can reduce anxiety, boost motivation, improve learning outcomes, and increase satisfaction (Bursali & Yilmaz, 2019; Chen et al., 2020). AR has also received considerable attention for the positive effects it has on the achievement of students academically (Boediono, Aulia, & Maulana, 2023; Wong et al., 2023; Pujiastuti & Haryadi, 2023; Ibrahim et al., 2024). In the programming education, previous studies developed AR modules in learning

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programming (Patel, 2017; Boonbrahm, Boonbrahm, & Sittichok, 2019; Kazanidis, Konstantinidis, & Chorianopoulos, 2018; Atika, Suryadi, & Kurniawan, 2020; Cevahir, Alkan, & Ozturk, 2022; Tasdonduren, Aybek, & Unal, 2022; Tsai & Lai, 2022; Yi-Ming, Wang, & Chang, 2023; Chuan, Liu, Yang, & Liu, 2023; Totogee, 2023). These applications show several different approaches includes Cevahir and et al. (2022) implemented animation-based AR, Tsai and Lai (2022) proposed a system for logic programming, and Nelson et al. (2017) studied an OOP module. Furthermore, Narman, Berry, Canfield, Logan, and Loftus (2020) developed an AR application for data structures learning in programming.

Notably, PlutoAR (Dash, Behera, & Dogra, 2024) demonstrated the effectiveness of mobile AR technology in creating portable, interactive programming experiences for K-10 students using affordable Android devices and highlights its flexibility, accessibility, and ability to create tangible learning experiences without requiring continuous internet connectivity. Mobile application augmented reality (AR) has been proven to positively impact the learning process and providing interactive 3D visualizations that enhance understanding and motivation of students. For example, Gutierrez-Jara, Malpica-Rodriguez, Perez-Aguilar, and Perez-Aguilar (2025) developed an AR mobile application for human anatomy education and it improved students' learning performance and motivation when they interacted with 3D models of human anatomy. Compared to traditional methods, the study showed better effective learning experiences. Additionally, Ramos, Noa, Villanueva, Carbonell, and Salazar (2021) have emerged as mobile AR applications made students more interested in and understood better the science and technology subjects. These studies show diverse methods for learning by making concepts that are abstract more concrete and applicable

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in reality while also allowing internet-free learning (Herpich, Nunes, Petri, & Tarouco, 2019; Gutierrez-Jara et al., 2025; Ramos et al, 2019).

However, critical analysis reveals that previous studies often fall short in integrating strategic problem-solving approaches and in measuring both student achievement and motivation. Many of the AR products developed suffer from issues such as cognitive overload and the ineffective use of multimedia, with limited attention given to evaluating usability and interactivity. Furthermore, there is a noticeable lack of studies that offer comprehensive learning materials supported by Augmented Reality mobile applications, particularly those aligned with the Malaysian Form 4 curriculum specifically the programming subtopic within the Form 4 Computer Science subject.

Therefore, this study aimed to design and develop an Augmented Reality mobile applications learning module, named the SmartAR Module. The study examined the effect on students' achievement before and after using the SmartAR Module, measured its usability, and evaluated students' motivation after using the module. Most significantly, this research addresses a critical gap in educational technology by creating an interactive AR programming module specifically designed for Malaysian Form 4 Computer Science students, contributing valuable insights to both programming education and multimedia educational design. The findings of this study have significant implications for curriculum development, instructional design and technology integration in the technology education at the secondary level. This study also fills the gap in multimedia education field.

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## 1.2 Research Background

An integrated, problem-centred approach to secondary STEM education is believed to be key in piquing students' interest and fostering a robust understanding of STEM subjects (Kennedy & Odell, 2014). The term STEM, coined in the 1990s by the National Science Foundation, stands for Science, Technology, Engineering, and Mathematics (Bybee, 2013). In line with global trends, the Malaysian Ministry of Education (MOE) has developed initiatives outlined in the Malaysian Education Blueprint (2013–2025) to increase both teacher and student competencies in STEM subjects, ultimately preparing students for a wide range of careers in these fields (Syazwani et al., 2020). Previous study by Srikoon et al. (2018) explains that STEM education aims to develop students' study-questioning, logical reasoning, and collaborative work behaviors. These skills are essential for enhancing critical thinking, creativity, and productivity, which are directly applicable to real-world situations (Widya, Ronal, & Laila, 2019). Han (2021) emphasizes the importance of creating appropriate instructional and social contexts to positively influence student learning and outcomes in STEM fields.

Various factors have been identified as crucial to student learning achievements. For example, Lastri et al. (2020) outline that learning motivation, interest in the subject, family environment, and teaching models significantly influence student performance. Academic achievement, a key indicator of academic success, is often the focus of educational efforts aimed at improving school outcomes (Suhaini et al., 2020). Sarif and Vandana (2022) define academic achievement as mastery of knowledge and skill development, which remains a primary concern for educators. Suhaini et al., (2020)

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further identifies four factors affecting student achievement: teaching strategies, student interest and motivation, school environment, and family support. Motivation is a crucial element for quality education (Filgona et al., 2020). Suhag et al. (2016) highlight that motivation enhances cognitive processing, making motivated students more engaged in material and less likely to simply passively observe learning activities. Yilmaz, Sahin, and Turgut (2019) also note that teacher competence, classroom management skills, and effective teaching methods are central to student motivation and performance.

In the modern era, programming skills are increasingly important, with expectations that these skills will drive educational development (Liang et al., 2022). Feurzeig et al. (1970) introduced programming as a way for students to understand mathematical concepts like variables, functions, and problem-solving techniques. Intelligence, defined as the ability to reason, plan, solve problems, and think abstractly (Gottfredson, 1994), plays a key role in programming education. The Ministry of Education (MOE) has incorporated computer science into the High School Curriculum to reinforce students' computer skills, knowledge, and values (KPM, 2016). This initiative aims to develop computational thinking, problem-solving abilities, and critical thinking (Fisk, 2017). The education system also promotes innovative thinking and problem-solving skills, in line with the goals of Industry 4.0 (Fisk, 2017).

Puganesri and Saifullizam (2019) emphasize the importance of computer science education in shaping students' social and economic futures. Computational Thinking (CT), introduced to foster problem-solving skills, is integral to programming and computer science (Angeli & Valanides, 2020; Papert, 1980). CT is defined as the ability to apply problem-solving strategies and build creativity and intelligence to meet

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the challenges of the 21st century (Salleh & Puteh, 2017). According to Predrag (2021) computational thinking is a skill that may be developed through the study of computer programming in basic school since it allows pupils to practice problem-solving methods like deconstruction, abstraction, pattern recognition, and algorithms. Students can learn the fundamental concepts of computation and information through programming, as well as how digital systems operate and how to apply this knowledge to become digitally literate at early stage (Hudin, 2023). However, several challenges hinder the teaching of programming at secondary schools, including a lack of motivation, programming incompetence, and negative perceptions towards the subject (Latih et al., 2020). The difficulty in understanding programming languages and the limited teaching time in schools contribute to these issues (Hani, Dewi, Liyana & Raha, 2021). A study by Masura (2022) identified several challenges in programming education, including the need for appropriate teaching materials, effective teaching strategies, and time management.

Additionally, Hudin's (2023) systematic review highlights key challenges in programming education, including teachers' lack of competency in programming knowledge, skills, attitudes, and digital pedagogy. It also identifies students' struggles with cognitive issues, limited computational thinking skills, and inadequate school resources, especially in rural areas. Ahmad and Ghazali (2020) emphasize educators face challenges in selecting appropriate teaching methods and tools, with traditional approaches proving ineffective. Additionally, programming syllabus and pedagogy need modernization to better support diverse learner needs and incorporate innovative teaching strategies. Furthermore, Fojcik, Hoyland, and Hoem (2022) emphasize that challenges in learning programming arise from both the structural aspects of

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programming such as syntax, interfaces, approaches, experience, and qualifications and the individual context of the learning situation, which includes the role of the teacher, students' motivation, and their expectations. This dual perspective on challenges is critical in understanding the complexities involved in programming education.

Moreover, Puganesri et al. (2019) found that even experienced teachers struggle to teach programming due to a lack of specialized materials and modules. This issue is exacerbated by teachers' limited expertise in computer science, which leads to ineffective teaching and a lack of problem-solving skills among students. Furthermore, inadequate resources and teaching methods contribute to poor academic performance (Ou, Liang, He, Liu, & Wu ,2023). In address these challenges, Malaysia curriculum has used multiple learning resources and hands on tools to make computer science subject significantly programming interestingly to improve students' achievement and motivation. Firstly, the staple textbooks for Form 4 and Form 5 aligned with Malaysian National Curriculum (KSSM) emphasizes *Kemahiran Berfikir Aras Tinggi* (KBAT) and 21$^{st}$ century skills. Next, Malaysian Ministry of Education's curriculum updates, secondary school students learning programming using Microsoft Visual Basic, JavaScript, MySQL and HTML. Additionally, Malaysia curriculum used Arduino Micro: Bit and Scratch free sources for hands-on programming and robotics to teach algorithmic thinking and AI concepts (Razak, Ismail, Mahadzir, Idrus, & Ramli, 2024). Furthermore, Razak et al., (2024) highlighted government allocated 38 million in Budget 2023 for teaching aids to address proficiency gaps and professional development programs.

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Additionally, in general ClassCode (Suzuki, Kato, Yatani, 2020) provides a web-based interactive environment that allows students to learn at their own pace and engage with coding exercises embedded within tutorials. Similarly, Computer-Supported Collaborative Learning (CSCL) by Ludvigsen & Morch (2010) provides platforms integrate collaborative and competitive elements to facilitate social interaction among learners, often through web-based digital learning environments and e-learning media. Although numerous tools exist to support the teaching and learning of programming, many challenges persist. From the students' perspective, a significant issue is their lack of problem-solving skills (Bosse & Gerosa, 2017; Gomes & Mendes, 2007; Robins, 2019; Savage & Piwek, 2019). Next, the existing Malaysia curriculums are tools, however lack of innovative teaching aids to support the tools. Bacia (2024) emphasizes that well-designed learning materials are critical to complement technological tools, improving student engagement, comprehension, and academic performance.

The integration of Augmented Reality (AR) is particularly promising, as it creates dynamic, immersive learning environments that increase student motivation and improve learning outcomes (Kesim, 2012). AR bridges the physical and virtual worlds, helping students grasp abstract concepts and programming principles, making them more tangible and easier to understand (Rahmadani & Sunarmi, 2023). Moreover, AR supports the development of critical thinking, problem-solving skills, and motivation, all essential for success in STEM education. Previous studies explored the use of marker-based augmented reality modules in various educational contexts. For instance, Bakri et al. (2020) demonstrated that AR could translate abstract concepts into reality with high quality, making it suitable for independent learning materials in complex

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subjects like quantum phenomena. Similarly, Rahmadani and Sunarmi (2023) highlighted the benefits of integrating AR e-modules in biology education, which improved student learning outcomes, retention, and science literacy. Boonbrahma et al. (2020) found that marker-based AR provides high precision in measurements, further reinforcing the potential of AR in education.

Several studies have explored the application of Augmented Reality (AR) in programming education within the computer science curriculum, both internationally and in Malaysia (Patel 2017 ; Boonbrahm et al. 2019; Kazanidis, Konstantinidis, & Chorianopoulos , 2018; Atika, Suryadi, & Kurniawan, 2020 ; Cevahir, Alkan, & Ozturk , 2022 ; Tasdonduren, Aybek, & Unal, 2022 ; Tsai & Lai, 2022 ; Yi-Ming, Wang, & Chang , 2023; Chuan, Liu, Yang, & Liu , 2023; Totogee , 2023 ; Ivarson, Erlandsson , Faraon & Khatib , 2024 ; Aydin & Cakiroglu , 2024). Mobile application augmented reality (AR) has been proven to positively impact the learning process and providing interactive 3D visualizations that enhance understanding and motivation of students. For example, Gutierrez-Jara, Malpica-Rodriguez, Perez-Aguilar, and Perez-Aguilar (2025) developed an AR mobile application for human anatomy education and it improved students' learning performance and motivation when they interacted with 3D models of human anatomy. Compared to traditional methods, the study showed better effective learning experiences. Additionally, Ramos, Noa, Villanueva, Carbonell, and Salazar (2021) have emerged as mobile AR applications made students more interested in and understood better the science and technology subjects. These studies show diverse methods for learning by making concepts that are abstract more concrete and applicable in reality while also allowing internet-free learning (Herpich, Nunes, Petri, & Tarouco, 2019; Gutierrez-Jara et al., 2025; Ramos et al, 2019).

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Chuan et al. (2023) developed an AR Bot that provided 3D visual learning feedback, improving spatial ability and supporting deeper computational thinking. While students showed increased motivation, the study did not observe a significant effect on academic achievement. Kazanidis et al., (2018) explored mobile AR for teaching mobile programming at the undergraduate level and found the tool useful and easy to use, though its impact on motivation and achievement remained unclear. Similarly, Tasdondurena et al. (2022) found that AR improved middle school students' self-efficacy and attitudes toward coding, but did not measure student achievement. Yang et al., (2023) utilized AR-based virtual educational robotics to teach programming and found that students exhibited higher enjoyment, improved algorithm design skills, and greater algorithm efficiency. Additionally, Ivarson et al., (2024) explored the impact of combining augmented reality (AR) and gamification on students' motivation and learning in higher education, focusing specifically on web development education. Aydin and Cakiroglu (2024) developed an AR-based programming editor that uses a traffic metaphor to dynamically visualize text-based codes, enhancing programming education.

In Malaysia, Atika et al., (2020) developed an AR-based application using a 3Dimension ruler to visualize distances between robots, promoting STEM learning. Their study demonstrated increased student interest and engagement, but had a limited scope and did not fully integrate problem-solving strategies. For instance, Husnu et al. (2021) focused on AR mobile applications for learning computer science but did not incorporate comprehensive learning modules or target secondary school students enrolled in programming courses. Although these studies highlighted AR's potential for programming education, several shortcomings were evident. Lack of studies contained

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interactive modules integrated with problem-solving learning strategies. Additionally, previous studies lack in measuring student motivation and achievement simultaneously. In their study, Wen, Wu, and Hsu (2023) has shown that motivation, particularly intrinsic motivation stemming from one's competence and autonomy, is highly important in the effective learning of programming. Motivational measurement aids educators in understanding the emotional and cognitive aspects that impact student engagement and academic performance. Also, Boguslawski, Deer, and Dawson (2025) discusses the analysis of motivation in programming education and its value in designing optimal learning environments that navigate the complicated interplay between intrinsic and extrinsic motivation and skills of programming. Hence the need to examine the two aspects, especially in programming learning, is essential.

Furthermore, many studies relied on outdated technology, including older versions of Unity, which may limit their relevance in today’s educational settings (Alhussein, Patel & Liu,2023). To address these gaps, this study designed and developed a programming module, the SmartAR Module, aligned with the Malaysian Form 4 curriculum (Dokumen Standard Kurikulum dan Pentaksiran, DSKP), to better support secondary school students in learning programming concepts. The study investigated the effects of the SmartAR Module on students' achievement in programming, focusing on problem-solving approaches and control structures. Additionally, the study evaluated the usability of the SmartAR Module and the students' motivation after using it. By addressing the gaps in current AR programming modules, this study aimed to enhance student achievement and motivation in learning programming and contribute to the development of innovative learning materials.

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## 1.3 Problem Statement

In Malaysian secondary school students have specific difficulties learning problem-solving programming which impacts their motivation and academic achievement. These challenges are attributed to inadequate problem-solving knowledge and poor teaching which is textbook-oriented (Ghazali & Ahmad, 2020). The complex syntax in programming language often leads students struggling with motivation and basic mathematical and logical skills (Nazeri & Suliman, 2018). Furthermore, the absence of personalized teaching methods and resources that cater to diverse learning styles, along with a shortage of specialized modules on computational thinking, contributes to poor student outcomes (Puganesri & Puteh, 2019). Latih, Peremol, and Jailani (2020) also highlighted that low student motivation in programming can lead to programming incompetence and negative perceptions of the subject. Additionally, current Malaysia curriculum has multiple learning tools such as Microsoft Visual Basic, JavaScript, MySQL and HTML, Arduino Micro: Bit and Scratch free sources for hands-on programming and robotics to teach algorithmic thinking and AI concepts.

In terms of learning material, staple textbooks for Form 4 and Form 5 aligned with Malaysian National Curriculum (KSSM) emphasizes Kemahiran Berfikir Aras Tinggi (KBAT) and 21st century skills. Although numerous tools exist to support the teaching and learning of programming, many challenges persist. From the students' perspective, a significant issue is their lack of problem-solving skills (Bosse & Gerosa, 2017; Gomes & Mendes, 2007; Robins, 2019; Savage & Piwek, 2019). Bacia (2024) emphasizes that well-designed learning materials are critical to complement technological tools, improving student engagement, comprehension, and academic

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performance. To integrate innovative learning material, previous studies have explored augmented reality (AR) modules to improve programming education (Zhu, Wang, Yuan,2022; Atika et al. 2020; Tsai et al., 2022; Totogee, 2023 Chuan et al., 2023; Cevahir et al., 2022; Boonbrahm et al., 2019; Ivarson et al., 2024; Aydin & Cakiroglu , 2024). Zhu et al., (2022) developed an AR mobile application for teaching programming, which enhanced students' understanding of abstract programming concepts, engagement, and motivation. However, this study focused solely on Python and used a curriculum that differs from Malaysia's Form 4 computer science curriculum. Next, Aydin & Cakiroglu (2024) developed an AR-based programming editor that uses a traffic metaphor to dynamically visualize text-based codes shows enhancing programming education. However, this study focused solely on traffic metaphor and used a curriculum that differs from Malaysia's Form 4 computer science curriculum.

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Another study by Atika et al. (2020) implement a 3D AR ruler in a robotic education module, to represent the distance between robots for secondary and higher education students to stimulate their STEM learning. Although the application increased students' motivation and engagement level towards the games, it failed to have a complete problem strategy and did not measure the academic achievements of the students. Furthermore, the study's curriculum did not align with the Form 4 Computer Science syllabus, highlighting a gap in existing AR-based modules for teaching programming in Malaysia. There is a significant lack of studies integrate AR programming modules with real problem-solving scenarios that affect the students' achievement and motivation in simultaneously. Existing AR modules predominantly focus on either improving student achievement (Tsai et al., 2022; Totogee, 2023) or

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enhancing student motivation (Chuan et al., 2023; Cevahir et al., 2022; Atika et al., 2020; Boonbrahm et al., 2019), but rarely address both aspects together. Moreover, previous studies (Kazanidis et al., 2018; Tasdondurena et al., 2022; Yi-Ming et al., 2023; Tsai et al., 2022) have often lacked the interactive elements necessary for student engagement and maintaining motivation. Furthermore, issues such as poor lighting and marker quality were identified as factors that negatively impacted learning outcomes in AR modules (Totogee, 2023). Additionally, many past studies (Kazanidis et al., 2018; Tasdondurena et al., 2022; Ming et al., 2023) have relied on basic AR principles without incorporating advanced features that foster critical thinking and problem-based learning.

In conclusion, previous studies has examined the AR programming modules, but there is still a significant gap between innovation programming learning module integrated problem-solving learning strategies. To fill this gap, this study designed and developed the augmented reality programming learning module, and measured its effect on Form 4 Malaysian students' achievement. By integrating effective learning strategies, this study demonstrated how an interactive AR module can improve students' academic achievement and increased motivation in programming. This study contributes to educational multimedia by providing an innovative AR learning tool for secondary school students.

## 1.4 Research Objective

This study has five research objectives, which are:

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i. To analyse the needs for an augmented reality programming learning module in secondary school computer science education, based on students' and teachers' perspectives.

ii. To design and develop the Augmented Reality Programming Module namely SmartAR Module, for learning programming subject in secondary school.

iii. To evaluate the usability of the SmartAR Module in learning programming in secondary school.

iv. To investigate the effect of the SmartAR Module on students' academic achievement.

v. To investigate students' motivation after using the SmartAR Module.

## 1.5 Research Questions

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This study comprised five research questions:

i. What are the needs for an augmented reality programming module in secondary school computer science education, based on students' and teachers' perspectives?

ii. What is the validity of the SmartAR Module according to technological and content experts?

iii. What is the usability of the SmartAR Module for learning programming in secondary school?

iv. What is the effect of SmartAR Module on students' academic achievement?

v. What is students' motivation after using the SmartAR Module?

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## 1.6 Hypothesis

The hypothesis in this study as below:

> Ho1: There is no significant difference between the pre-test mean scores and post-test mean scores in students' achievement in learning programming before and after using the SmartAR Module.

## 1.7 Theoretical Framework

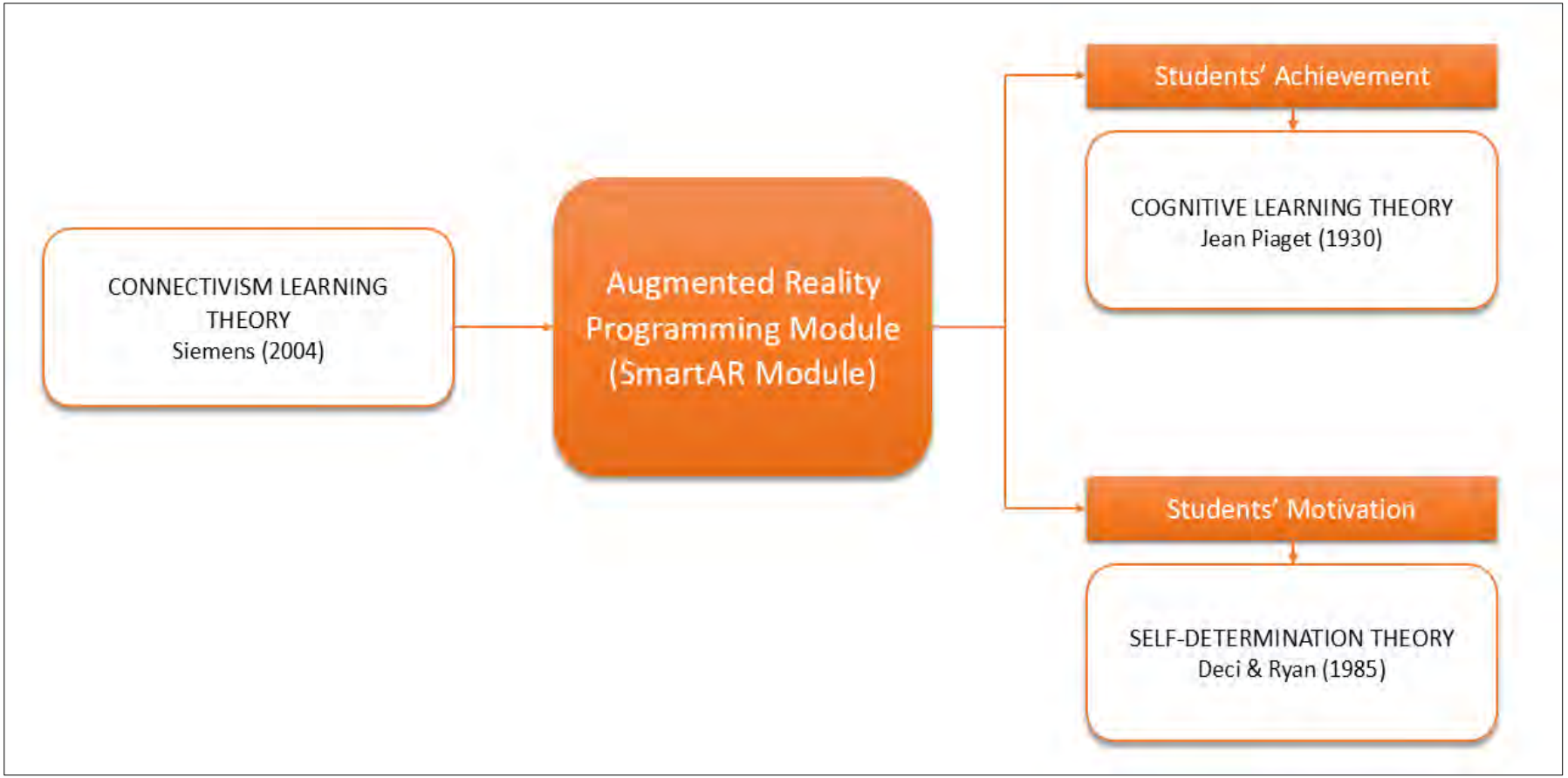
The theoretical framework supported the study by incorporating relevant theoretical components identified in previous studies, thereby serving as a guide and reference point for the current study. This study included three learning theories: Connectivism (Siemens, 2004), Cognitive Learning Theory (Piaget et al, 1970), and Self-Determination Theory (Deci & Ryan, 1985) supported by ARCS principles components, as illustrated in Figure 1.1.

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**Figure 1.1**

*Theoretical Framework of SmartAR Module*






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### 1.7.1 Connectivism Learning Theory

Connectivism Learning Theory (Siemens, 2004) provides an outline on how learning occurs in the contemporary world. Siemens (2005) emphasized that CLT views knowledge as existing across a network of connections, and learning as the process of navigating and building those networks by connecting specialized nodes or information sources. In this manner, learners are able to access, share, and create knowledge using digital tools in a collaborative manner in both formal and informal settings. In support of this view, CLT where knowledge is described as being embedded in technology and people, knowledge is managed as an asset by Downes (2007) examined. The research highlighted the slippage of knowledge and the degree of adaptation and interconnection to ecosystems in more modern learning ways. Furthermore, Chetty (2022) combines Siemens' and Downes' views on CLT acknowledging knowledge's, technology's role, and its fluidity in contemporary learning environments, and argues that connectivism fosters the creation and sharing of knowledge in a collaborative manner, both in formal and informal contexts.

In the classroom, connectivism promotes involvement and student-centred learning. Kop and Hill (2008) discussed its contribution to self-regulated learning within classrooms where learners independently design and manage their learning networks using both social and technological resources. Bell (2011) argued more strongly that connectivism enables collaborative knowledge building, digital literacy, and self-directed learning through technological networks. Additionally, Jeny (2024) applied CLT in classroom and shows it leveraging digital tools, fostering network-based learning, encouraging diverse perspectives, and moving away from teacher-

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centered methods toward learner autonomy and continuous, connected learning. With online learning, connectivism is often associated, but it is also relevant to traditional classrooms (Chee & Wee, 2008) and blended learning (Khushk et al., 2022), which makes it versatile across different educational settings. Previous studies (Corbett & Spinello, 2020; Tschofen et al., 2023; Goldie, 2016; Downes, 2010) have described four basic components of CLT such autonomy, connectedness, diversity, and openness. In the case of autonomy, it is defined as the freedom of learners to control and self-manage their learning, devoid of conventional teaching (Ryan & Deci, 2002). Corbett and Spinello (2020) noted that self-directed learners exhibit strong control over their learning choices and strategies. Connectedness highlights the flow of knowledge through networks of people and digital tools (Dunaway, 2011), reinforcing the importance of building learning communities. Diversity appreciates regard of alternative views and approaches to enhance creativity and problem-solving. Openness on the other hand supports restriction-less exchange of concepts and materials which enhances imagination and invention.

Recent studies have claimed the success of applying CLT principles using technology advanced learning. For instance, Mockovak and Toro (2022) emphasised CLT principles helped students' critical thinking and academic performance by evaluate and synthesize a wide variety of information. In the same view, Yildiz (2021) noted that CLT based AR applications fostered participation while creativity and retention of knowledge was enhanced among the students. Moreover, Zhao, Li, Wang, and Shi (2023), highlights the use of Connectivism in Augmented Reality (AR) involves that space, technology, people, and knowledge systems come together as a living network for dynamic learning. In this case, AR is to act as the medium which

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allows for motion interlinking and change among the constituents of the learning processes. Therefore, in order to comprehensively meet the educational requirements of the current times, this study undertakes the Connectivism Learning Theory (CLT) for the design and development of the SmartAR Module. By integrating CLT principles such as learner independence, integrated learning spaces, and unbounded access to various digital materials, the module fosters active engagement and improved outcomes for Form 4 students in programming.

#### 1.7.1.1 Augmented Reality Programming Module (SmartAR Module)

The development of the SmartAR Module supported by Connectivism Learning Theory (CLT) principles such as autonomy, connectedness, diversity, and openness. Tschofen and Mackness (2012) highlights that diverse learner interpretations of connectivity provide flexible digital environments in form of autonomy and openness. Wang, Chen, and Anderson (2014) further addressed the importance of learners' recursive interactions with digital enabling tools, which AR provides through contextual overlays. Additionally, Zhao, Li, Wang and Shi (2020) apply AR to CLT directly, explaining how the merging of virtual and real surroundings supports autonomy, connectedness, diversity, and openness. Therefore, the SmartAR Module was developed with these principles of the CLT by applying AR technology. These allows to construct a flexible and captivating environment that addresses the requirements of learners in the 21st century. The SmartAR Module, as an autonomous learner control mobile application enabled students to interact with the material and using the application by actively following user guidance. Bacca et al., (2014) highlights AR

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enable students to learn theoretical content in autonomous way by allow learner learn on own pace without constant teacher intervention.

The autonomy provided empowered students to choose tasks that matched their learning preferences and nurtured their self-determination. Teacher was available to help students when required. These allows students promote autonomous toward achieving pre-defined goals and objectives. Alsomali's (2023) classify the importance of user guidance allows learners are able to actively and independently explore content through guided, interactive, hands-on experiences. Makransky, & Petersen (2021) AR enable students to construct knowledge through self-guided exploration and experiments. By allowing learners to control their own pace and direction, AR supports personalized exploration and fosters self-directed learning as core elements of learner autonomy. In a AR systematic review, Markouzis et al. (2022) highlighted its effectiveness in facilitating social and collaborative learning interactions, sharing activities that require discussion among peers. Volioti et al. (2022) also showed how primary-level pupils used AR in geographical education as a tool for collaboration and social interaction, emphasizing multi-dimensional connectedness in teaching and learning. In this study, students were encouraged in connectedness to foster collaboration by integrating facilitated teamwork where they had to collaboratively solve complex programming puzzles designed with multiple layers of challenges.

To foster different learning needs, the SmartAR Module provided text, graphics, videos, 3D objects, animations, infographics, mind maps, and AR components. Markouzis et al. (2022) highlighted the potential of AR applications in informal learning contexts, enabling self-s content creation and collaboration which actively

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engages learners in the creation and dissemination of content. SmartAR Module, accomplished by designing tools that were simple to operate and promoted active participation through step-by-step instructions and forms that structured active creation, guiding students towards collaborative design and creation. By applying these core principles, the SmartAR Module effectively embedded problem-solving skills into the learning process. Furthermore, the integration of Cognitive Learning Theory complemented the module's design by reinforcing students' academic performance and ensuring a comprehensive, engaging learning experience.

### 1.7.2 Cognitive Learning Theory

The Connectivism Learning Theory was complemented by the Cognitive Learning Theory, developed by Jean Piaget in 1930. In Piaget's words, learning encompasses mental functions that make it possible for a person to adjust to and comprehend their surroundings (Elikoz, 2019). As cited by Ni'amah and Hafidzulloh (2021), scholars such as Bruner, Ausubel, and Gagné viewed and expounded upon Cognitive Learning Theory as stressing active intellectual engagement such as achieving, organizing, and equilibrating that dictate how learners acquire, organize, and apply knowledge. As noted by Fan (2024) regarding the advantages of Cognitive Learning Theory, deeper understanding of concepts can be attained through discovery, as well as the meaningful structuring of information. This technique allows the learners to form concepts on their own, instead of passively receiving information. The learners' mental processes help in skill acquisition like critical thinking and problem solving, which enhances their performance in academics. Previous study supports the impact of cognitive presence in

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learning environments. For instance, Gutierrez, Lunsky, Heer, Szulewski, and Chaplin (2020) found that cognitive presence marked by active intellectual engagement and the integration of knowledge significantly predicts student performance and academic success.

Similarly, a study by Shi and Qu (2022 showed that cognitive skills such as remembering, logical reasoning, and information processing positively influence secondary school students' academic achievement. Notably, the study found that self-discipline partial mediator of this relationship, with planning skills acting as a moderator which means these students have stronger self-regulation and are able to utilize their cognitive skills more effectively. Therefore, this study supports the view that students' academic achievement can be enhanced through the application of Cognitive Learning Theory. The SmartAR Module included metacognitive components: five thinking and learning processes aiding in goal achievement (Gagné, 2005; Keener et al. 2012; Keller, 2005): (1) comprehension monitoring and self-regulation, (2) elaboration, (3) organizing, (4) transformation, and (5) rehearsal). These strategies are in accordance with Piaget's view that the existence of knowledge and deep learning processes involves cognitive operations. The objective of this study was to enhance students' information processing and application skills, particularly in programming, problem-solving, and other relevant disciplines, through the application of Cognitive Learning Theory.

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#### 1.7.2.1 Student Achievements

In this study, the first dependent variable which student achievement is supported by Cognitive Learning Theory (CLT). Wang and Kao (2022) emphasize that metacognition and active information processing enable students to take control of their learning, adjust strategies, and achieve better outcomes. Previous studies provide insights regarding the positive influence of AR on student achievement. As an example, Hsu, Lin, and Yang (2016) pointed out that the application of AR in the integration of real-world STEM issues helps in capturing student's attention. It also helps in deepening problem solving, understanding of concepts, and overall performance and motivation in STEM disciplines. In a similar way, studies cited by Dominguez, Pacho, Bowers, Wild, and Masneri (2023) illustrate that AR's depiction of real-world phenomena assists learners in grasping more readily concepts which are usually not perceptually observable. It helps in cultivating active efforts to learn and bridging the gulf between theoretical knowledge and practical application.

To assist with this, this study utilized principles of CLT such as systematized learning strategy. A pre-test was conducted in week 1, then the implementation of SmartAR Module at school conducted for seven weeks, and finally on week 9 post test conducted to evaluate students. This timing allowed learners to self-regulate their methods depending on their performance as indicated by comparing the pretest and the post-test scores through the KSSM curriculum grading schema. Additionally, the SmartAR Module was developed based on Jannoson's seven learning strategies which featured authentic situations such that students could use prior knowledge to acquire new information to enhance understanding. Further CLT principles were applied

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through individualized assessments designed for varying e-learning speeds for each student in order to align with their needs and facilitate achievements in programming.

### 1.7.3 Self-Determination Theory

The study is also underpinned by the Self Determination Theory (SDT), developed by Ryan and Deci (2000), to evaluate the student's motivation post the SmartAR Module usage. Ryan and Deci (2000) define SDT as a metatheory of motive psychology and personality development, asserting that people are active and innately driven to pursue and undertake adversities that foster their growth. The study further explains that SDT views individuals as active participants in their development, driven by the fulfilment of three basic psychological needs: autonomy, competence, and relatedness (Thomas, 2022). Self-determination theory divides motivation into two types: intrinsic and extrinsic (Ryan & Deci, 2000). Frederic (2022) highlighted that SDT has been used to understand students' motivation at school in various subjects. A previous study by Wu, Jiang, and Ding (2021, 2022) emphasized that focusing on satisfying students' needs for autonomy, competence, and relatedness allows educators to create more motivating learning environments that foster intrinsic motivation and improve academic outcomes.

Therefore, this study adapted IMMS questionnaire by Keller (2000) supported by Self-Determination Theory (SDT), to measure students' motivation after using the SmartAR Module. Previous studies by Tsai, Lin, and Chou (2020), and Lee and Tsai (2022) focused on motivation measurement and employed SDT and ARCS principles. Their findings suggested that the integration was more comprehensive because it

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considered both primary (ARCS) and enduring, psychological factors (SDT) motivational influences. These studies also showed how the ARCS principles worked to facilitate effective instructional design while SDT framed the underlying psychological concepts of motivation through theory.

#### 1.7.3.1 Student Motivation

The second dependent variable of the study was students' motivation, measured after using the SmartAR Module. This study utilized the Instructional Materials Motivation Survey (IMMS; Keller, 2010) questionnaire, and to interpret the motivation levels, a scale similar to that used by Zainuddin, Chu, Shujahat, and Perera (2020) was adopted. The scores were categorized as: very low (1.00-1.80), low (1.81-2.60), moderate (2.61-3.40), high (3.41-4.20), and very high (4.21-5.00). The more autonomous students' motivation was, the better their academic achievement, persistence, learning, satisfaction, and positive emotions in school (Thomas, 2022). Therefore, the second dependent variable of this study, student motivation, was grounded in Self-Determination Theory supported by ARCS framework.

## 1.8 Conceptual Framework

A conceptual framework organizes and provides the reasoning behind a particular research study (Jabareen, 2021). According to Smith et al. (2022), a conceptual framework helps researchers clarify their thoughts and maintain focus throughout the

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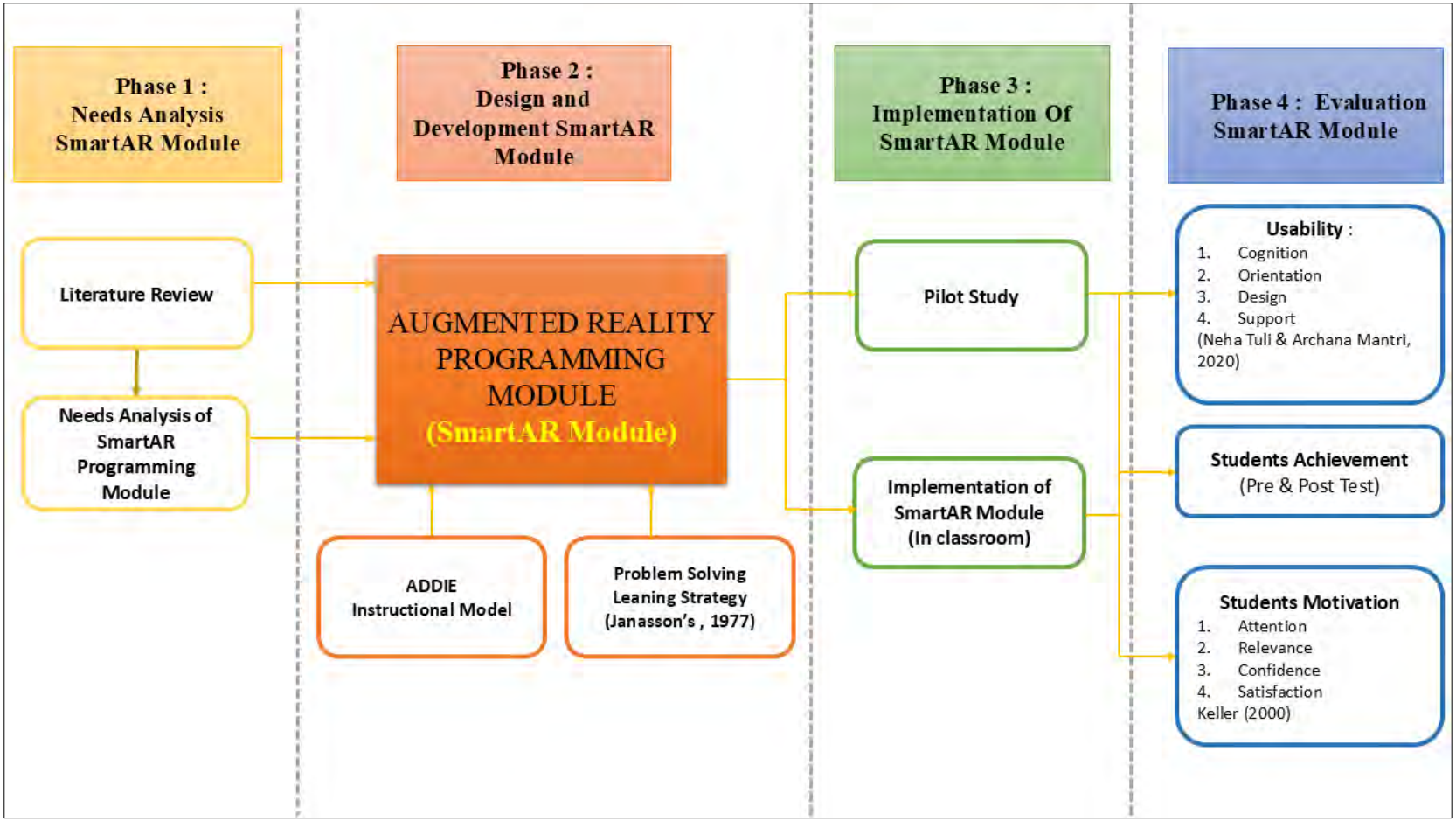

study process. It is also used to explain the rationale and layout of the study to the colleagues, supervisors, and readers (Garcia & Patel, 2021). In addition, a construction of a well-designed framework increases the internal validity of the study by synchronizing its triangulation its alignment: theory, research questions, and methodology (Lopez, 2021). In this study, the conceptual framework was adapted from Quigley's (1970) ADDIE instructional model. Phase 1 is the Needs Analysis of the SmartAR Module, Phase 2 is the Design and Development of the SmartAR Module, Phase 3 is the Implementation of the SmartAR Module, and Phase 4 is the Evaluation, as can be seen in Figure 1.2.

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**Figure 1.2**

*Conceptual Framework of the study*






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### 1.8.1 Phase 1: Need analysis of SmartAR Module

In this study a comprehensive literature review conducted to determine the needs analysis for the augmented reality programming module, namely SmartAR Module, specifically designed for Form 4 students learning programming in computer science. The literature review served as a foundational element in this academic research, as knowledge advancement relies on the body of existing work (Xiao & Watson, 2019). The quality of the literature review depended significantly on the literature compiled (Xiao et al., 2019). Following the literature review, semi-structured interviews were conducted with five Form 4 computer science students and two teachers. The interview aimed to determine the needs and requirements for the SmartAR Module. The gathered information underwent thematic analysis by categorised into theme and subthemes.

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### 1.8.2 Phase 2: Design and Development of SmartAR Module

In this phase ADDIE knows as Analysis, Design, Development, Implementation and Evaluation instructional model will be used to design and develop SmartAR Module. This study chose ADDIE as it offers systematic and detailed framework that aligns instructional content with learning standards, ensuring modules are well-structured and pedagogically appropriate (Sahaat, Nasri & Bakar, 2020). Moreover, ADDIE provides comprehensive process that supports continuous improvement and learner-centred module development, enhancing instructional effectiveness (Peterson, 2003).

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In the design phase, the Smart AR Module prototype was created in a form storyboard based on gathered user requirements. The storyboard and module were designed from scratch using Canva visual tool. To create an interactive learning experience few elements were integrated into SmartAR Module including learning activities adapting Jonassen (1977) seven problem-solving learning strategy, integration of animation and various multimedia and interactive 3Dimensional objects draft. This study chose Jonassen (1977) problem solving learning strategy for the evidence base of 15 years of empirical research on problem-solving efficacy (Jonassen, 2004; Ifenthaler et al., 2012). Moreover, the flexibility makes convenient in adaptable to STEM, humanities, and vocational training. (Macklin ,2001).

Additionally, this problem-solving strategy is suitable for real world alignment for solution-finding skills (Jonassen, 2003) and assist develops critical thinking (Jonassen, 1997; Jonassen 2000). The next step is development, where the storyboard is transformed into a functional model with operating software according to the selected instructional strategies. Key activities in this phase included marker development, 3D objects design, and software development. These activities were designed to create maximum interaction and learning for the user.

### 1.8.3 Phase 3: Implementation of SmartAR Module

Implementation was the third phase in this study. Prior to the implementation of SmartAR Module to classroom, expert validated the SmartAR Module and instruments. Then a pilot study was conducted to measure the reliability of the SmartAR Module for

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two weeks. After made required amendments the SmartAR Module was implemented in the classroom for the experimental implementation. The implementation lasted nine weeks.

### 1.8.4 Phase 4: Evaluation of SmartAR Module

The final phase of the SmartAR Module was the evaluation phase to measure the usability of SmartAR Module, student achievement and the student's motivation after using SmartAR Module. Firstly, students' achievements were measured using achievement tests with pre-test and post-test questions. Additionally, this study utilized the Instructional Materials Motivation Survey (IMMS; Keller, 2010) to evaluate students' motivation in using the SmartAR Module for learning programming. The IMMS was a 36-item Likert-scaled measure of learner motivation (Keller, 1987). In this study, treatment of this study is SmartAR Module, and the students' achievement and motivation are the dependent variable. The student's achievement was measured using pre-test and post-test and evaluated according KSSM grade. Next the students' motivation after using the SmartAR Module were evaluated using Keller's IMMS questionnaires adapted according to this study context. To sustain the usability of SmartAR application, this study adapted Tuli & Mantra (2020) augmented reality usability questionnaires to measure usability of SmartAR Module.

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## 1.9 Research Scope

The scope of this study includes key areas such as mobile applications, technology, sample selection, subjects, learning materials and assessments, usability, and key variables.

### 1.9.1 Mobile Application

This study focused on mobile applications compatible with Android Jelly Bean Version 4.2 and higher. The mobile devices used needed to feature a high-quality rear camera and ample storage capacity. The SmartAR Module applications can be installed on mobile application through the customized .apk file installation method.

### 1.9.2 Augmented Reality

This study used the Augmented Reality (AR) technology specifically marker-based AR as base of treatment. Mobile applications were developed using this AR approach, which relies on visual markers to trigger virtual content. Markers were designed with Canva and Adobe Photoshop software, then stored in Vuforia's free-license database for AR functionality. Additionally, the project assets were sourced from the Unity Asset Store, with a few created from scratch.

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### 1.9.3 Samples

This study included three sample groups: the first group consisted of five Form 4 computer science students and two computer science teachers, who participated in the needs analysis of the SmartAR Module to address research question one; the second group comprised three content experts and four technology experts, who contributed to addressing research question two; and the third group included 30 Form 4 students, who were involved in addressing research questions three, four, and five.

### 1.9.4 Subjects

This study focuses on Chapter 1 of the Form 4 Computer Science curriculum under the Malaysian syllabus, specifically on two key subtopics: (1) the problem-solving approach and (2) control structures.

### 1.9.5 Learning Module

This study content focus on the Form 4 Computer Science curriculum outlined in the Malaysian National Curriculum (DKSP). It included five interactive learning activities, allowing students to engage with and understand key concepts through problem-based scenarios. Additionally, to enhance student engagement, the SmartAR Module mobile application featured three animated videos, integrating multimedia elements to support

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learning. The module also provided two objective exercises, giving students the opportunity to further explore specific topics within the curriculum.

### 1.9.6 Usability

The usability of this study was measured using Tuli and Mantri's (2020) augmented reality usability questionnaire. The evaluated attributes included (1) Cognition, (2) Orientation, (3) Design, and (4) Support. The design of the applications was assessed based on the simplicity of navigation and the acceptability of the user interface.

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### 1.9.7 Variables

This study consisted two dependent variables. The dependent variables were student achievements and students' motivation after learning programming using the SmartAR Module. These variables were investigated throughout the comprehensive study.

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### 1.9.8 Treatment

The treatment of this study is SmartAR Module. The module designed and development using ADDIE design model.

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## 1.10 Research Significance

The aim of this study was to create an augmented reality programming module called SmartAR Module for teaching programming within the Form 4 computer science curriculum to Malaysian secondary school students. In general, the study's findings have benefited a variety of stakeholders, including students, teachers, schools, and the Ministry of Education.

### 1.10.1 Students

The SmartAR Module has significantly improved students' programming skills, particularly in logical understanding and the application of computational thinking techniques. Additionally, the incorporation of real-life, relatable problem-solving scenarios helped students connect with the material and understand problem-solving strategies more effectively. These examples strengthened their programming logic, enabling them to internalize problem-solving techniques and prepare to write code step-by-step without relying on an electronic device during examinations. Furthermore, the module increased students' willingness to study programming by incorporating features such as interactive learning modules for reference, engaging drag-and-drop activities, scanning markers, and animation-based videos. The application provided five activities, allowing learners to assess their knowledge at their own pace. Additionally, the study included two sets of objective questions, each comprising ten questions, to delve deeper into the subtopics. The implementation of Bloom's Taxonomy in the SmartAR Module was instrumental in developing 21st-century learners. As a result, adopting the

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SmartAR Module significantly improved students' achievement in learning programming.

### 1.10.2 Teachers

The second group that benefited from the SmartAR Module was secondary school computer science teachers. This module provided comprehensive guidance on using augmented reality mobile applications for numerous problem-based scenario. As a result, teachers were able to use the module more effectively and efficiently. Moreover, the SmartAR Module application contained assessments that teachers could make for students to solve after undertaking a lesson, thereby, reducing the time teachers spent devising instructional aids and tutorials. The elements and contents of this learning module were validated by content and technological experts, ensuring alignment with the DKSP curriculum structure and making the resources easy to learn . As a result, teachers could easily adapt the teaching, organize the students to learn, and explore the features on their own. This innovative approach improved teaching quality and implemented 21st-century learning.

### 1.10.3 Secondary Schools

This study used a one-group pretest-post-test research design to examine the effect of the SmartAR Module, an augmented reality application, on learning programming. This

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study method was chosen to establish a cause-and-effect relationship between the module, augmented reality, and programming problem-solving skills. The effect on students' achievement was examined using a pre-experimental research design, which increased the internal validity of the findings. Consequently, the school benefited from innovative modules that enhanced current teaching and learning aids.

### 1.10.4 The Ministry of Education

The SmartAR Module has benefited the Ministry of Education, which is responsible for the education system. This studyz aimed to assist students in achieving elevated levels of achievement in computer science by adding constant engagement and motivation to learn. This practice has produced skilled and competitive students upon their graduation. Modern society is increasingly becoming digital, and inventors are always coming up with new technology. As a result, teaching with augmented reality technology has encouraged students to think creatively. Therefore, the accomplishments of SmartAR have served as excellent guidance and a demonstration of 21st-century education, consisting of good achievements in learning programming.

## 1.11 Operational Definitions

This section provides operational definitions that often used in the study, such as mobile applications, augmented reality, and students' achievement and motivation in learning.

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### 1.11.1 Mobile Application

Mobile applications are enabled by the convergence between information technologies and telecommunication technologies (Rupnik & Krisper, 2009). An operating system (OS) built exclusively for mobile devices such as smartphones and tablets (Villannueva , 2019). Mobile applications are software programmes designed to run on a computer, tablet, or mobile phone to accomplish a particular purpose (Chandran, 2021). Previous study by Shaikh and Ahmed, (2013) classify available from mobile application distribution platform such as Window Phone Store, App Store, Google Play, Nokia Store, BlackBerry App World. The study also highlighted part of application are free where as some apps are paid. In this study, an Android mobile application was used to implement the SmartAR Module for learning programming to secondary school students.

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### 1.11.2 SmartAR Module

The learning module or module lesson is a collection of educational innovation and technology that can be utilized for revising and improving the different courses or educational processes (Chantarasombat, Chusorn & Pimthong, 2022). This can be achieved step by step and by investigating the efficiency of the module carefully (Sigkabundit & Sigkabundit, 2011). The learning module was an instructional innovation that enhanced the students' higher learning potential and was effective as a criterion (Chantarasombat, 2020). Previous study by Sirisuthi et al. (2021) addressed the learning module as an innovative learning technique as it focused on the students'

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learning by summarizing the exact question for students to be able to apply and continuously follow-up their learning, made students interested in their class, and wanted to learn more to express their own creativity. In this study, the SmartAR Module referred to an activity module composed of a set of instructional resources, guidance, and practices for learning programming in accordance with the Form 4 computer science topic, namely the SmartAR Module. The exercise questions served as markers, allowing students to scan and examine the solutions and subsequent steps. This module covered the following topics: (1) problem-solving approach, and (2) structure control. The purpose of this study was to improve students' achievement in the fundamental programming topic.

### 1.11.3 Augmented Reality

Augmented reality offers a better way to design, curate, and deliver consumable instructions by overlaying digital content in real-world work environments (Microsoft, 2023). Apart that Cakir, Güven and Çelik (2021) emphasize that augmented reality is a technological application that is used not only in theoretical education but also in interesting informal teaching environments. In this study, augmented reality was the primary technology involved in designing and developing SmartAR Module for learning programming.

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### 1.11.4 Students' Achievement

Student's achievement is an academic achievement as a performance outcome that indicates which students had accomplished specific goals (Gonçalves, 2022) . In this study, students' achievement refers to the achievements' students in learning programming subject using pre-test and post-test score. The indicator of score categorised based on the *Kurikulum Standard Sekolah Menengah* KSSM grading scale. The test scores were evaluated based on pretest and post-test.

### 1.11.5 Students' Motivation

The first dependent variable in this study is student motivation after using SmartAR Module, which was measured using a motivation questionnaire adapted from Instructional Materials Motivation Survey (IMMS; Keller, 2010) 30 items. The motivation questionnaire consist of four construct includes Attention, Relevance, Confidence and Satisfaction. The scores group by Five Likert-scale.

### 1.11.6 *Dokumen Standard Kurikulum dan Pentaksiran (*DKSP)

In this study, the curriculum adhered to the standards of the Malaysian National Curriculum, known as *Dokumen Standard Kurikulum dan Pentaksiran (DSKP).* The DSKP provides detailed learning outcomes, assessment criteria, and structured guidelines to ensure consistency in education quality and coverage across subjects. For

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the Form 4 Computer Science subject, the DSKP provides programming concepts, problem solving methods, and control structures in programming as chapters and subtopics, which are vital for nurturing computational thinking benchmarks. The SmartAR Module was designed and developed according to DSKP curriculum standard.

### 1.11.7 Usability

Usability defined as ease of use and usefulness in determining acceptance of information technology (Alrfooh & Lakulu ,2020). Alejandro et al., (2019) emphasised the importance of usability as provides the characteristic of a software product of being effective, efficient and producing satisfaction for users (Alejandro et al.,2019). In this study, the SmartAR Module usability was measured using the Tuli and Mantra (2020) Augmented Reality usability questionnaire. The usability questionnaire consist of four construct includes cognition, orientation, design, and support.

## 1.12 Summary

This chapter provided an introduction of research background, problem statement, research objectives, and research questions. Additionally, the chapter highlights research hypotheses, a theoretical framework, a conceptual framework, research scope, research significance, and operational definitions. The next chapter will discuss the literature review of the study.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter provides a comprehensive literature review, beginning with the integration of computer science in secondary education and the significance of well-designed learning modules in fostering programming skills and problem-solving competencies. Next, discuss the incorporation of augmented reality (AR) in programming education, focusing on existing AR-based learning modules, types of AR particularly marker-based AR and the development tools employed for AR content creation. Furthermore, the chapter discusses the educational potential of AR, supported by relevant learning theories and comparative analyses of problem-solving strategies. The review also considers the impact of AR on student achievement, methods for measuring student motivation, and the usability of AR applications. The ARCS principles is introduced as

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a framework for understanding student motivation in AR-enhanced learning environments.

## 2.2 Computer Science in Secondary Schools

Over the last decade, there has been an explosion of national interest in computer science (CS) education (Jacob & Warschauer, 2024). Grasping these 21st-century abilities is crucial (Satori, Komariah, & Suryana, 2019). With rapid changes happening now and anticipated in the future, a variety of skills are necessary to address the increasingly complex challenges we face. Overcoming these challenges requires a process of critical and creative thinking (Zainil, Kenedi, Rahmatina, Indrawati, & Handrianto, 2023). Recognizing this importance, the Ministry of Education (MOE) in Malaysia has integrated computer science into the High School Curriculum (KPM, 2016). According to KPM (2016), the Computer Science (CS) curriculum is designed to enhance computational thinking, enabling students to effectively solve problems and make informed decisions. It also fosters critical and creative thinking skills.

Nasution, Hidayat & Syah (2022) defines CS comes from understanding and implementing various training materials to carry out an activity with computer. Additionally, Jacob & Warschauer (2024) emphasised CS represents a discipline like science, math, engineering, and medicine and refers to the study of computers, algorithms, hardware, and software and their effects on society (CITE). Computer refers to presence of technology and its noun refers to a tool for ensuring that “to compute” carries out the meaning, example to perform computations involving

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reasoning and thinking (Nasution et al., 2022). Table 2.1 shows the computer science subject teach in Malaysia curriculum source by Latih et al., (2020).

**Table 2.1**

*Malaysian computer science curriculum*

| Level | Subject |
|---|---|
| Post-Secondary (Form 6) | Information and Communication Technology |
| Upper-Secondary (Form 4 - Form 5) | Computer Science |
| Lower-Secondary (Form 1 – Form 3) | Basic of Computer Science |
| | Design & Technology |
| Primary School (Year 4- Year 6) | Design & Technology |

Previous study by Latih et al., (2020) highlighted that primary school from year four to six is studying programming through the Design and Technology subject. Students learn to create algorithms and develop simple programs. The students also learn to program hardware such as Arduino and Micro-Bit, which is an introduction to robotics and artificial intelligence. Meanwhile, lower secondary from one to three learning programming in two subjects such as Basics of Computer Science subject and the Design and Technology subject based on school preference. Next form 4 to form 5 learn programming through computer science subject and exposed to basic programming from scratch using different programming languages such as Php and Html. Its importance to integrate programming skills into school learning to prepare an 21$^{st}$ learning adopted generations.

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In 21st century, combination of specific skills, content knowledge, expertise and literacy with innovative support system is required to help students to master them in multidimensional abilities (Vijayalakshmi, 2021). Each 21st learning skills classified into three such learning and innovation skills, literacy skills and career and life skills. The most significant is learning and innovation skills to develop a critical thinking and problem-solving criteria. Previous study by Piedade (2019) developed a cross blocked and visual programming application (VPE) with computer science peers. Study discovered that the use of an adequate VPE can improve pupils' learning and outcomes and provide a strong way to develop computational thinking skills and creativity. However, the study has limitations in terms of selecting a smaller sample (11), thus the chances of capturing the majority of the students' thoughts are relatively slim.

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Apart that, a previous study by Nazatul (2013) developed an augmented mobile application in learning computer science subject namely AR-CPU. The study addressed that the implementation of the application revealed that the use of mobile augmented reality can assist in engaging students in a group discussion for solving questions related to complex matters. However, lack of real objects as 3-Dimensional tracing use is highly noticeable. In augmented reality game applications, attaching appropriate 3-Dimensional tracing elements is important to better students' achievement, and motivation in learning. Even though previous studies believe that learning computer technology in secondary school is advantageous, yet students and teachers consequently facing several challenges. The International Society for Technology in Education (ISTE) (2011) highlighted that effective teaching and learning in CS education requires knowledge of various instructional strategies and materials (Olgon,2020). A SWOT test conducted by Helyawati (2018) stated the weakness of

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learning computer science are time limitation of teaching and learning (PnP) duration, loss interest in learning and ignorance of student in prioritize the subject.

Previous study by Mary (2017) listed several challenges in learning computer science subject in school such as lack of clear understanding outside field of Computer Science as an academic discipline, A need for Computer Science as a distinct subject in school curriculum is controversial and poorly understood and identifying and allocating the additional resources for teaching Computer Science is a challenge. Additionally , Cheah (2020) emphasized that traditional teaching methods and static materials like books and slides are often ineffective for teaching programming due to the dynamic nature of its concepts. Ahmad & Ghazali (2020) further support this view, noting that ineffective textbook-based teaching can hinder programming competency.

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Next, Robins (2019) highlighted that most modern programming languages follow an object-oriented approach, which requires enhanced visualization to enable students to develop mental representations of complex problems. Ahmad and Ghazali (2020) and Kadar et al. (2021), which emphasize that inadequate problem-solving skills among learners exacerbate difficulties in understanding programming concepts. Furthermore, a lack of consolidation of knowledge and skills in problem-solving and logical reasoning further complicates the learning process during the early stages (Bosse & Gerosa, 2017; Savage & Piwek, 2019).The most frequently discussed challenge among learners is their ability to solve problems and acquire essential problem-solving skills (Cheah, 2020; Medeiros et al., 2019; Rahim et al., 2018). Puganesri et al. (2019), who emphasized the pedagogical challenges in effectively transmitting programming knowledge.

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According to Hudin's (2023) systematic literature review, the key challenges in learning programming include teachers' competency issues across four areas: programming knowledge, skills, attitudes, and digital pedagogy. Many teachers lack sufficient content knowledge and technical skills, leading to reduced confidence in teaching. Students' readiness is another significant barrier, with young learners struggling with cognitive issues like insufficient digital literacy and metacognitive challenges such as maintaining focus during lessons. The review also identified poor computational thinking skills among students as a major concern, impacting their ability to understand programming concepts and problem-solving. Limited school facilities and resources, particularly in rural areas, hinder effective programming education, with many schools lacking modern hardware, software, and robotic sets. Additionally, the study highlighted insufficient parental support due to limited understanding of programming education's importance, and policy-related challenges including time constraints in the curriculum and inadequate teaching resources.

Computer science is a newly introduced subject in secondary school in terms of the future. However, teachers and students continue to face difficulties in making the move from old learning practises to modern learning. Thus, this study design and developed an interactive augmented reality learning module namely SmartAR Module with user guidance. Therefore, students and teachers will have less complexity in using SmartAR Module mobile applications in learning computer science subjects.

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## 2.3 Importance of Learning Module

Learning modules serve as essential educational tools designed to systematically achieve specific learning objectives (Radhika, 2019). These structured resources play a crucial role in modern education by providing the primary content that learners engage with, thereby enhancing comprehension and facilitating effective instruction (Bukoye, 2019; Mithans & Grmek, 2020). Learning modules importance is particularly evident in differentiated instruction (DI), where modules are carefully tailored to accommodate diverse learner abilities, creating more inclusive and effective learning environments (Ardiawan et al., 2024). Research has consistently shown that well-designed modules offer numerous pedagogical benefits, including promoting experiential learning through authentic tasks that encourage reflection and skill development (Nardo, 2017). This approach aligns with contemporary educational needs, as modules foster independent study by guiding learners through progressively challenging exercises, thereby cultivating autonomy and reducing reliance on teacher-led instruction (Shaifuddin & Nashir, 2022). Mayer's (2017) cognitive load theory reinforces this by explaining that the strategic incorporation of multimedia within the modules optimally enhances motivation and facilitates knowledge retention. Learning modules are especially useful in catering to diverse student needs because they help teachers organise classroom activities while streamlined towards curricular outcomes (Nardo, 2017).

More recent research illustrates the impact and scope of learning modules within an educational setting. In ICT integration, Nepal's shift to student-centric online modules resulted in collaborative and accessible systems that supported resource

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sharing, especially for marginalised groups (Rai, 2024). Similarly, intelligent language learning modules enhanced vocabulary acquisition and writing skills while fostering motivation and peer collaboration, though technical literacy barriers and learning anxiety emerged as challenges (Buddha, Shuib, Idris, & Eke (2024). STEM education applications reveal a dual effect while e-modules and Google apps increased engagement, excessive reliance risked reducing peer interaction and fostering individualism without proper pedagogical oversight (Mardiantiningsih, Ramli, & Antrakusuma, 2024). Innovative approaches like meme-based modules show promise in boosting engagement and critical thinking in linguistics and medical education, though require careful teacher training to mitigate misinformation risks (Guillen, Parrales, Urena , 2024). Autonomous learning modules effectively develop self-study skills in language education, however maintain a need for teacher monitoring to ensure learning accuracy (Nardo , 2017).

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Common limitations across studies include infrastructure gaps such Nepal's inadequate ICT access, technical constraints in language systems, and the persistent need for balanced teacher involvement despite module autonomy. These findings collectively underscore that while learning modules offer significant benefits in accessibility, engagement, and skill development, their success depends on thoughtful implementation that addresses technological, pedagogical, and equity considerations. These general principles of module design take on particular significance in programming education, where abstract concepts like algorithms and data structures benefit greatly from structured, progressive learning materials (Cheah, 2020). Programming modules often incorporate unique elements such as code visualization, debugging exercises, and project-based tasks that build computational thinking skills

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(Thompson & Lee, 2023). However, while the effectiveness of learning modules has been established across various disciplines, research specifically examining programming modules particularly those incorporating emerging technologies like augmented reality - remains limited (Ivarson et al., 2024). Existing studies have not to fully explore how module design principles apply to the unique challenges of programming education, such as addressing high cognitive load and low student motivation (Gunbatar & Karalar, 2018). This leads to examine existing programming learning modules and their characteristics, with particular attention to how they address these pedagogical challenges in next subtopic.

### 2.3.1 Existing Programming Learning Modules

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Current implementations of programming learning modules demonstrate diverse pedagogical approaches to address core challenges in computer science education. Previous studies (Maspaeni, Muslim, Ibrahim, 2022; Suzuki, Kato, Yatani 2020; Rawan, Hammad and Hamtini ,2023; Alrubaye, Ludi, Mkaouer 2019) as shown in Table 2.2.

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**Table 2.2**

*Existing Programming Learning Module*

| Author / Year | Objective | Research Method | Benefits | Challenges |
|---|---|---|---|---|
| Maspaeni, Muslim, Ibrahim (2022) | To improve student learning outcomes in the Object-Oriented Programming (OOP) course by developing and implementing a blended learning model, specifically lab-rotation-based blended learning. | Research and Development (R&D) approach | • Improved student learning achievement: Post-test average improved from 57.20 to 80.40, with completion rate increasing from 35% to 85%.<br>• Flexibility: Learning is no longer limited by space and time.<br>• Enhanced collaboration: Better facilitation of discussion and group work. | • Lack of existing research combining both online systems and offline modules<br>• Difficulty in applying traditional approaches to lab-based programming courses without flexible, practice-focused materials |
| Suzuki, Kato, Yatani (2020) | To develop and evaluate "ClassCode," a web-based interactive learning environment that supports programming education in classroom settings, enabling personalized, self-paced learning. | Qualitative Research Approach | • Self-paced Learning: Students able complete tutorials and coding exercises at their own speed<br>• Interactive Exercises: Embedding coding tasks within lessons helps reinforce learning through practice.<br>• Enhanced Engagement: Features like milestone problems and help mechanisms improve motivation and student interaction. | • Scalability Unverified : System's performance and effectiveness in large classrooms or across institutions remain unknown.<br>• Limited Deployment: ClassCode has not yet been tested in a full-scale real-world classroom |
| Rawan , Hammad and Hamtini (2023) | To develop and evaluate a gamification-based learning approach for teaching C++ | Mixed Method | • Increased Motivation: The gamified group showed strong motivation, particularly | • Lack of Content Diversity: platform was tailored specifically for C++ programming |



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| | | | | |
|---|---|---|---|---|
| | programming concepts in an online setting, aiming to achieve effectiveness comparable to traditional in-person learning | | influenced by leaderboards and point systems.<br>• Better Engagement: Students were more engaged in lessons compared to traditional methods. | and may not yet be adaptable to other subjects or languages. |
| Alrubaye, Ludi, Mkaouer (2019) | To address the gap between block-based and text-based programming learning by introducing a hybrid-based learning approach | Hybrid-based learning | • Boosts Memorization: Hybrid format aids in retention of programming syntax and logic.<br>• Increases Learning Efficiency: Reported 30%+ improvement in comprehension and ease of learning. | • Need for Hybrid Support: Without a bridging solution, students may become discouraged or confused, slowing their learning progress.<br>• Learning Gap Exists: Students often struggle to apply block-based programming knowledge when transitioning to text-based languages. |

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Recent studies demonstrate the effectiveness of innovative programming learning modules in enhancing student outcomes and engagement. Maspaeni et al. (2022) showed that a lab-rotation blended learning model significantly improved OOP learning outcomes, with post-test scores increasing by 23.2 points and course completion rates more than doubling (35% to 85%). Similarly, Suzuki et al. (2020) found that their web-based "ClassCode" system enabled effective self-paced learning through interactive coding exercises, though its scalability remains unverified. These approaches address critical challenges in programming education by combining structured guidance with flexibility. Rawan et al. (2023) further enhanced engagement through gamification, reporting increased motivation via leaderboards and point systems in their C++ modules, while Alrubaye et al. (2019) successfully bridged the gap between block-based and text-based programming through hybrid learning, achieving a 30% improvement in comprehension. Collectively, these studies prove that well-designed modules can overcome traditional limitations of programming education. Despite their benefits, these modules face implementation challenges that require careful consideration. A common issue across studies is the lack of adaptability - whether in scaling solutions (Suzuki et al., 2020), applying gamification to other languages (Rawan et al., 2023), or transitioning between programming paradigms (Alrubaye et al., 2019). Maspaeni et al. (2022) additionally highlighted the significant development effort required for blended modules, particularly in creating practice-focused materials for lab-based courses. These challenges underscore the need for: (1) modular designs that allow content adaptation across languages and institutions, (2) comprehensive teacher training programs, and (3) infrastructure support for technology-dependent solutions. The studies collectively suggest that while innovative

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modules transform programming education, their success depends on addressing these implementation barriers through iterative design and institutional support.

While these studies demonstrate both the potential and challenges of conventional programming learning modules, emerging technologies like Augmented Reality (AR) offer new possibilities for addressing persistent issues in programming education. The limitations of scalability, teacher training, and infrastructure identified in traditional modules (Suzuki et al., 2020; Maspaeni et al., 2022) may find innovative solutions through AR's immersive capabilities. Godoh (2022) emphasized AR apps that transform traditional STEM modules, often perceived as boring, into interactive and immersive experiences to enhance learning. The previous programming learning modules showed pedagogical innovation but there are many gaps. These methods are still confined to 2D interfaces, and do not provide sufficient support for teaching abstract programming concepts. Suzuki et al. (2020) and Rawan et al. (2023) show cross-platform adaptability issues. The former’s large-scale unverified deployment and the latter’s language-specific adaptation illustrate this problem. More engaging and adaptable solutions are needed in teaching programming to fill the gaps while ensuring access for educational institutions.

## 2.4 Augmented Reality

The term "Industrial Revolution" (IR) refers to the transformation of traditional industrial practices through the adoption of dominant technologies of each era (Santhi

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& Muthusamy, 2023). The first three industrial revolutions, driven by mechanization, electrification, and automation, respectively, shifted society from an agrarian to a manufacturing economy, improving the quality of life for factory workers and advancing healthcare systems (Santhi & Muthusamy, 2023). Technological advancements have led to the emergence of the Fourth Industrial Revolution (4IR) (Alshammari, 2024). In 2011, German Professor Wolfgang Wahlster introduced the concept of Industry 4.0 at the Hannover Fair, with the revolution gaining significant momentum by 2016, as discussed by Hoque (2019). The technological advancements, such as blockchain, artificial intelligence, robotics, cloud computing, data science, virtual reality, augmented reality and 3D printing, have led to the emergence of the Fourth Industrial Revolution (4IR) (Kuruczleki , Pelle, Laczi, & Fekete, 2012; Guangli , Gang, Ming, Shuqin & Xiongfei , 2018 ; Martin, 2018). These technologies have facilitated changes in people's economic and social lives, resulting in the disappearance of some jobs and the establishment of others (World Economic Forum, 2022).

Significantly, Augmented Reality (AR) has gained prominence in the context of Industry 4.0. Augmented reality facilitates to understand information that is not fully comprehended through senses and cognitive processes under normal circumstances (Azuma, 1997; Kaufmann & Schmalstieg, 2003; Klopfer & Squire, 2008). It is a technology that integrates the real environment with digital data (Boonbrahm, Kaewrat, Pengkaew, Khachorncharoenkul, & Thammarat, 2019). Furthermore, Bojukrapan (2018) added AR merges the real and virtual worlds through devices and software, allowing 3D images, graphics, and text to be overlaid on the real world via devices such as computers and smartphones.

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### 2.4.1 Types of Augmented Reality

Augmented reality has a working principle that can be categorised into two types of image analysis: using marker as the main work (marker-based AR) and using different characteristics in the image for analysis (marker-less-based AR) (Kaur, Mantri & Horan, 2020; Wannapiroon et al., 2021; Alper et al (2021). Cheng, Chen and Chen (2017) elaborate marker-based AR has to use a marker as a trigger while marker less AR can be used without markers. In marker-based AR, the system needs the user's position and place to focus, and the marker can be in the form of a 2D picture, QR code, or 3D object. The function of the marker is to identify the position of the virtual objects to be displayed (Boonbrahm et al., 2020). In marker-based augmented reality (AR) systems, markers are usually relatively independent and predefined by the system creator in advance (Boyang, 2021).

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Marker-less augmented reality detects objects or characteristic points of a scene without any prior knowledge of the environment (Zainab, 2020). In marker-less AR, the user can place the virtual object at any position within the range of the camera view using a combination of GPS and the compass sensor on the smartphone, as we have seen in the case of Pokémon Go (Paladini, 2018). Meanwhile, according to Simon (2018), location-based augmented reality is defined as an innovative representation of location-specific information in diverse applications. Despite having many types of augmented reality, every type has its own advantages and disadvantages. Table 2.3 shows the advantages and drawbacks of the comparison table compiled by Cheng et al.

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(2017) in their study. The study compared four (4) aspects such as methods, position accuracy, stability, and hardware support.

**Table 2.3**

*Comparison of Marker and Marker-less Augmented Reality by Cheng et al (2017)*

| **Comparison Aspects** | | **Marker-based AR** | **Marker less AR** |
|---|---|---|---|
| Methods | Relative Position / angle | Depends on markers | Depends on localization technology |
| | AR Software Development Kit (SDK) | Commonly used | Rarely used |
| Position Accuracy | High / low | Relatively higher | Relatively lower |
| | Influence factors | Brightness | Localization technology |
| Stability | High / low | Relatively lower | Relatively higher |
| | Influence factors | Markers and SDKs | Localization technology |
| Hardware Support | Desktop | Supported | Usually not supported |
| | Mobile | Supported | Supported |

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From the comparison table, able to determine that marker based has less complexity compared to marker-less augmented reality. Meanwhile, in the study conducted by Stefan et al (2018) highlight location-based drawback as hardly used by any software development kits (SDKs) that can be effectively used by developers, as important functionality and customisation options are generally missing. Several studies have utilized marker-based augmented reality (AR) to develop educational materials. For example, Daud, Ghani, Rahman, Yusof, and Amiruddin (2021) designed a marker-based educational material for Arabic vocabulary using AR technology. The study found that a minimum distance of 10 cm and an angle range of 30° to 90° were necessary for displaying 3D objects effectively. Similarly, Baba, Zorlu, and Zorlu

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(2022) investigated the effectiveness of AR and modeling-based teaching in the "Solar System and Eclipses" unit, finding that markers helped students focus better and were easy to use. Additionally, Ozeren and Top (2023) designed and developed "CellAR" for the "Cell and Cell Division" unit using marker-based AR. The study found that marker-based AR was both interesting and effective. However, the study used two-dimensional pictures as markers to run the AR application. They suggest that using three-dimensional models as markers in future studies could enhance concretization and make the experience more relatable to real life.

Several previous studies have also explored the use of markerless AR. For instance, Nadeem, Chandra, Livirya, and Beryozkina (2020) developed a markerless AR application for lab orientation, integrated with multimedia. However, the study highlighted that the high cost of the application made it unaffordable for some users. Similarly, Basumatary and Maity (2024) designed and developed BodoRao, a markerless AR application for teaching endangered languages in primary education. A major disadvantage, as noted in their study, is that markerless AR is highly dependent on the environment's visual features and tracking quality, which can affect its reliability. In conclusion Marker-based augmented reality (AR) is often simpler to implement and provides higher positional accuracy because it uses predefined markers, such as QR codes or 3D objects, to track and display virtual objects. However, it is less flexible as it relies on the visibility of these markers. In contrast, marker-less AR uses GPS, compass sensors, or other localization technologies, offering greater flexibility, but it can be less stable and have lower accuracy depending on the environment (Zainab,

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2020; Boyang, 2021). This study used marker-based AR for its simplicity and higher positional accuracy, making it a suitable choice for the SmartAR Module.

### 2.4.2 Augmented Reality Development Tools

Augmented Reality (AR) technology enhances learning by offering immersive, multisensory environments that improve comprehension and retention. The use of appropriate development tools enables users to fully leverage open-source capabilities and effectively acquire knowledge. AR development tools empower educators to design enriched learning experiences that foster active participation, motivation, and curiosity among students (Cai, Akcayir, & Demmans, 2021). Furthermore, these tools support the creation of flexible and adaptable educational content tailored to diverse learning needs and contexts, including remote and distance learning environments, thereby promoting innovation in teaching methodologies (Li, Xirui, Song, Hong, & Wang, 2024). The ability to manipulate virtual objects and conduct real-time virtual experiments helps students develop critical thinking, problem-solving skills, and a deeper understanding—skills essential in programming and computational thinking education (Godoy, 2024).There are numerous augmented reality development tools available on the market lately. Table 2.4 shows the AR display often used in education. The highly used devices are tablet and mobile phones.

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**Table 2.4**

*AR display often used in education.*

| Devices | Image | Characteristics | Usage count | Author |
|---|---|---|---|---|
| Tablet/Mobile Phone |  | Like the normal mobile application devices | 478 | (Lin et al., 2020; Chang et al., 2020; Tuli et al., 2021) |
| Hololens |  | Ver.1<br>1268 x 720 | 82 | (Harris et al., 2020; Dolega et al.,2022) |
| Magic Leap |  | Ver.2<br>2048 x 1080 | 13 | (Wunder et al.,2020; Hess et al., 2022) |
| Google Glass |  | 1280 x 920 | 12 | (Rath et al., 2019; Rossi et al., 2020) |



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Recent research has identified several key tools and platforms for developing Augmented Reality (AR) applications in educational contexts, particularly for programming instruction. Among the most widely adopted development environments are Unity and Unreal Engine, which offer cross-platform capabilities and robust feature sets for creating mobile and web-based AR experiences (Vakaliuk & Pochtoviuk, 2023; Kolahchi et al., 2023; *AR/VR Technology Stack Review*, 2023). For marker-based AR applications, specialized software development kits (SDKs) such as Vuforia and Wikitude are commonly used due to their reliable image tracking capabilities and ease of integration (Vakaliuk & Pochtoviuk, 2023; Kramarenko et al., 2024). Simplified authoring tools like Adobe Aero, ProtoAR, and Reality Composer have gained popularity among novice developers and educators, as they minimize programming requirements while still enabling the creation of functional AR prototypes (Ashtari & Chilana, 2024). In terms of mobile-native development, ARKit (iOS) and ARCore (Android) remain dominant and are frequently used in combination with Unity for extended compatibility across platforms (Kolahchi et al., 2023). Additionally, emerging web-based solutions such as WebXR and A-Frame provide lightweight, installation-free alternatives suitable for educational settings with limited technical resources (*AR/VR Technology Stack Review*, 2023).

The selection of development tools depends on project complexity, target platforms, and the developer's technical proficiency, with Unity maintaining its position as the most comprehensive solution for professional AR development (Ashtari & Chilana, 2024; Vakaliuk & Pochtoviuk, 2023). Several existing AR educational applications have been developed using Unity. For example, all three AR apps

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evaluated by Christina (2022) were developed using the Unity game engine and C# programming language, while Vuforia was used for real-time image tracking and recognition. The ARGBL application, developed by Maria (2021), was implemented using the free version of Unity and targeted Android mobile devices. Similarly, Inmaculada (2021) used Unity version 2018.3.8f1 alongside the Vuforia plugin to manage AR functionalities and camera operations. Ratna (2021) incorporated Unity, Autodesk 3ds Max, Vuforia, and Firebase in developing a mobile AR application.

Prior studies have highlighted several advantages of Unity. According to Unity (2020), the platform is powerful, user-friendly, and free. Afzal (2020) noted that Unity is simple to learn and widely preferred by professionals. Karia (2019) emphasized that Unity provides all the essential tools and a built-in physics system, streamlining the development process. However, Unity is not without criticism. Shakeel (2020) pointed out that documentation for certain functions is outdated or unavailable. Serdar (2017) noted that Unity 5's integration with the PhysX physics engine has performance limitations and lacks key features necessary for developing high-end applications. Additionally, the absence of accessible source code makes debugging and performance optimization challenging.

Beyond Unity, another widely used mobile development tool is Android Studio. The official integrated development environment (IDE) for the Android operating system, built on JetBrains' IntelliJ IDEA (Android Studio, 2023). Android Studio supports native application development using Java or Kotlin, the Android SDK, and is considered the standard IDE for Android (Tomáš, 2021). However, despite its

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popularity, current literature lacks substantial evidence supporting Android Studio's direct compatibility with AR technologies. Therefore, for this study, Unity was selected as the development platform for creating mobile AR applications, while the Vuforia database was used to manage marker tracking functionalities.

## 2.5 Existing Programming Augmented Reality Learning Modules

Programming is fundamentally defined as a set of computer-executable instructions designed to perform specific functions (Usman, 2016), requiring advanced logical thinking and problem-solving skills (Tsai et al., 2021). Programming is often described as a core component of computational thinking (CT) and computer science education, essential for developing problem-solving, abstraction, and algorithmic skills in students (Babazadeh & Negrini, 2022; Chen, Xiao, Song, & Chen, 2024). It involves writing instructions in a programming language to create software, games, or solve real-world problems, fostering logical thinking, creativity, and collaboration (Yildirim & Ozdener , 2021; Chen et al., 2024). Integrating programming into school curricula equips students with essential 21st-century skills and prepares them for technology-driven careers (Babazadeh & Negrini, 2022; Chen et al., 2024). Furthermore, incorporating programming into other subjects, such as science, enhances interdisciplinary learning and helps make abstract concepts more concrete and accessible (Wang, Zhang, Eckel, Hawkins, & Musslewhite, 2022).

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However, programming education faces multifaceted challenges at both instructional and learning levels. One of the primary barriers for teachers is inadequate preparedness.Many educators report lacking the necessary training and confidence to effectively teach programming, particularly because it remains a relatively recent addition to the school curriculum (Puganesri et al., 2019). This is further compounded by systemic issues, including curriculum and assessment gaps, such as the absence of standardized, age-appropriate programming languages and effective evaluation tools for K–12 learners. From the student perspective, several cognitive challenges hinder the learning process. These include difficulties in visualizing abstract concepts (Poonpong et al., 2019), limited understanding of computational thinking principles (Mary, 2018), and deficiencies in problem-solving abilities (Dolgopolovas et al., 2018; Kadar et al., 2021), mathematical foundations, and syntax comprehension. Moreover, motivational barriers such as low engagement (Dasuki, 2015; Humble, 2021) and negative peer influence (Kinnunen, 2018) further impede effective learning.

Contemporary programming education is challenged by four interrelated factors. First, students often struggle to conceptualize abstract programming structures, which hinders their ability to build accurate mental models, thereby affecting their problem-solving and debugging capabilities (Kara & Güngör, 2024). Second, engagement remains a persistent issue, as traditional programming modules are frequently perceived as tedious and disconnected from real-world applications (Usman et al., 2023). Third, cognitive overload is a major barrier: students are often overwhelmed by the need to simultaneously master syntax, understand computational thinking, and develop logical reasoning a complex, multidimensional challenge (Mary, 2018; Wang et al., 2023).

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Lastly, systemic limitations further exacerbate these issues. Many teachers feel underprepared to incorporate emerging technologies such as Augmented Reality (AR) into programming instruction (Puganesri et al., 2019), and resource constraints in schools frequently deprive both educators and learners of the tools necessary for effective teaching and learning. To overcome this problem in learning programming, mentioned researchers proposed an augmented reality mobile application for learning programming with and without learning module (Tsai & Cheng, 2022 ; Chuan et al., 2023 ; Tasdondurena & Korucu ,2022 ; Yi-Ming et al., 2023 ; Cevahir et al., 2022 ; Abidin & Zawawi , 2020 ; Totogee , 2023 ; Atika, Majid & Zainal , 2020) . Table 2.5 shows the matrix of existing augmented reality application in learning programming.

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**Table 2.5**

*Table of existing Augmented Reality in Learning Programming*

| Author(s) | Objective | Sample | Result | Challenges / Limitation | Similar curriculum |
|---|---|---|---|---|---|
| Tsai & Cheng (2022) | Proposes an AR logic programming teaching system for elementary students to develop programming logic through AR and game-based materials. | 42 fifth and sixth graders | **Achievement**: AR-based group showed significantly better post-test performance, indicating greater effectiveness in knowledge acquisition.<br>**Motivation:**<br>Measured using ARCS principles<br>The AR-based learning group had significantly higher motivation, especially in the Attention dimension.<br>The immersive and interactive sustain student interest | Programming Depth: The command blocks used in the AR module are limited; deeper programming concepts were not addressed.<br>Platform Limitations: Although Unity AR Foundation supports multiple platforms, the study only implemented a limited version.<br>Interaction Limitation: Lacks real-time teacher-learner interaction in the AR environment. | No |
| Chuan et al., (2023) | AR Bot to offers 3D visual learning feedback to strengthen spatial ability, to promote students' deeper CT processes | 75 first-year university students in Taiwan | **Achievement**: No significant difference in academic achievement between the AR Bot group and Scratch group.<br>**Motivation**: AR Bot group showed higher enjoyment of learning. | Academic performance did not improve significantly despite higher motivation and CT skill development.<br>Cost and access to physical robots are what AR Bot aims to resolve. | No |



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| Author(s) | Objective | Sample | Result | Challenges / Limitation | Similar curriculum |
|---|---|---|---|---|---|
| Tasdondurena & Korucu (2022) | To examine middle school students' perceptions of information technology self-efficacy and their attitudes towards coding | 63 primary students attending 5th and 6th grades | **Achievemen**: Not measured<br>**Motivation**: The experimental group also had higher post-test scores on the Attitude Scale Towards Coding. | The study did not evaluate actual programming achivement focused only on perceptions and attitudes. | No |
| Yi-Ming et al., (2023) | To develop and evaluate an AR-based learning system that makes abstract programming concepts more tangible for elementary school students, and to compare how varying levels of interactivity in AR instruction affect students' programming achievement | 98 fifth graders primary school students | **Achievement**: Both AR-based groups outperformed than traditional learning group.<br>High interactive AR group showed the highest improvement<br>**Motivation**:<br>High interactive AR group showed higher motivation compared to other groups.<br>Hands-on interactivity (like assembling puzzle cards) was key to increasing motivation. | AR alone is not enough: Merely using AR did not enhance motivation significantly interactivity is critical. | No |



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| Author(s) | Objective | Sample | Result | Challenges / Limitation | Similar curriculum |
|---|---|---|---|---|---|
| Cevahir et al., (2022) | To examine effect of using animation-based worked examples (ARAWEs) that are prepared using Augmented Reality (AR) technology instead of using traditional paper-based worked examples (TWEs) on the achievement, motivation, and attitude of high school students during their programming education | 94 Second year students from technical Anatolian high school in Turkey | **Achievement**: Students who used animation-based worked examples using AR (ARAWEs) had significantly higher achievement than those using traditional paper-based worked examples (TWEs).<br><br>**Motivation**: The motivation level of the ARAWEs group significantly increased compared to the TWE group. | • Reliance on attitude and motivation scales results depend on the validity of those instruments. | No |
| Abidin & Zawawi (2020) | To help university students better understand Object-Oriented Programming (OOP) concepts by using an Augmented Reality-based learning application (OOP-AR) that enhances engagement and classroom interactivity. | 20 students | **Achievement**: Not measured<br><br>**Motivation**: Satisfaction with the application's effectiveness and usability.Students found it less boring and more exciting, suggesting a positive motivational impact, although not measured with standardized tools. | • Errors in 3D model rendering were encountered during AR use.<br>• AR animations need improvement for a better learning experience.<br>• Content coverage was limited not all OOP concepts included. | No |



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| **Author(s)** | **Objective** | **Sample** | Result | **Challenges / Limitation** | **Similar curriculum** |
|---|---|---|---|---|---|
| Totogee (2023) | To develop a mobile Augmented Reality application that facilitates visualization and interaction with 3D learning models | High school students | Improved students' engagements and learning outcomes | • Lighting conditions and the quality of the camera<br>• Wide scope contains all subject.<br>• Payment requires.<br>• Lack of problem-solving skills | No |
| Atika, Majid & Zainal (2020) | To design and develop an AR based application that can visualize the distance between two robots for supporting learning process in a game-based module | Four secondary school students | Achievement: Not measured<br>Motivation: positive feedback, but not measured using standardized tools. | • Lack of formal evaluation data achievement/motivation).<br>• Only feedback reported no empirical evidence of learning gain. | No |



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The reviewed studies highlight both the potential benefits and challenges of using Augmented Reality (AR) in programming education. A key strength of AR is its ability to enhance student motivation and engagement, as evidenced by multiple studies. For instance, Tsai & Cheng (2022) found that AR-based learning significantly improved students' attention and knowledge retention, while Yi-Ming et al. (2023) demonstrated that highly interactive AR environments led to better academic performance compared to traditional methods. Additionally, AR helps visualize abstract programming concepts, making them more accessible to learners. Studies such as Abidin & Zawawi (2020) and Totogee (2023) showed that 3D models and simulations in AR can improve comprehension of complex topics like Object-Oriented Programming (OOP) and spatial reasoning in coding. However, several limitations hinder the widespread adoption of AR in programming education. Technical challenges, such as device compatibility issues (Tsai & Cheng, 2022) and rendering errors in 3D models (Abidin & Zawawi, 2020), affect the usability of AR applications. Pedagogically, some studies found that AR may lack depth in teaching advanced programming concepts (Tsai & Cheng, 2022) or fail to translate increased motivation into measurable academic gains (Chuan et al., 2023). Furthermore, many studies relied on self-reported feedback rather than standardized assessments, limiting the validity of their findings (Tasdondurena & Korucu, 2022; Atika, Majid & Zainal, 2020). Another concern is accessibility, as some AR solutions require specific hardware or payment (Totogee, 2023), potentially excluding learners with limited resources.

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The existing studies on AR-based programming education highlights promising benefits but reveals significant limitations. For instance, studies such as Tsai & Cheng (2022) and Yi-Ming et al. (2023) demonstrate AR's ability to enhance motivation and conceptual understanding. However, the study failed in measuring actual learning outcomes instead on self-reported attitudes or limited assessments. Additionally, existing AR applications are simplifying content such basic command blocks without addressing advanced topic. These shorten the critical thinking and problem-solving skill of students. Technical challenges, including device dependencies, usability errors, and accessibility barriers, further hinder practical implementation. Most critically, the lack of integration with Malaysian computer science curricula and teacher training remain isolated innovations rather than scalable educational tools. These gaps show the need for more comprehensive studies that combine immersive technology with robust pedagogical design and systemic support. Therefore, this study aims to conduct a comprehensive study on the effect of the augmented reality programming module on secondary school students' achievement in programming. Additionally, this study will examine students' motivation after using SmartAR Module and usability of SmartAR Module. The features, design elements, and learning material of this study selected and validated by experienced teachers and augmented reality experts. Additionally, an assessment included in the programming module to cultivate students' interest in learning and revise acquired knowledge.

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## 2.6 Augmented Reality in Education

Advances in technology have influenced almost every aspect of human life, including industry, agriculture, medicine, management, art, science, and education. Technology has become inseparable from daily human activities (Anisimova, 2020). In educational technology, diverse tools and approaches are being implemented globally to enhance teaching and learning processes. Among these, the use of Augmented Reality (AR) applications is gaining traction in the educational field (Daud et al., 2021; Yildiz, 2021). AR is characterised as a live, direct or indirect, view of a physical, real-world environment in which the elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data (Saidin, Halim, Yahaya, & Zulkifli, 2024).

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Augmented Reality has become an interactive technology widely applied in various learning and educational contexts, offering innovative ways to engage students and improve learning experiences (Hidayat & Wardat, 2023). Previous studies (Yılmaz & Goktas , 2018; Djibril & Cakir , 2022 ; Marini , 2022 ) have highlighted how the implementation of Augmented Reality in education is largely benefits for students. Yılmaz and Goktas (2018) highlighted that AR provides benefits such as visualizing complex relationships, providing experiences that cannot be done in real life, embodying abstract concepts, enabling learning with fun and increasing student participation. Additionally, Djibril and Cakir (2022) highlighted, AR has been used to offer solutions to the problems faced by education and to create an interactive learning environment that can be an advantage to improve students' learning and increase their

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knowledge and skills. The interactive features of AR can create a more stimulating learning environment and help learners get better learning outcomes (Marini, 2022). Previous study by Garzon et al. (2021) conducted a systematic literature review regarding trending topics in educational augmented reality. The study shows seven main domain educational AR content are special education, industry 4.0, storytelling ,3d printing, mobile applications and higher education as shown in table 2.6.

**Table 2.6**

*Popular domain of Educational Augmented Reality*

| Domain | Topics |
|---|---|
| Special Education | Cakir & Korkmaz (2019) analyse the effectiveness of AR based environments considering special educational needs. |
| | AR application for learning mathematics with a focus on special education needs (Cascales-Martínez et al., 2017). |
| Industry 4.0 | Construction of a smart factory using AR (Tzimas et al., 2019). |
| Storytelling | AR application for a literary museum (Fenu & Pittarello, 2018). |
| | Creative writing and storytelling (Ahn & Choi, 2016). |
| 3D Printing | Mixed-reality and 3D printed models in surgery (Barber et al., 2018). |
| | 3D printed and digital models (Saorin et al., 2017). |
| Mobile Applications | Music awareness with AR (Rusiñol et al., 2018). |
| | Conceptual design in mobile applications using AR, an application in geography (Wang et al., 2017). |
| Higher Education | Teaching strategies based on AR in higher education (Ojino & Mich, 2018; Pons, 2018; Saltan & Arslan, 2017) |

In the domain of special education, AR environments have been analyzed for their effectiveness in addressing the needs of students with special educational requirements (Cakir & Korkmaz, 2019), and AR applications have been utilized to teach mathematics to students with these needs (Cascales et al., 2017). For Industry 4.0,

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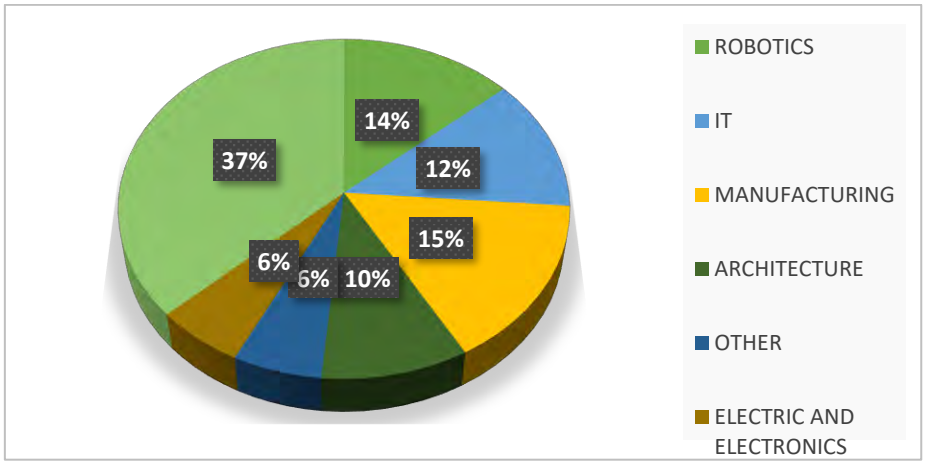
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AR has been employed in constructing smart factories (Tzimas et al., 2019). In storytelling, AR has enhanced experiences in literary museums (Fenu & Pittarello, 2018) and supported creative writing (Ahn & Choi, 2016). In 3D printing, AR has been integrated with mixed-reality models for surgical applications (Barber et al., 2018) and with digital models for educational purposes (Saorin et al., 2017). Mobile applications have leveraged AR for music awareness (Rusiñol et al., 2018) and for conceptual design in geography (Wang et al., 2017). In higher education, AR has supported teaching strategies to enhance student engagement and learning outcomes (Ojino & Mich, 2018; Pons, 2018; Saltan & Arslan, 2017). Apart this , Kaminska, Zwoliński , Leśniewicz , Raposo & Vairinhos , (2023) conducted systematic literature review and has classified two main domain using Augmented reality actively such as engineering and life science. Figure 2.1 shows the percentage use of most used engineering domains using AR for educational purposes.

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**Figure 2.1**

*The percentage use of engineering domains using AR for educational.*




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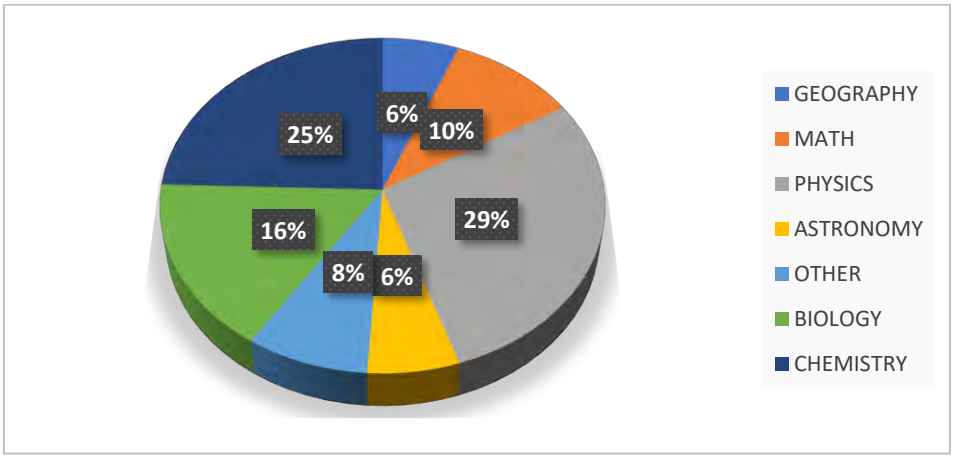
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Among these domains, Mechanics stands out as the most significant, with a usage rate of 36.5%, showcasing its extensive integration of AR tools to enhance conceptual learning and practical applications. Manufacturing follows at 15.4%, reflecting AR's role in simulating processes and operations in industrial settings. Other key domains include Robotics (13.5%), IT (12.5%), and Architecture (9.6%), each leveraging AR to create interactive and immersive environments for design and problem-solving. Electric and Electronics and other fields each account for 5.8%, indicating moderate adoption of AR technologies to aid in education and training within these specialized areas. The data highlights AR's transformative impact across diverse engineering disciplines. Meanwhile, Figure 2.2 shows the percentage use of most used science life domains using AR for educational purposes.

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**Figure 2.2**

*The percentage use of science life domains using AR for educational.*




Physics leads with a significant share of 28.6%, reflecting AR's role in visualizing complex physical phenomena and enhancing understanding through simulations. Chemistry follows closely at 24.5%, where AR is widely applied for

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interactive experiments and molecular visualizations. Biology accounts for 16.3%, demonstrating AR's effectiveness in presenting intricate biological processes and structures.Other domains include Mathematics (10.2%), which benefits from AR's ability to simplify abstract concepts, and Geography and Astronomy, each at 6.1%, where AR aids in exploring spatial data and celestial phenomena. The remaining 8.2% is categorized as "Other," representing niche applications across various life science disciplines. This distribution underscores AR's broad utility in enriching education across diverse science fields. Table 2.7 highlights the innovative applications of Augmented Reality (AR) in supporting educational activities across science and engineering domains. In the science life domain, AR has been effectively utilized to enhance learning experiences. For example, Tian et al. (2019) introduced an AR smartphone tool to aid in seasonal constellation observation, while Zarraonandia et al. (2019) developed an AR-based game to teach about local plant environments. Puket et al. (2019) employed AR note cards enriched with content, leveraging a free app for chemistry education. Wyss et al. (2021) utilized AR through HoloLens headsets to teach molecular biology to faculty members.

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**Table 2.7**

*Role of Augmented reality in science life and engineering domains.*

| Author | Domain | Subject | Unique Approach |
|---|---|---|---|
| Tian, Urata, Endo, Mouri, & Kato, (2019) | Science Life | Science | AR smartphone tool for seasonal constellation observation |
| Zarraonandia Montero, Diaz, & Aedo, (2019) | | Biology | AR pervasive game that aims to promote learning about the plants in the local environment |
| Puket et al., (2019) | | Chemistry | AR note-cards rich in content, utilizing a free HP Reveal app and a smartphone |
| Wyss , Bührer, Furrer, Degonda, & Hiss (2021) | | Biology | HoloLens headset to support the education of faculty members in the area of biological molecular structures |
| Gorden , Ryan, & Loughlin (2018) | Engineering | Engineering Science | AR-supported interfaces as a basic form of interacting with virtual laboratories. |

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In the engineering domain, Gorden et al. (2018) explored AR-supported interfaces to facilitate interactive learning in virtual laboratories for engineering science. These applications demonstrate AR's ability to provide hands-on, immersive educational experiences, making complex concepts more accessible and engaging for learners. Furthermore, a previous study by Sirakaya & Alsancak (2018) investigated the distribution of methods used in educational AR studies, as shown in Figure 2.3. The study shows that 50% of studies conducted quantitative research, followed by literature reviews and mixed methods of quantitative and qualitative research. The systematic literature review highlighted the most studies use quantitative methods in education to identify the effect of AR us). student achievement (Chiang et al., 2014; Estapa & Nadolny, 2015; Ferrer-Torregrosa et al., 2014; Lu & Liu, 2015) or to determine student

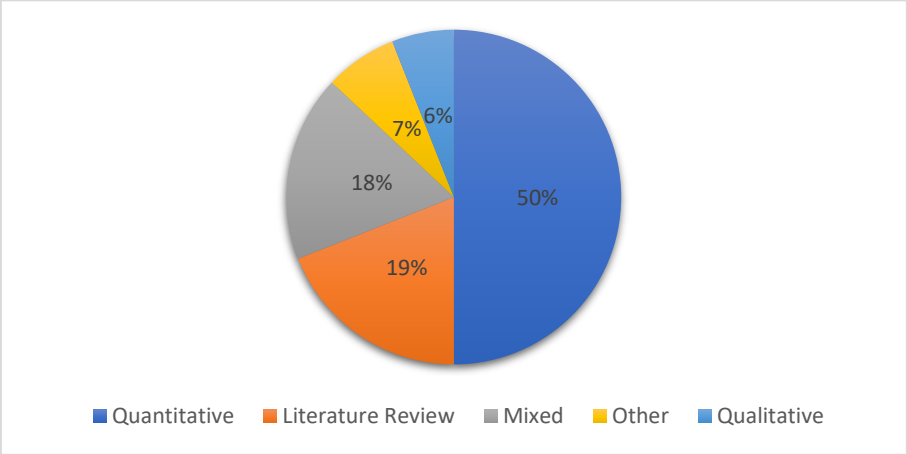
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views on AR (Cai, Wang, & Chiang, 2014; Crandall et al., 2015; Serio, Ibáñez, & Kloos, 2013).

**Figure 2.3**

*Distribution of methods used in educational AR studies.*




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The study also emphasizes the second lower percentage, which is 7% of studies conducted using other research methods such as design and development research, etc. Next, the lowest percentage is in qualitative studies at 6%. Meanwhile, in the study conducted by Stefan et al (2018) highlight location-based drawback as hardly used by any software development kits (SDKs) that can be effectively used by developers, as important functionality and customisation options are generally missing. Augmented reality simplicity, robustness and efficiency have a great advantage; the objects to detect are provided to the application and require to be always visible by the sensor (Zainab et al., 2020). Garzon et al., (2021) emphasized that 2011 is the year where the number of publications in AR in education sky-rocketed and then rose steadily year after year. This is because students who are tutored with more complex AR content learn better

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and show a wider variety of inquiry styles. Apart that, AR visual representations appear to stimulate students to think about a wide range of scientific ideas, to make deeper connections between scientific concepts, and encourage students to have a more active learning style with increased transitions between inquiry activities (Radu et al., 2022). Moreover, AR has changed the presentation of learning materials that allows learning activities to be more interactive and richer in multimedia. AR has the potential to increase students' engagement and motivation in learning (Yoke et al., 2019).

However, there are still several disadvantages that education institutions have highlighted when employing AR in education (Yoke et al., 2019; Alzahrani ,2020). Yoke et al. (2019) emphasize that it requires a smartphone to operate, has health concerns, is less dependent on the instructor, is difficult to write notes for students, and cannot function without access to the internet. Next findings by Alzahrani (2020) suggest that challenges associated with AR in e-learning include information and cognitive overload, lack of experience in using the technology, resistance from teachers, complex technology, costly technology, and technical issues such as connectivity problems. Despite the fact that augmented reality has several disadvantages, the use of augmented reality in education is rapidly growing.

### 2.6.1 Existing Marker-based Augmented Reality in Education

Markers are the most optimal solution to solve the problem of calculating the pose for augmented reality and do not require powerful devices. Its simplicity, robustness and

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efficiency have a great advantage; the objects to detect are provided to the application and require to be always visible by the sensor (Oufqir, Zainab , Abderrahmani, Abdellatif & Khalid, 2020). Previous studies developed marker-based augmented reality applications in education (Talan et al., 2022; Yang et al., 2023). A previous study by Talan et al., (2022) examine the effects of marker based augmented reality applications on secondary students' academic achievement in science course. The study used flash cards as marker and provides virtual reality glasses, smartphones, laptops, and tablets to ensure that the application runs more. Figure 2.4 shows user interface of proposed applications. The outcome of studies indicates that the marker-based AR enabled effective and sustained learning, reinforced learning, made classes interesting and fun, and improved visual intelligence. These positive opinions of the students can be considered as the reason for the increase in their academic achievement.

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**Figure 2.4**

*Interface of Science AR Marker Based Application.*




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Apart that, previous study Yang et al., (2023) proposed augmented reality marker based virtual educational robotics on programming students' enjoyment of learning, computational thinking skills, and academic achievement. The study utilize marker function in form of includes 27 AR cards, containing multiple image-based AR technology markers was designed as a paper card about the size of a playing card. A paper card represents learning material, a test, or a game, and each corresponds to a learning goal. The front of the card was composed of an illustration of the level, which was mainly used for AR identification. The back of the card was the knowledge introduction and level tips. After scanning the cards with a tablet, students could do the following: (1) watch 3D animation teaching videos of robots or parts, (2) write a visual building block program, and (3) display the results of the virtual robot operation simulation. Figure 2.5 shows the user interface of proposed applications.

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**Figure 2.5**

*Interface of Block Programming AR Marker Based Application.*




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The studies result shows that, students who used AR Bot had higher enjoyment of learning, algorithm design skills, and algorithm efficiency skills but not higher problem decomposition skills and academic achievement than students who used Scratch.

## 2.7 Mobile Augmented Reality in Teaching & Learning

Augmented reality technology is used in many different areas in education, as well as at different learning levels such as preschool, primary school, middle school, and high school (Sirakaya & Alsancak, 2018). This technology enables the transformation of textbooks, classrooms and stationary objects in learning environments into multimedia possibilities, increasing the functional richness of the environment and enabling different cognitive areas to work in learning (Turhan, Metin, & Çevik, 2022). Saidin et al (2024) emphases to bring the technology closer to students in learning , AR has been evolving over the years and has become portable and available in mobile devices as a result of rapid technological development.

The use of mobile augmented reality (MAR) technology has recently improved in education and training methods (Djibril & Cakir, 2022). Previous studies have shared the benefits of using mobile augmented reality in education (Costa, Manso & Patrício, 2020; Garrett, Anthony, & Jackson, 2018; Hemamalini et al 2022; Djamila & Huseyin, 2022; Akcayır & Akcayır, 2017; Altinpulluk, 2019). Costa et al (2020) highlighted the portability of MAR makes the technology popular than desktop computers. (Garrett et

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al, 2018; Djamila & Huseyin, 2022) highlights that use of MAR are relatively affordable compares to other hardware. Hemamalini et al (2022) highlighted those benefits of MAR promotes the integration of sensory input such as sound, video, graphics or GPS data and the real-world physical elements through mobile phones. Furthermore, the most comprehensive meta-studies on the subject identified significant potential for MAR-learning settings (MARLS) to increase learner engagement, motivation, learning effects, and the quality and quantity of interaction (Akcayır and Akcayır, 2017; Altinpulluk, 2019).Previous studies have design and developed MAR to support learning (Hyttinen & Suhonen, 2023; Tzortzoglou, Kosmas & Avraamidou (2023); Simon, Marfisi-Schottman & George (2024) ; Djibril & Cakirb (2023); Schmidthaler, Anđic, Schmollmüller, Sabitzer & Lavicza (2023) ; Ozeren & Top (2023)) as shown in Table 2.8.

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**Table 2.8**

*Advantages of Previous MAR Application*

| Author | Subject | Findings |
|---|---|---|
| Hyttinen & Suhonen (2023) | To explore the development and utilization of a Mobile Augmented Reality (MAR) application for teaching an asynchronous online lesson on e-commerce. | MAR applications can be effective for learning with compact materials and micro credentials. |
| Tzortzoglou et al., (2023) | Designed and Implemented "EcoAegean" : A mobile augmented reality game (ARG) focused on sustainability | MAR proved to be an easy-to-use tool, oriented towards creating low-cost location-based AR experiences and games |
| Simon, et al., (2024) | Spart – An affordable mobile augmented reality alternative to interactive tabletops in education | MAR is robust, affordable and accurate solution and allows augmenting any flat surface show affordability and mobility. |
| Djibril & Cakirb (2023) | Investigated students' perspectives on the use of MAR as an educational tool and its impact on learning performance. | MAR technology was perceived as an effective tool for improving engagement, understanding, and overall learning outcomes in health education. |
| Schmidthaler et al., (2023) | Investigated Austrian secondary school biology teachers' perceptions of mobile AR (mAR) applications in biology education, focusing on benefits, obstacles, and recommendations. | MAR enhances students' learning outcomes, motivation, collaboration, and overall enthusiasm for learning biology. |
| Ozeren & Top (2023) | Examined the effects of the augmented reality application "CellAR" on academic achievement and motivation of seventh-grade students in the "Cell and Cell Division" unit. | The use of augmented reality applications like CellAR can significantly enhance academic performance and motivation by making learning more interactive, concrete, and engaging. |



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MAR has proven effective for teaching compact materials and micro-credentials in asynchronous online lessons (Hyttinen & Suhonen, 2023), while applications like "EcoAegean" have demonstrated its ease of use and suitability for creating low-cost, location-based educational experiences focused on sustainability (Tzortzoglou, Kosmas & Avraamidou, 2023). MAR solutions such as "Spart" offer affordable and mobile alternatives to interactive tabletops, enabling augmented interactions on any flat surface (Simon, Marfisi-Schottman & George, 2024). In health education, MAR technology has been shown to improve engagement, understanding, and learning outcomes (Djibril & Cakirb, 2023). Studies in biology education highlight MAR's ability to enhance learning outcomes, motivation, and collaboration, though challenges like curriculum alignment persist (Schmidthaler et al., 2023). Similarly, the "CellAR" application significantly boosted seventh-grade students' academic performance and motivation by making abstract concepts tangible and fostering interactive learning (Ozeren & Top, 2023). Collectively, these findings showcase MAR's versatility, affordability, and effectiveness in modern education.

Several studies have highlighted the challenges associated with MAR integration. Schmidthaler et al. (2023) noted obstacles such as insufficient technical devices, internet connectivity issues, curriculum misalignment, and concerns over the scientific accuracy of content. Similarly, Hyttinen and Suhonen (2023) identified technical limitations, including difficulties with QR code scanning, poor image quality, small screens for viewing, lack of note-taking functionality, limited student interaction during lessons, and the questionable reliability of free software. Additionally, the opacity of potential privacy risks when combining and analysing these different data types of

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multiple permissions of mobile augmented reality applications (Thilakarathna, & Seneviratne, 2018; Harborth et al., 2019).

Despite its challenges, MAR continues to offer significant benefits. Ayfer et al. (2021) identified advantages such as improved learning performance, increased motivation, heightened interest in lessons, better attitudes toward learning, enhanced spatial abilities, improved thinking skills, and stronger communication among students. Similarly, Nouf (2020) highlighted MAR's role in boosting engagement, focus, interactivity, knowledge retention, and accessibility, encouraging educators to incorporate it into their teaching practices. Even though MAR has proven advantages, most studies focus on technological innovation rather than teaching depth, failing to associate MAR with skill retention, advanced learning outcomes, or chronic metacognition. Many applications, such as Spart (Simon et al., 2024), prioritize cost and mobility, which could disengage learners actively. This neglects adherence to widely accepted and utilized standards of education. Future studies should develop comprehensive frameworks and professional development programs with sustained impact MAR’s motivational potential. Therefore, this study aimed to address these critical gaps by developing and evaluating an Augmented Reality Programming Module to enhances student motivation and achievement programming. By incorporating pedagogical best practices and addressing technical limitations identified in previous research, this study will provide a comprehensive, practical and sustainable solution for programming education.

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## 2.8 Learning Theory

Learning theories form the essential foundation for understanding how knowledge is acquired, processed, and applied in educational settings (Khalil & Elkhider, 2016). These theories play a crucial role in guiding the design of instructional activities, ensuring that teaching approaches and assessment methods are purposefully selected to maximize learning effectiveness (Bearman et al., 2017). Within educational research, the theoretical framework serves as the backbone of study design, providing structure and direction for topic selection, research questions, methodology, and analysis (Osanloo et al., 2019). As Grant and Osanloo (2014) emphasize, a well-chosen theoretical framework establishes the study's philosophical and epistemological foundations while contextualizing it within existing scholarship. Ravitch and Carl (2016) further highlight that the framework acts as a guiding structure that situates formal theories within the research context, with an inappropriate choice potentially compromising the study's coherence and alignment.

The application of learning theories is particularly valuable for ensuring that educational methods align with desired learning outcomes (Squires et al., 2024). While six major theoretical perspectives are commonly recognized in education - behaviorism, constructivism, cognitivism, sociocultural theory, humanism, and connectivism (Squires et al., 2024) - simulation-based learning has primarily been associated with just three: behaviorism, cognitivism, and constructivism (Bearman et al., 2017; Erlam et al., 2017; Lavoie et al., 2018). The intentional integration of learning theories in simulation design enables educators to create authentic learning experiences

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that effectively engage learners while optimizing resource utilization (Bearman et al., 2017; INACSL, 2016; O'Shea et al., 2022).

### 2.8.1 Comparative Analysis of Connectivism and Constructivism Learning Theories

This study adopts connectivism as the foundational learning theory for the SmartAR Module, deliberately selecting it over constructivism due to its inherent compatibility with technology-enhanced learning environments. As Matter (2018) asserts, connectivism represents an evolution of constructivist principles by explicitly incorporating the critical role of digital networks in contemporary learning processes. While constructivism emphasizes individual knowledge construction occurring within social or authentic contexts (Rutherford-Hemming, 2012; Torre et al., 2006), connectivism reconceptualizes learning as a distributed process that occurs across interconnected networks of individuals, digital tools, and information sources (Dacholfany et al., 2022). This fundamental distinction renders connectivism particularly suitable for augmented reality (AR) applications, which by their nature integrate physical and digital realities through networked information systems and collaborative interfaces.

The epistemological foundations of these theories reveal further critical distinctions. Connectivism is fundamentally predicated on the principle that learning occurs through connection formation, with technology serving as both medium and catalyst for knowledge network development (Dacholfany et al., 2022). In contrast,

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constructivism posits that learners actively construct new knowledge through the interpretation of experiences and the integration of novel information with existing cognitive schemas (Merriam & Baumgartner, 2020). This essential difference in orientation between network formation and individual meaning-making carries significant implications for instructional design in digital environments. Matter (2018) further elucidates how connectivism transcends the limitations of individual cognition inherent in constructivist models. Where constructivism traditionally locates knowledge within the individual's cognitive processes (developed through experience and reflection), connectivism proposes a more distributed model of knowledge that resides equally within digital networks and artifacts. This paradigm shift aligns precisely with the SmartAR Module's design objectives, which prioritize collaborative knowledge construction across digital-physical interfaces over individual knowledge acquisition. Previous support for this theoretical selection comes from Mukhlisa et al. (2024), whose comprehensive investigation demonstrates connectivism's efficacy as a digital-age pedagogical framework. Their research documents successful implementations across diverse educational contexts, revealing how connectivism:

1. Facilitates the development of personal knowledge networks that support lifelong learning

2. Cultivates critical digital literacy skills, including information sourcing and evaluation competencies

3. Demonstrates remarkable adaptability to evolving educational technologies

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These findings substantiate connectivism's superiority over constructivism for technology-mediated learning environments, particularly those employing AR systems. The SmartAR Module's deliberate exclusion of constructivist elements constitutes a theoretically justified design decision, as its pedagogical architecture prioritizes networked knowledge exchange a core tenet of connectivism over the individual knowledge construction emphasized by constructivist approaches. This strategic alignment ensures optimal learning outcomes in digital-physical hybrid environments where distributed cognition and collaborative knowledge building are paramount.

### 2.8.2 Connectivism Learning Theory

Connectivism Learning Theory (CLT) has emerged as a pivotal learning theory for the digital age, emphasizing knowledge acquisition through network formation (Squires et al., 2024). Introduced by Siemens (2004), CLT integrates principles from chaos, complexity, and self-organization theories (Siemens, 2008), framing learning as a process of connecting specialized information nodes, particularly in digital environments (Downes, 2011; Dacholfany et al., 2022). Unlike traditional theories, connectivism posits that knowledge is distributed across networks rather than confined to individuals (Downes, 2011). Dorothy (2013) further describes connectivism as learning rooted in social networks, emphasizing the importance of cyber nodes in knowledge construction. Similarly, Michael (2022) highlights that connectivism enables learners to efficiently expand their understanding by connecting specialized information sets. In essence, connectivism underscores the significance of continuous

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connection-building as a central mechanism for learning in an increasingly digital and information-rich world. The theoretical foundation of connectivism rests on four core principles identified by Siemens (2004) as shown in Table 2.9.

**Table 2.9**

*Four Core Principles Connectivism*

| Principle | Description |
|---|---|
| Autonomy | 1. Central to connectivism, highlighting that learners make decisions about what and how to learn, which fosters self-directed and lifelong learning (Downes, 2012)<br>2. Engage actively and meaningfully in networked learning environments (Adam , Varma , Kadar & Yadri , 2023)<br>3. learners acting from personal interest and integrated values (Tschofen , 2012)<br>4. Enables independent selection of information sources beyond traditional instruction (Frederique et al., 2020) |
| Connectedness | 1. Nurturing and maintaining connections" necessary for continual learning and knowledge flow (Downes, 2012) |
| Diversity | 1. Enriches learning by exposing learners to multiple viewpoints, which promotes creativity and critical thinking. (Downes, 2012; Nazari, Hussin & Niknejad , 2021; Corbett & Spinello, 2020) |
| Openness | 1. Curiosity, exploration, and the willingness to share and collaborate without restrictive barriers (Nazari et al., 2021)<br>2. free exchange of ideas, resources, and creative outputs across networks. (Frederique et al., 2020) |

Autonomy emphasizes learners' ability to self-direct their educational pathways, making independent decisions about what and how to learn (Downes, 2012; Tschofen, 2012). Connectedness highlights the importance of maintaining active learning networks for continuous knowledge exchange (Downes, 2012). Diversity enriches the learning experience by exposing students to multiple perspectives, thereby enhancing critical thinking (Nazari et al., 2021), while openness promotes collaborative knowledge-building through unrestricted sharing of ideas (Frederique et al., 2020).

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These principles collectively advocate for a shift from traditional classroom isolation to digitally networked learning ecosystems (Jeny, 2024).

Previous studies have demonstrated how connectivism provides a theoretical foundation for AR by facilitating dynamic connections between learners, digital content, and real-world environments. (Techakosit & Wannapiroon, 2015; Jeny 2024; Tran, 2025; Mukhlisa, Haenilaha, Sunyonoa, Maulinaa & Noerhasmalinac, 2024; Chen & Yaqian , 2022; Mehmet & Safieh, 2012). Techakosit and Wannapiroon (2015) designed a connectivism-based learning environment within an AR science laboratory to enhance scientific literacy. Their study illustrated how AR technology, underpinned by connectivism, enables learners to interact with scientific content in a networked manner, promoting deeper engagement and understanding. Similarly, Jeny (2024) highlighted how connectivism transforms traditional classrooms into digitally networked spaces, where AR serves as a tool for collaborative learning and knowledge sharing. By leveraging digital networks, AR fosters connectivity among learners, enhancing both engagement and information exchange.

Further supporting this perspective, Tran (2025) explored the use of wearable AR to enhance presence and engagement in real-world contexts. The study applied connectivism to demonstrate how AR mediates meaningful connections between digital information and physical environments, reinforcing learning through context-aware interactions. Likewise, Mukhlisa et al. (2024) argued that emerging technologies such as AR and artificial intelligence (AI) reshape education by promoting networked knowledge and digital literacy. Connectivism, in this context, provides a framework for

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understanding how AR facilitates distributed knowledge and collaborative learning in digital environments. Chen and Yaqian (2022) further reinforced the connection between connectivism and AR by examining complex network patterns in connectivist learning environments. Their findings revealed that connectivist networks exhibit self-organization, modularity, and small-world effects characteristics that align with AR's ability to create dynamic, interactive learning spaces. By analysing the evolution of these networks over time, the study demonstrated how AR-enhanced learning environments adapt and grow through continuous digital interactions. Additionally, Mehmet and Safieh (2012) provided insights from educators, emphasizing the advantages of connectivism in fostering social interaction, peer tutoring, and independent learning qualities that AR effectively supports. The findings suggest that AR, when grounded in connectivism principles, enhances learner autonomy and collaboration, further validating the synergy between the two.

However, significant challenges emerge when implementing connectivism in practice. Plueger (2024) identifies a lack of structured guidance as potentially leading to learner confusion, particularly for students who require more support. Siemens (2025) himself has expressed concerns about diminished human interaction in overly digital learning environments, noting that pure connectivist models may neglect essential face-to-face pedagogical dynamics. Additionally, Jeny (2024) highlights persistent technological disparities that prevent equitable access to networked learning opportunities. These limitations are compounded by Stephen's (2019) critique questioning whether all learners possess the necessary self-regulation skills to thrive in completely autonomous learning environments.

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To address these challenges while preserving connectivism's benefits, this study designed and developed the SmartAR Module, an innovative solution that combines structured learning design with connectivist principles. Unlike purely open connectivist models, SmartAR provides curated learning pathways within AR environments while still encouraging network exploration. This approach maintains the theory's emphasis on autonomy and connectedness but introduces necessary scaffolding to prevent disengagement. By integrating expert-validated and content validated with AR's interactive capabilities, SmartAR effectively bridges the gap between self-directed network learning and guided educational experiences, offering a balanced solution to connectivism's implementation challenges in modern pedagogy.

### 2.8.3 Cognitive Learning Theory

Cognition refers to capabilities including memory, thinking, and reasoning, spatial processing, problem solving, language, and perception (Lindsey, 2016). Cognitive learning theory is one of the learning theories developed to aid students in their learning. Cognitive Learning Theory proposed by Jean Piaget (1936). Piaget's theory of cognitive development explains how a child constructs a mental model of the world (Mana, 2020). Swiss Psychologist Jean Piaget’s (1896-1980) theory of children’s cognitive development has had tremendous impact on the field of education (Andrew, 2014). The basic concept of learning is the main viewpoint in the Cognitive Learning Theories as it refers to mental processes that eventually bring about learning in an individual (Nadir, 2019). Cognitive learning theory is best used to guide learning when trying to build

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usefulness Knowledge structures, and clinical reasoning teaching (Alahmad, 2020). Previous study by Michelle (2020) classified stages of this learning theory such as Stage 1 is the sensorimotor stage, birth to 2years, second stage preoperational stage children between two to seven years, stage 3 is the concrete operational stage from age of seven to eleven years and final stage namely the formal operations stage children eleven years onwards.

Previous study by Fazlina (2021) addressed five metacognitive strategies practice thinking process and learning to encounter goal are (1) comprehension monitoring, (2) elaboration, (3) organising, (4) transformation and (5) rehearsal (Gagner, 2005; Keener et al., 2012; Keller, 2005). Firstly, comprehension monitoring is defined as a metacognitive process that includes both the evaluation and regulation of understanding derived from discourse, in other words, verbal communication (Keener et al., 2012). By comprehensively monitor students learning, teachers will be aware of student's level of readiness and understanding in programming. Next, elaboration strategies comprise enlarge target information by linking with relevant information (Gager et al., 2005). Incorporating programming with daily life is an example of elaboration learning strategies.

Thirdly, organizes strategy demands learners to categorise information in sequence (Fazlina, 2021). The fourth strategy is transformation enquire students to transform difficult information into comprehensible information (Pham,2011) Finally rehearsal is providing efficient reading and repeating of subject matter during a learning activity (Tay et al., 2016). Previous study by Chen (2020) mentioned that the learners

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learn by understanding the situation and absorbing the process through field dependent and independent variable. Thus, needs of an appropriate element employ in lesson plan is important to ease the process for students to learn. The study highlighted importance of adopting to learners learning style and design course relatively increase students' academic achievement. However, usage of cognitive learning will take time for teachers planning and design accurate information.

Apart that, a literature review by Prayekti (2018) highlighted that "students' cognitive learning styles strongly influenced their learning outcomes either by independent or dependent cognitive styles". The study significantly highlighted that the dependent cognitive value significantly influenced student outcomes compared to independent cognitive. Although Jean Piaget has categorically split phases according to children's knowledge, previous studies critiqued the learning theory. The main disadvantage of the cognitive approach is that it refers to cognitive processes that we cannot directly observe (Alahmad, 2020). Overestimating the ability of adolescence and underestimating infant's capacity (Zana ,2020). Although cognitive processes include thinking processes, observation is a preferred way for assigning the children's phases. Despite the fact that teachers are unable to predict a student's performance based on observation, this is generally conveyed as a criticism. Previous studies include (Hidayana ,2024; Qu & Shi 2022; Aprilia, 2024; Harahap, 2024; Gins & Leppink, 2019) have used cognitive learning theory to support students' achievement as shown in Table 2.10.

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**Table 2.10**

*Existing Cognitive Learning Theory in Measuring Student Achievements.*

| Authors | Objective | Findings |
|---|---|---|
| Hidayana (2024) | To examine how cognitive influence achievement | Cognitive engagement and achievement motivation enhance students' entrepreneurial intentions, supporting achievement through motivation |
| Qu & Shi (2022) | Investigate cognitive ability as predictor of academic achievement with self-regulation | Cognitive processes as self-discipline and planning mediate cognitive ability's effect, improving academic achievement by fostering self-regulated learning |
| Aprilia, (2024) | To explore cognitive learning principles, improve problem-solving and knowledge | Cognitive strategies enhanced problem-solving and creativity, supporting deeper knowledge internalization and adaptive use |
| Harahap (2024) | To improve students' critical thinking skills using cognitive learning theory | Positive impact on critical thinking and social skills, showing cognitive learning theory enhances analytical and evaluative abilities |
| Gins & Leppink (2019) | To review cognitive load theory principles for instructional design to optimize learning | Reducing extraneous cognitive load improves student learning and achievement, supporting effective instructional design |



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The previous studies demonstrated how cognitive learning theory principles enhance student achievement. Hidayana (2024) uncovered that motivation accomplishes achievement and cognitive engagement. On the other hand, Qu & Shi (2022) stressed self-regulated learning as a facilitator for achieving academic goals. Aprilia (2024) showed to enhance problem-solving skills through the application of cognitive strategies. Additionally, Harahap (2024) emphasized the role of these strategies in fostering critical thinking. Ginns & Leppink (2019) have also stressed the usefulness of optimizing cognitive load in education to enhance design in instruction to achieve better learning results. All of these insights confirm the validity of cognitive learning theory in terms of achieving optimal motivational, self-regulated, problem-solving, and critical thinking. Overall, these studies illustrate the advantages of cognitive learning theory in motivation, self-regulation, problem solving, and instruction, and at the same time illustrates weaknesses regarding social-emotional integration, measurement, learner variability, and instructional complex.

Therefore, the students' achievement in learning programming will be supported by cognitive learning theory. This theory emphasis on mental processing strategies directly support programming skill development by helping learners organize, retain, and apply complex coding concepts. Research by Aprilia (2024) and Harahap (2024) demonstrates that cognitive strategies enhance critical thinking and problem-solving. These criteria essential to debugging and algorithmic reasoning in programming.

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## 2.9 Problem Solving Learning Strategy

In contemporary educational paradigms, problem-solving learning (PSL) has emerged as a critical pedagogical approach for developing essential 21st century competencies. International Collaboration Book Chapter (2007) defines problem-solving learning (PSL) as a learning process focused on developing students' abilities to solve problems using logic, critical thinking, and creativity. Theoretical foundations of PSL reveal its structured cognitive architecture. Omar (2022) delineates problem-solving as a sophisticated mental process comprising organized phases: (1) problem identification and definition, (2) hypothesis formulation, (3) systematic data collection and analysis, and (4) iterative solution testing. This framework mirrors the cognitive demands of authentic, real-world challenges where solutions are not predetermined. Rahman's (2019) research further elaborates this process, identifying two core competencies: systematic observation and critical analysis, which collectively enable effective solution generation.

These cognitive operations are particularly vital for developing what Rahman (2019) identifies as indispensable 21st century skills - including creative problem-solving, metacognitive awareness, and innovative thinking - that prepare learners for modern societal demands (Harefa & Purba, 2019). Problem-solving skills are widely recognised as essential for effective teaching in contemporary educational settings (Barab & Plucker, 2018; Cruickshank & Haefele, 2001; Kuo, 2019). Scholarly consensus demonstrates multidimensional interpretations of problem-solving

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competencies. Shute et al. (2016) conceptualize these skills as cognitive processes activated when confronting novel problems without immediate solutions. This definition emphasizes the adaptive and generative nature of problem-solving cognition. Ismet et al. (2020) specifically highlight their pedagogical value in teacher education, where such skills serve dual purposes: enhancing preservice teachers' own cognitive abilities while equipping them to facilitate similar skill development in future students. Rahman (2019) provides foundational perspective by framing problem-solving as a fundamental human cognitive process, essential for both academic and real-world functioning.

However, students face numerous challenges in obtaining problem-solving skills strategies due to their tendency to question things that are low-level factual rather than analyze abstract things (Krajcik & Blumenfeld, 2006), difficulties in defining and analyzing the problem, and a lack of knowledge in problem-solving skills techniques (Zainaf, Robiah, & Habibah, 2019). Especially in programming subjects, there are numerous abstract problems to solve effectively. In programming languages, logic and syntax are difficult to understand (Latih et al., 2020), as are languages of communication, the digital divide, and schools' teaching and learning time (Hani, Dewi, Liyana, & Raha, 2021). Therefore, it's important to integrate problem-solving skills using appropriate problem-solving techniques to improve students' achievement and critical thinking skills.There are various of problem-solving learning strategy available includes Polya's Problem-Solving Strategy (1973), Wood & Middleton's Scaffolding Approach (1975) , Jonassen's Problem-Solving Model (1977) and Stein et al.'s Problem-Solving Framework (1996). Polya (1973) outlines four key stages in the

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problem-solving strategy: understanding the problem, devising a plan, carrying out the plan, and looking back. Building on this, Wood and Middleton (1975) introduced a five-step model that includes defining the problem, thinking about it, planning a solution, carrying out the plan, and reflecting on the process. According to Prem (2020), each step plays a vital role starting with clearly interpreting the problem and identifying unknowns, followed by gathering information and considering strategies, executing the plan, and finally, reflecting on the outcome to reinforce learning.

Stein et al. (1996) further developed a problem-solving framework that consists of five sequential stages: (1) problem identification, (2) problem definition and representation, (3) strategy formulation, (4) organization of information, and (5) monitoring and evaluation. This framework emphasizes not only understanding and planning but also managing and accessing the problem-solving process effectively. Additionally, Jonasson (1977) proposed a problem-solving learning strategy with seven criteria aimed at producing interactive learning materials: presenting problem elements, defining both the problem and the solution, enabling real-world application, structuring domain knowledge, identifying the correct answer, providing a comprehensive solution, and prescribing a solution process. The analysis of existing studies used the problem-solving strategies shows in table 2.11.

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**Table 2.11**

*Analysis of Problem-Solving Learning Strategies*

| Problem Solving Strategy | Benefits | Challenges | Authors | Title of research |
|---|---|---|---|---|
| Polya (1973) | Structured, promotes metacognition, widely applicable | Abstract for novices, needs scaffolding, time-consuming | Karatas & Baki (2013) | Problem-Solving Strategies in Mathematics Education |
| | | | Chang et al. (2006): | Scaffolding Problem-Solving Skills in Novice Learners" |
| | | | Widianaa et al. (2024) | Enhancing Problem-Solving Through Metacognitive Strategies |
| Wood & Middleton (1975) | Supports learner, reduces frustration | Requires skilled teachers, risk of over-scaffolding | Konya & Foldesi (2016) | Observational Analysis of Scaffolding in Classroom Settings |
| Jonassen (1977) | Promotes knowledge construction, supports tech integration | Complex design, needs self-regulation, prior knowledge | Tang , Long, Tong , Wang & Jones (2020) | Technology-Enhanced Problem-Solving and Self-Regulated Learning |
| | | | Rennick,Litster, Hurst & Bedi (2021) | Characterizing Engineering Design Activities Using Jonassen's Problem Solving |
| | | | Lah, Hashim, Harun, & Abdullah, (2024). | The evaluation of problem-solving oriented e-module in learning computer-based subject. |
| Stein et al. (1996) | Multiple strategies, teacher support | Teacher-dependent, less known, requires time | Konya & Foldesi (2016) | Teacher-Dependent Reflective Strategies in Problem-Solving Contexts |



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Problem-solving learning strategies have been extensively studied in educational studies, with several prominent frameworks demonstrating both significant benefits and notable challenges. Polya's (1973) four-step model provides a structured approach to problem-solving that effectively promotes metacognitive skills and logical reasoning, as evidenced by Karatas and Baki (2013). However, Chang et al. (2006) note that its abstract nature may present difficulties for novice learners, requiring careful instructional scaffolding and substantial time investment. Wood and Middleton's (1975) scaffolding approach offers an alternative methodology that gradually supports learners, reducing frustration while building problem-solving confidence, as demonstrated in classroom observational studies by Konya and Foldesi (2016). This method, while effective, depends heavily on teacher expertise and carries the risk of creating excessive student dependence on instructor support.

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Next, Stein et al.'s (1996) reflective strategy, while less widely known, provides valuable emphasis on metacognitive reflection and multiple solution approaches, with Konya and Foldesi (2016) documenting its benefits when properly implemented. However, this method's effectiveness is closely tied to teacher involvement and requires significant instructional time, potentially limiting its practical application in time-constrained curricula. Additionally, the constructivist framework developed by Jonassen (1977) emphasizes knowledge construction and technology integration, showing particular promise in contemporary educational settings. Research by Tang et al. (2020) confirms its effectiveness in fostering deep learning and self-regulation, though the approach's complexity and reliance on prior knowledge may limit its

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accessibility for some student populations. Ajani (2024) found significant improvement in pre-service teachers' problem-solving abilities, metacognitive awareness, and ability to tackle ill-structured problems after intervention. Jonassen's model provided a comprehensive structure that supported both well-structured and ill-structured problem-solving, making it adaptable to diverse educational contexts. Demonstrated that Jonassen's model helps learners develop higher-order thinking skills and supports transfer of learning to real-world teaching challenges.

Next Wong et al. (2024) further demonstrated that students with higher self-efficacy performed better on complex tasks when using Jonassen's approach, highlighting its emphasis on cognitive and metacognitive skill development. Additionally, Olewnik, Yerrick, Simmons & Lee (2020) highlights Janosson problem solving strategies improve cognitive complexity meanwhile polya is less emphasis on complexity. Comparative analysis reveals that Jonassen's model offers distinct advantages for early learning contexts, particularly in its integration of technology and support for knowledge construction. Therefore, this study will Jonassen Problem Solving Strategy to integrated with SmartAR Module.

Jonassen's model stands out among other problem-solving frameworks due to its strong alignment with the complexities of ill-structured problems, high level of technology integration, and deep emphasis on metacognitive processes. Compared to Polya (1973) and Wood & Middleton (1975), whose models provide only limited attention to ill-structured problems, Jonassen (1997) explicitly addresses these challenges by offering structured support through technology-based tools, such as

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Mindtools. While Stein et al. (1996) moderately acknowledge the role of ill-structured problems and incorporate some degree of technology, Jonassen's framework places a much greater emphasis on cognitive scaffolding, encouraging learners to reflect, monitor, and regulate their own thinking. Moreover, Jonassen's model has been extensively applied and empirically supported in STEM disciplines, particularly in engineering and computer science education, whereas the other models are either more generic in scope or limited primarily to mathematics. This comprehensive and practical approach makes Jonassen's model especially suitable for modern, technology-rich learning environments that require adaptive and critical thinking skills.

## 2.10 Students Achievement in Augmented Reality Learning

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Student achievement, defined as the measurable outcomes of knowledge acquisition, skill development, and attitudinal growth in educational settings (James, Talin, & Bikar, 2022), remains a central concern for educators and policymakers worldwide (Sarif & Vandana, 2022). As James et al. (2022) emphasize, systematically assessing achievement serves multiple critical functions: it provides accountability for meeting national educational objectives, informs evidence-based interventions, and enables the evaluation of pedagogical reforms. This measurement imperative is further supported by Grabarek and Kallemeyn (2020), who demonstrate how achievement data directly guides curriculum development, instructional strategies, and resource distribution to optimize learning outcomes.

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The consequences of inadequate achievement measurement are well-documented in the literature. Battistin (2016) and Sievertsen (2022) identify several systemic risks, including: (1) the implementation of ineffective educational policies due to insufficient evidence, (2) missed developmental opportunities for students when placement decisions lack empirical basis, (3) perpetuation of educational inequalities through unaddressed achievement gaps, and (4) erosion of institutional accountability that may compromise educational standards.

Maltese and Hochbein (2012) reinforce these findings by highlighting the critical role of achievement data in rigorous educational research, particularly for evaluating instructional methodologies and institutional improvement initiatives. Arbabisarjou (2016) further clarifies that comprehensive achievement assessment requires comparing learner outcomes against established educational goals to determine the effectiveness of teaching and learning processes. Previous studies have explored various approaches to measuring students' achievements in programming education, employing diverse methodologies and focusing on multiple influencing factors (Alves, Gajic, Henriques, Ivancevic, & Tavares, 2020; Malkoc, Steinmaurer, Gütl, Luttenberger, & Paechter, 2024; Ozturk et al., 2021; Ngadengon, Subramaniam, Yasak, Ideris, & Ramly, 2025; Silva et al., 2024). Alves et al. (2020) assessed student achievement through grades and self-reported progress in programming knowledge and confidence. Their findings suggest that tools like C Tutor may enhance understanding and confidence, though the study calls for further research with a more rigorous experimental design to confirm these effects.

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Similarly, Malkoc et al. (2024) measured achievement using course grades and assessments, focusing on engagement, academic self-concept, and gender-related factors. Their study revealed improved achievement in flipped classroom settings, attributed to higher engagement and a more positive academic self-concept. In a separate study, Ozturk et al. (2021) evaluated the impact of project-based learning using pretest and posttest scores on programming knowledge and skills. The results showed significant improvements in achievement, with reduced cognitive load, indicating that active, hands-on learning strategies effectively support comprehension and skill acquisition.

Meanwhile, Ngadengon et al. (2025) investigated challenges in programming education within Malaysian polytechnics, measuring achievement indirectly through student perceptions of syllabus content, teaching quality, motivation, and the learning environment. The findings highlighted that issues such as an imbalance between theory and practice, low motivation, and ineffective teaching methods were major barriers to student success, suggesting that curriculum design and instructional practices play a critical role in shaping learning outcomes. Finally, Silva et al. (2024) examined the use of an Educational Programming Language (EPL)-based learning app, measuring student achievement through skill assessments. The study demonstrated that integrating domain-specific educational software can enhance programming skills and support effective learning. Their experimental design lends reliability to the conclusion that tailored technological tools can positively impact programming education. Therefore, previous studies have employed technology in learning programming especially Augmented reality (AR). In the context of augmented reality (AR) learning

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environments, these achievement considerations take on additional dimensions. Samihah et al. (2017) identify six critical factors influencing AR's educational effectiveness:

1. Curriculum integration balancing technical and pedagogical aspects
2. Interaction stability ensuring reliable engagement
3. Self-learning capability enabling independent study
4. Parental involvement in the learning process
5. Student background and contextual factors
6. Platform characteristics and technological infrastructure

The successful implementation of AR in education also depends on complementary factors such as teaching quality (Hind et al., 2015) and materials development (Masuhara, 2006). These elements collectively contribute to creating learning environments that can potentially enhance student achievement through immersive, interactive experiences that bridge theoretical knowledge and practical application. Previous studies used Augmented Reality (AR)-based programming interventions have focused on measuring students' academic achievement, while others concentrated primarily on motivation or perceptions. Two notable studies that measured achievement include Tsai and Cheng (2022) and Yi-Ming et al. (2023). Tsai and Cheng (2022) implemented an AR logic programming teaching system for elementary students and found that the AR-based group showed significantly better post-test performance, demonstrating improved knowledge acquisition. Additionally, students in the AR group reported higher motivation, particularly in the Attention

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dimension of the ARCS principles, due to the immersive and interactive nature of the AR environment. Similarly, Yi-Ming et al. (2023) developed an AR-based learning system to teach abstract programming concepts to primary school students and found that both AR-based groups outperformed the traditional learning group. Notably, the group exposed to high-interactive AR showed the greatest improvement in programming achievement and reported higher motivation, suggesting that interactivity is a critical factor in AR-based learning effectiveness.

In contrast, some AR programming studies did not measure students' academic achievement but rather focused on motivation and perceptions. For instance, Tasdondurena and Korucu (2022) explored middle school students' perceptions of self-efficacy and attitudes toward coding, finding that the experimental group scored higher on the Attitude Scale Towards Coding. However, the study did not evaluate actual programming performance or knowledge gain. Likewise, Abidin and Zawawi (2020) aimed to support the understanding of Object-Oriented Programming (OOP) concepts using an AR-based learning application and found that students were more engaged and satisfied with the learning experience. Despite this, the study did not include standardized assessments of achievement or motivation, limiting its conclusions to subjective feedback. These findings suggest that while AR can enhance motivation and engagement, its impact on learning outcomes must be empirically validated through proper achievement assessments.

Although augmented reality (AR) has the potential to increase student engagament and motivation within a programming course (Tsai & Cheng, 2022; Yi-Ming et al.,

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2023), its impact on learning achievement remains . Most AR studies focus on altering perceptions and attitudes (Tasdondurena & Korucu, 2022; Abidin & Zawawi, 2020), which do not measure knowledge gain, consequently creating a bridge devoid of measurable outcomes. For AR to be effective, future designs need to attend to systemic issues such as unscheduled curriculum components and inadequate teacher training (Samihah et al., 2017), alongside demonstrating the retention of programming skills long after the initial engagement stimuli. Therefore, this study designed and developed an augmented reality programming module, namely the SmartAR Module, to measure student achievement using pretest and post-test achievement test. This study incorporated cognitive learning theory to create an effective augmented reality learning module aimed at improving student achievement in learning programming.

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## 2.11 Students Motivation after using SmartAR Module

Motivating the learner to learn is pertinent to curriculum implementation as motivation is an influential factor in the teaching-learning situations (Filgona et al., 2022). Bakar (2014) illustrate motivation as a complex part of human psychology and behaviour that influences how individuals choose to invest their time, how they think, feel and persist in the task. In addition, Himid (2012) define motivated as the driver of guidance, control and persistence in human behaviour. Gredler, Broussard and Garrison (2004) defined motivation as the attribute that moves us to do or not to do something. It is an internal impetus or drive to do a specific action or behaviour (Ryan & Deci, 2000). It is noted

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that a person's motivation is the driving force behind their actions, thoughts, emotions, and relationships with those around them (Abdullah, 2022).

Motivation is divided into two (2) two categories such as (1) intrinsic motivation and (2) extrinsic motivation. Intrinsic motivation is characterized as the natural, inherent drive to seek out challenges and meanwhile, extrinsic motivation comes from external sources such rewards (Zidni, 2022). Ryan & Deci (2000) reliance that intrinsic motivation is defined as the doing of an activity for its inherent satisfactions rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards. Meanwhile Fischer, Malycha, & Schafmann, (2019) stated that extrinsic motivation combines relational and transactional rewards. In a broad sense, it refers to external factors that inspire an individual to perform. An example of intrinsic motivation discussed by Lisa (2017) is playing at outdoors for having fun and satisfying and no other reason. Comparatively example of extrinsic motivation is conducting a task for purpose such washing dished to get allowances.

Motivation is one of the most studied psychological constructs in educational psychology (Koenka, 2020). Studies on academic motivation focuses on explaining why students behave the way they do and how this affects learning and performance (Schunk, 2014). Previous study by Jacob (2020) explained that student motivation is an essential element in education for a quality education. Seifert & Sutton (2003) classified the motives and their sources as (i) motives as behaviour change, (ii) motives as goals, (iii) motives as interests, (iv) motives as attributions about success, (v) motives as

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beliefs about self-efficacy, and (vi) motives as self-determination. Seifert and Sutton asset that motives are affected by the kind of goals set by students whether they are oriented to mastery, performance, failure-avoidance, or social contact. To enhance learners' motivation, previous studies have suggested that teachers' behaviours and instructional practices play an important role (Assor, Kaplan, Kanat-Maymon, and Roth, 2005; Bernaus & Gardner, 2008; Corpus, McClintic-Gilbert, & Hayenga, 2009). In addition, to improve students' motivation, the teacher must pay attention to several factors, including setting a clear goal, showing the need for the lesson, arousing, and maintaining learners' interest in the lesson, and increasing chances of success (Filgona et al., 2020).

Technology offers new opportunities in both practical and pedagogic dimension and potentially improve motivation (Gordon, Grey & Brayshaw, 2005). Previous study by Raposo, Durão, Estradas & Ribeiro (2020) shows that technology helps students to feel confident, allows them to learn with pleasure, generates group dynamics and globally, creates happy moments that increase motivation and improve learning. In the advancement of Industrial Revolution, a vast variety of technologies exist, including augmented reality, virtual reality, mixed reality, Artificial Intelligence as the innovative technologies (Russell & Norvig, 2019). Augmented Reality (AR) technology has great potential in educational contexts and is becoming more widespread by combining content and interactive three-dimensional elements (Çavaş & Çulha, 2020). Previous study Tasneem et al., (2020) highlighted that implication of augmented reality mobile application increased the learning motivation of students. The study used Instructional Materials Motivation Survey adopted from Keller (2010) to design the research

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instrument and student motivation were measure before after implementation of the treatment. The results showed that using an augmented reality mobile application increased the learning motivation of students in motivational factor of attention, satisfaction, and confidence.

Another study conducted by Kaur, Mantri & Horan (2019) descripted that utilization of Augmented reality in education as improved student motivation. The study used a self-developed questionnaire-based survey was using the ARCS principles (2009) to find out the level of student motivation on the parameters measuring attention (A), relevance (R), confidence (C) and satisfaction (S) for interactive learning.The result shows that , augmented reality provides innovative and interactive ways of learning a particular concept and has an edge over the traditional styles of teaching and learning in classroom settings as it has a significant impact on the student motivation while performing a particular task. The study also highlighted a traditional learning approach provide difficulties to student grasp complex abstract.

A study conducted by Gopalan, et al (2016) stated that the immersion and interaction features offered by AR may encourage students to engage in learning activities and may improve student motivation to learn. Augmented reality has given empirical support for the positive and statistically significant relationship between engaging, enjoyment and fun and students' motivation for science learning (Valarmathie et al, 2016). Previous studies have widely explored the use of Augmented Reality (AR) to enhance student motivation in various educational contexts, as summarized in Table 2.12. Wong, Hosshan, Hanafi, and Mudiono (2023) investigated

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the application of AR as an assistive technology for special education needs, focusing on three students learning vocational skills. Their study addressed challenges such as the difficulty of delivering lessons in schools and insufficient learning materials for after-school use. The integration of AR into special education teaching strategies resulted in increased student interest and motivation.

Similarly, Pujiastuti et al. (2023) examined the impact of hybrid learning integrated with AR to improve higher-order thinking skills in geometry among 200 students. The combination of hybrid and interactive learning strategies not only supported visualization of 3D objects but also engaged and motivated students in their learning process. Chuang, Lo, and Wu (2023) integrated chatbot and AR technology into biology learning for 109 students during the COVID-19 pandemic. Their creative AR design addressed the challenges of remote learning and enhanced students' learning motivation while promoting self-directed learning. A V, G, et al. (2022) developed AREL, an AR-based enriched learning system for Tamil, Hindi, and mathematics. Designed to support remote learning during the pandemic, the system incorporated speech-to-3D learning, which fostered multimodal interaction and significantly increased student motivation. Rukayah, Daryanto, Atmojo, Saputri, and Salimi (2022) introduced AR media in STEAM learning for elementary school students and teachers, highlighting its role in adopting 21st-century teaching practices. This blended learning approach effectively increased student motivation. Lastly, Hsieh (2021) utilized AR to create an experiential learning environment in science education, allowing 22 students to explore oysters interactively. The innovative approach enhanced student motivation and engagement with the subject.

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**Table 2.12**

*Previous Augmented Reality Use in Measuring Students Motivation.*

| Title | Sample | Subject | Reason / Motivation to use AR | Learning / Instructional Strategy | Impact |
|---|---|---|---|---|---|
| Wong et al. (2023) : Augmented Reality (AR): An Assistive Technology for Special Education Needs | 3 students | Vocational Skills | **Reason**:<br>Difficulty in delivering lesson in School<br>Insufficient learning material to teach after school hours | Technology Integration in Special Education Teaching | Interest, Increased Student Motivation. |
| Pujiastuti, et al. (2023): Hybrid learning impact with augmented reality to improve higher order | 200 students | Geometry | **Reason**<br>Struggle in visualize 3D Object<br>Students lack of interest in conventional media | Hybrid/Blended Learning<br>Interactive Learning | Motivated and engaged with learning |
| Chuang et al. (2023) :Integrating Chatbot and Augmented Reality Technology into Biology Learning during COVID-19 | 109 students | Biology | **Reason:** To support learning during Covid as unable conduct physical class | Creative Augmented Reality Design Learning Motivation | Enhances Learning Motivation<br>Support Self Learning |
| A V, G, et al. (2022).: AREL – Augmented Reality–based enriched learning | - | Tamil, Hindi, Maths | Reason: To support learning during Covid as unable conduct physical class | Speech to 3D Based Learning | Increased motivation<br>Supports Multimodal Interaction |
| Rukayah et al. (2022) : Augmented Reality Media Development in STEAM Learning in Elementary Schools | 129 students and 7 teachers | History | **Motivation:**<br>Need of innovative for teaching and learning to adopt 21st century learning | Blended Learning | Increase Motivation |



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However, lack of previous studies examines students' motivational factors in using Augmented reality application in learning. Teachers use multimedia especially electronics and digital media, and there is a lack of training for teachers to create interactive media and knowledge of the latest technological developments that can be utilized as interactive media (Ivan, 2020). The time-consuming leads students get distracted in entertainment and challenging for teacher to bring them into zone. Whereas Dörnyei & Ushioda (2021) figured out that the demotivation among the learners extracted three main factors likewise teachers' attitude and teaching method, lack of facilities available at school and lack of self-confidence. Above all, as listed in Table 2.12 the existing augmented reality applications for enhancing student motivation are predominantly focused on subjects such as vocational skills, biology, tamil, geometry, history, and science. However, there is a lack of augmented reality applications aimed at measuring students' motivation in learning computer science subjects.

The incorporation of Augmented Reality (AR) in the field of education has great potential to enhance learner motivation. These allows them engaging and captivating features of learning experiences through AR technologies. However, challenges like the lack of training for teachers on the use of AR technologies, innovative designing interactive materials, may affect the proper application of AR in the classroom. Other subjects like biology and vocational skills have embraced the use of AR technology to a much greater extent than others. However subjects like computer science which still needs to be investigated further. Thus, further studies are needed to evaluate its

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motivational impact in this area and address gaps in educational technology integration. Therefore, this study designed and developed an augmented reality programming module, namely the SmartAR Module, to measure student motivation after using the SmartAR Module. This study incorporated self-development learning theory to create an effective augmented reality learning module aimed at improving student motivation in learning programming.

### 2.11.1 ARCS principles (Attention (A), Relevance (R), Confidence (C) and Satisfaction (S))

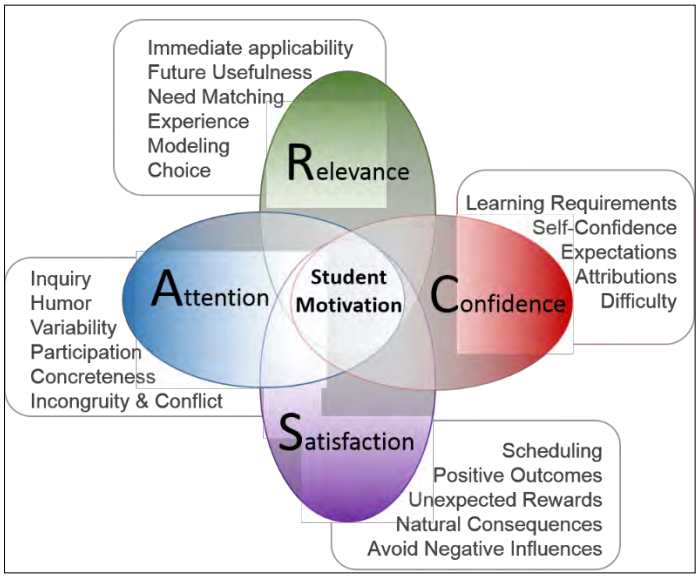
The ARCS principles was created by John M. Keller in 1979, the purpose of this method, according to Keller (1999) is that teachers can construct external conditions to stimulate and sustain learners' motivation Keller took Tolman and Lewin's expectancy-value theory, which is based on the idea that learners feel motivated to learn since there is a purpose or need in the learning process and the expectation of success (Insuasty et al., 2023). According to Kurt and Keçik (2017), ARCS principles always keep the student in mind, ensuring that they are engaged throughout the process. Besides, Keller (2016) claims that teachers who implement ARCS need to keep students' motivation by instilling positive attitudes in them. Keller (2000) decided to implement a model focusing on motivation which is divided in four steps called Attention (A), Relevance (R), Confidence (C) and Satisfaction (S) one advantage is that ARCS can be implemented in any learning setting, it might be in the classroom, remote, or asynchronous (Insuasty et al., 2023).

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**Figure 2.6**

*Keller's ARCS principles with Four Motivational Factors. Source from https://www.itap.purdue.edu/learning/images/cdm/ARCS3.png*




There are two types of instruments that can be used measure to motivation with respect to the ARCS principles (Keller, 2010). ARCS principles application has designed two surveys namely Course Interest Survey (CIS) (Keller, 2010) and the Instructional Material Motivation Survey (IMMS) (Keller, 2010), to measure participants' motivation frequently. The major difference between CIS and IMMS is that CIS is designed for teacher-led classrooms while IMMS is mainly for self-directed learning (Keller et al., 2018). Previous study by Nofal et al., (2008) explained attention as interest displayed by learners in taking in the concept being taught by perceptual arousal consist of surprise, inquiry arousal offering challenging questions and problems to solve and variability, using a variety of resources and methods of teaching. Next relevance using language familiar with learner. Thirdly, confidence is positive expectations for achieving success among learners. Finally, satisfaction is reward from

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a learning experience such as achievement. These elements are meant to encourage and sustain the learner's motivation (McKivigan , 2019).

Additionally, Pratama et al., (2019) emphasis forming a problem-solving approach to design aspects of motivation and learning environment in encouraging and maintaining student motivation to learn. Keller (2016) claims that teachers who implement ARCS need to keep students' motivation by instilling positive attitudes in them. Thus, it is noticeable that satisfied students feel more motivated, independent, and capable to solve problems in real contexts. Previous studies have measured students' motivation to learn programming using interactive learning tools (Chuan et al., 2023; Cevahir et al., 2022; Atika et al., 2020; Boonbrahm et al., 2019). However, there is a lack of studies that examine motivational factors that influence students' motivation to use interactive learning tools in learning. Therefore, this study aims to use the ARCS factors to determine the factors that influence students to use the SmartAR Module in learning programming. In addition, this study used IMMS 34 selected items to measure students' motivation in use SmartAR Module in learning programming. Previous studies (Loorbach, Peters, Karreman & Steehouder , 2015; Delbone & Cardoso, 2021; Annamalai, 2016) have used IMMS to measure students' motivation as shown In Table 2.13.

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**Table 2.13**

*Table of Previous Studies Used IMMS*

| Author and Title | Approach | Findings |
|---|---|---|
| Loorbach, et al., (2015): Validation of the (IMMS) in a self-directed instructional setting aimed at working with technology | Used IMMS to measure learners' motivational reactions (attention, relevance, confidence, satisfaction) to different instructional materials. IMMS to a 12-item | 1. IMMS effectively measured motivation aligned with ARCS principles<br>2. IMMS scores reflected motivational differences when materials varied. |
| Delbone & Cardoso (2021): Psychometric assessment of the Instructional Materials Motivation Survey (IMMS) instrument in a remote learning environment | Used IMMS to assess student motivation after exposure to remote learning materials in medical education. | IMMS showed good construct validity and reliability, confirming its suitability for measuring motivation in remote learning contexts. |
| Annamalai, (2016) : Implementing ARCS principles to Design a Motivating Multimedia E-Book for Polytechnic ESL Classroom | IMMS questionnaire was used to measure students' perceptions of attention, relevance, confidence, and satisfaction after using the e-book. | IMMS demonstrated high reliability (Cronbach's alpha = 0.94) and confirmed that the e-book design effectively motivated learners. |



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The Instructional Material Motivation Survey (IMMS) effectively supports Keller's ARCS principles. These provide a structured means to measure the four key motivational components includes Attention, Relevance, Confidence, and Satisfaction. In the studies by Loorbach et al. (2015), Delbone and Cardoso (2021), and Annamalai (2016), IMMS was used to quantitatively to assess learning materials engagement with learners and fostered motivation. For instance, Annamalai's (2016) study on a multimedia e-book designed for ESL learners demonstrated that IMMS captured learners' heightened attention through engaging multimedia elements. Meanwhile the relevance of content by connecting it to students' real-life contexts and future goals. Similarly, Loorbach et al. (2015) used IMMS to distinguish between motivational responses in attention and confidence for different levels of sensitivity responsiveness. Delbone and Cardoso (2021) studied the IMMS further at a remote learning environment by verifying its reliability measuring relevance and satisfaction within the educational setting. Despite these strengths, all IMMS have to same challenges pertaining to its reliance on self-reported data; respondent answering tendency and self-appraisal biases could be problematic. Further, the lack of scope behavioural and performative data. Additionally, the fixed questionnaire format may not fully capture the evolving or culturally nuanced nature of motivation without adaptation. To summarize, while IMMS serves as an instrument to enforce ARCS principles in instructional design. It is best applicable with narrative evidence and other adaptations that address learner motivation. Therefore, this study used IMMS questionnaire to evaluate students' motivation after using SmartAR Module in learning programming.

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## 2.12 Measurement of Augmented Reality Usability in Education

Usability has been defined as, “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction” (ISO 9241-11, 1998).It represents a fundamental dimension of human-computer interaction, encompassing the effectiveness, efficiency, and satisfaction with which users achieve specified goals (Hussain et al., 2014). Alejandro et al. (2019) further refine this concept as a software quality attribute that balances functional performance with user experience. At its core, usability bridges the gap between technological capability and human cognition, requiring careful consideration of both system functionality and user psychology (Federici & Borsci, 2010). The dual components of usability - ease of use and perceived usefulness - emerge as critical determinants of technology adoption (Alrfooh & Lakulu, 2020). These dimensions align with Donald Norman's (2002) foundational principle of user-centered design, which advocates for systems that accommodate natural human thought processes rather than imposing artificial technical frameworks.

Augmented Reality (AR) technology has great potential in educational contexts and is becoming more widespread by combining content and interactive three-dimensional elements (Çavaş & Çulha, 2020). And its important to m evaluating its usability to better the user’s experience with the device or application to give better user experience (Derby & Chaparro, 2021). However, there were several studies highlighted challenging overcoming by students in learning by incorporating augmented reality with poor usability (Radu, Ave, Avram & Ave, 2017; Ghazwani & Smith., 2020). Radu

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et al., (2017) emphasize AR makes difficulty in orienting while fixing tracking, strained body postures in older students, difficulty recovering from tracking loss, tripping interruption due to self-distraction. Additionally, study by (Ghazwani et al.., 2020) highlighted the user interface usability challenges as (1) AR browser: limited user engagement and motivation, non-adjustable user viewpoint, non-adjustable virtual content, (2) 3d user interface: require visibility for interaction, smaller 3d UI in small display devices, lack of physical feedback (3) multimodal user interface: increases battery usage, increases AR device weight.

Additionally, Hornbæk (2005) highlights Augmented Reality (AR) applications face several usability challenges that hinder user experience and adoption. One of the primary issues is the lack of standardized design across platforms and applications. User interface (UI) elements and interactions vary significantly, leading to confusion among users. Some AR applications present cluttered screens filled with excessive text, while others overly emphasize holographic visuals at the expense of providing necessary contextual information. Additionally, many applications separate menu controls from the AR holograms, making it difficult for users to understand which elements they are manipulating. The use of novel or complex gestures further complicates the learning process, especially when these gestures are not intuitive. To mitigate this issue, researchers have introduced numerous usability frameworks such as Tuli and Mantra (2020) Usability principle for Augmented Reality, system usability scale by John Brooke (1986), Nielsen (1993), Kateryna V. Vlasenko et al (2023) seven principles. Table 2.14 shows the analysis of these usability frameworks.

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**Table 2.14**

*Usability Framework Analysis*

| Usability | Principle | Advantages | Previous Studies / Domain |
|---|---|---|---|
| Tuli and Mantra (2020) AR Usability Principles | Interactivity, Compatibility, Credibility | Tailored for AR, addresses AR-specific challenges like spatial interaction and real-world integration | AR kindergarten learning apps usability studies (Tuli & Mantri, 2020) |
| System Usability Scale (SUS) - Brooke (1986) | 10-item questionnaire measuring overall usability | Quick, reliable, easy to administer, provides a standardized usability score | Healthcare screening app usability, AR/VR usability (Zhang et al., 2020) |
| Nielsen's Usability Heuristics (1993) | 10 heuristics: Visibility of system status, Match between system and real world, User control, Consistency, Error prevention, Recognition vs recall, Flexibility, Aesthetic, Help users recognize errors, Help and documentation | Widely accepted, covers broad usability aspects, applicable to many systems | AR educational app heuristic evaluation (Altınpulluk , Kesim & Kurubacak , 2020 ; Al-Obaidi & Prince , 2022) |
| Kateryna V. Vlasenko et al. (2023) Seven Principles | Seven principles focusing on user experience, accessibility, error prevention, consistency, feedback, user control, and learnability | Updated for modern UX challenges, incorporates accessibility and inclusivity | AR usability in open/distance learning, universal design (Altınpulluk et al., 2020) |



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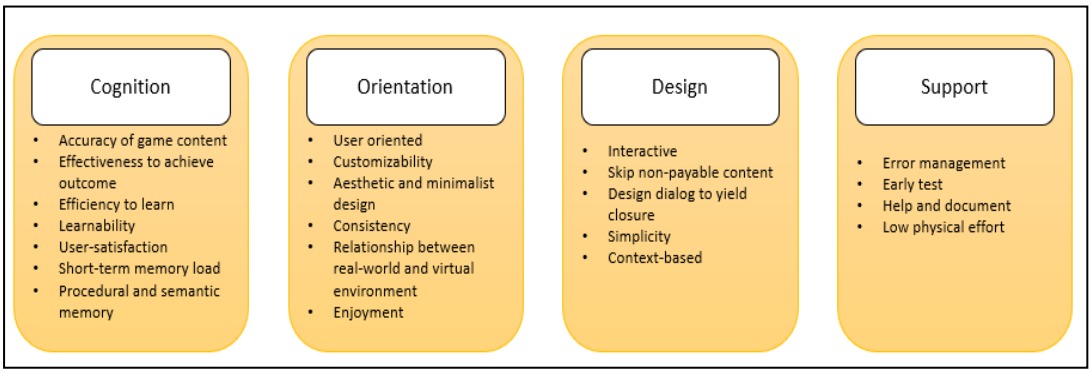


The usability of Augmented Reality (AR) applications, particularly in educational settings, has been explored through various frameworks, each offering distinct advantages and limitations. Tuli and Mantri (2020) introduced an AR-specific usability framework tailored for educational environments, focusing on four key principles: cognition, orientation, design, and support. These principles address the unique challenges of AR, such as spatial interaction and real-world integration, making them especially relevant for AR-based learning modules. Their study on AR usability in kindergarten apps illustrates how this framework supports cognitive engagement and intuitive interaction in early education contexts. The attribute consists of (1) Cognition, (2) Orientation, (3) Design and (4) Support. Figure 2.7 shows the classified usability principle in adopted by Neha Tuli & Archana Mantri (2020) four augmented reality mobile application usability principles.

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**Figure 2.7**

*Four augmented reality mobile application usability principles*




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Meanwhile, broader frameworks like the System Usability Scale (SUS) by Brooke (1986) provide a standardized, efficient method for assessing general usability. Although widely used in healthcare and AR/VR settings (Zhang et al., 2020), SUS lacks the depth required to evaluate AR-specific interaction elements. Similarly, Nielsen's (1993) usability heuristics, which include attributes like system status visibility and error prevention, remain foundational and have been successfully applied in AR educational app evaluations (Altınpulluk, Kesim & Kurubacak, 2020; Al-Obaidi & Prince, 2022). A book written by Nielsen (1993) highlighted five usability attributes as shown in table 2.15.

**Table 2.15**

*Five usability attributes by Neilsen (1993)*

| Attribute | Description |
|---|---|
| Learnability | The system should be easy to learn so that the user can rapidly start getting some work done with the system. |
| Efficiency | The system should be efficient to use so that once the user has learned the system, a high level of productivity is possible |
| Memorability | The system should be easy to remember so that the casual user is able to return to the system after some period of not having used it without having to learn everything all over again. |
| Errors | The system should have a low error rate so that users make few errors during the use of the system, and so that if they do make errors, they can easily recover from them. Further, catastrophic errors must not occur |
| Satisfaction | The system should be pleasant to use so that users are subjectively satisfied when using it; they like it. |

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However, Nielsen's usability framework were developed prior to the emergence of AR technology and do not fully address its immersive and multimodal nature. More recently, Kateryna V. Vlasenko et al. (2023) proposed a set of seven modern usability principles includes (1) Information Quality (IQ), (2) System Navigation (SN), (3) System Learnability (SL), (4) Visual Design (VD), (5) Responsiveness (RS), (6) Instructional Assessment (IA) and (7) System Interactivity (SI) aimed at improving user experience, accessibility, and feedback in digital systems. aimed at improving user experience, accessibility, and feedback in digital systems. In comparing these frameworks, three main gaps emerge: the lack of attention to cognitive load management in AR interfaces, the insufficient alignment with pedagogical objectives, and the absence of tools to assess the balance between usability and the learning curve inherent in AR applications. Furthermore, many of these frameworks are primarily developed for mobile applications, with limited adaptability to web-based AR platforms.

The reasoning for selecting Tuli and Mantri's (2020) AR usability principles for measuring usability in this study stems from their focus on AR applications in educational settings. Tuli and Mantri's framework does not suffer from the same limitations as rival frameworks. System Usability Scale (SUS) or Nielsen's heuristics, are tailored to older interface designs. Tuli and Mantri's framework incorporates spatial interaction, real-world integration, cognitive load, and user orientation. These are pertinent for an augmented reality (AR) learning environment. Given these considerations, Tuli and Mantri's (2020) AR usability principles stand out as the most relevant for this study. Their focus on cognition, orientation, design, and support

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directly aligns with the learning goals and user interaction requirements of the SmartAR Module. Therefore, this study adopts the four usability principles proposed by Tuli and Mantri (2020) as the guiding framework for evaluating the SmartAR Module's effectiveness and user experience.

## 2.13 Summary

This chapter has given an account of the relevant literature and studies related to the subjects, which is about the introduction, theoretical arguments, augmented reality, mobile augmented reality, augmented reality in education, and augmented reality in education. Apart from that, to support the study, challenges in learning Computer Science subjects in secondary school and a previous study on Augmented Reality learning modules in programming were discussed. Finally, this chapter has discussed student motivation, achievement in learning.

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# CHAPTER 3

# RESEARCH METHODOLOGY

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## 3.1 Introduction

This chapter discussed the research design, internal and external threats, research procedure, research ethics, population and sample, research instruments, validity of research instruments, validity of SmartAR Module, pilot study, reliability of instrument reliability, and data analysis that were used in this study.

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## 3.2 One Group Pretest Posttest Design

The research approach of this study is Quantitative approach. Experimental design is a methodological approach in research that involves controlling variables to maximize precision and draw specific conclusions about a hypothesis (Bell, 2009). The primary objective of experimental research is to establish strong causal internal validity, enhancing the credibility of findings by minimizing confounding variables (Zubair, 2022). This study adopts a Pre-Experimental Research Design, specifically the One-Group Pretest-Posttest Design, as described by Donald Campbell and Julian Stanley (1963). In the one-group pretest-post-test design, involves conducting a pre-test, implementation of intervention, and then conduct post-test to evaluate the changes (American Psychological Association, 2020). Zubair (2022) define pre-experimental designs focus on observing cause-and-effect relationships within a set group over time. These allows the researchers to evaluate the impact of an independent variable that could influence dependent variable (Zubair, 2022).

The advantage of pre-experimental design is the feasibility, efficiency, requiring fewer resources and less time compared to more rigorous experimental frameworks. This makes it especially practical for exploratory studies with limited budgets (Price et al., 2015; Creswell & Creswell, 2021). However, this design has notable limitations, including the absence of random assignment and control groups, which can weaken causal inferences and introduce potential threats to internal validity (Price, Jhangiani, & Chiang, 2015; Creswell, 2022). Despite these limitations, Creswell (2021) highlighted the benefits, noting that it strikes a balance

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between simplicity and validity, providing useful data about changes over time, which essential for preliminary or exploratory studies.

Previous studies have utilized the one-group pretest-posttest research design (Yıldırır, 2020; Sutoyo, Agustini, Fikriyati, 2023; Yuliyanti, Purwianingsih, & Peristiwati, 2023 ; Keskinkilic , 2024 ; ). For instance, Yıldırır (2020) investigated secondary school students' cognitive structures, finding that the pre-experimental design allowed researchers to measure changes in students' understanding of arguments and related concepts systematically. Next, Keskinkilic (2024) study used a one-group pretest-posttest research design helped the study by providing a clear framework to assess the impact of the STEM training on teachers' attitudes and awareness. This design also helped eliminate external variables, as it focused on a single group of participants and compared their initial and final responses.

Similarly, Sutoyo et al. (2023) used the same design to assess the effectiveness of an online critical thinking cycle learning model in improving pre-service science teachers' critical thinking dispositions and skills. This approach enabled a clear evaluation of changes before and after the model’s implementation. Likewise, Yuliyanti et al. (2023) applied the one-group pretest-posttest design to analyze the impact of blended learning combined with the revised Argument-Driven Inquiry (rADI) model on students' argumentation skills and concept mastery in Monera, particularly Bacteria. The results showed significant improvements, with high N-Gain scores in both areas.

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The one-group pretest-posttest research design helped measure changes in student achievement and motivation systematically, similar to the methodologies used in previous studies (Yıldırır, 2020; Sutoyo et al., 2023; Yuliyanti et al., 2023). In alignment with these studies, this research employed a pre-experimental design to evaluate the effects of the SmartAR Module on student outcomes. By comparing the pre-test and post-test results, the study aimed to provide insights into the module's effect on student achievement. Therefore, this study used the one-group pretest-posttest research design because it allows for a comparative analysis of student performance before and after the intervention. This design is particularly useful for evaluating the initial effects of new educational interventions, such as the SmartAR Module, which aims to explore its influence on students' achievements and motivation. Table 3.1 presents the application of this design in the current study.

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**Table 3.1**

*The One-Group Pretest Posttest Design of the study*

| | Pre Test | Treatment | Post Test |
|---|---|---|---|
| Students' achievement | ✓ | Learning using My-SmartAR module | ✓ |

### 3.2.1 Threats

The one-group pretest-posttest design is a research method where a single group of participants is measured before and after an intervention or treatment to assess its effects (Gopalan, Rosinger, & Ahn, 2020). This design is often chosen for its time and cost

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efficiency, providing quick insights into potential outcomes with minimal resources (Brown & Smith, 2022; Lopez & Chen, 2021). However , the one-group pretest-posttest design has limitations, such as the lack of a control group, making it difficult to rule out alternative explanations for observed effects (Handley, Gorukanti, & Cattamanchi, 2018; Creswell, 2022). However, a major limitation of this design is the absence of a control group, which makes it difficult to rule out other factors that could explain the observed changes (Handley, Gorukanti, & Cattamanchi, 2018; Creswell, 2022).Despite these limitations, the design has been widely applied in various research contexts. For example, Rinjeni, Rakhama, and Nadlifatin (2024) used it to assess the impact of gamification on learning motivation across different personality types, and Mannahali, Angreany, and Rosmaladewi (2024) evaluated YouTube's effectiveness in enhancing language skills. This design is particularly useful for evaluating the initial effects of new educational interventions, such as the SmartAR Module, which aims to explore its influence on students' achievements and motivation. Table 3.1 presents the application of this design in the current study. However, using this research design introduced some internal and external threats.

## 3.3 Threats to Validity

In this study, threats referred to elements that could influence the observed variables in the experiment. The discussion focused on two primary threats to validity: internal validity and external validity.

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### 3.3.1 Threats to Internal Validity

A book by Brill (2018) defined internal validity as the extent to which observed differences in the dependent variable are directly related to the independent variable. Campbell (1957) classified eight internal threats in his article, such as (1) history, (2) maturation, (3) testing, (4) instrumentation, (5) statistical regression, (6) selection, (7) mortality, and (8) diffusion to treatment. These concepts are said to be threats to the internal validity of experiments because they pose alternate explanations for the apparent causal relationship between the independent variable and dependent variable of an experiment if they are not adequately controlled (Katherin, 2018). In this study, due to the absence of a control group and to minimize potential bias, the focus was placed on addressing five internal validity threats: (i) instrumentation, (ii) selection, (iii) testing, (iv) experimental mortality, and (v) researcher bias.

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**i. Instrumentation**

In this study, instrument decay referred to the research instrument engaging pretest and post-test. These threats could occur when instruments were administered consistently. To eliminate this risk, the pretest and posttest questions were validated by content validation by seven experts to establish test appropriateness.

**ii. Selection**

In this study, participants were chosen using purposive random sampling. The chosen sample was used for both the pre-test and post-test. No new participants were introduced in the middle, either in the pre-test or the post-test. These

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approaches aimed to avoid selection bias and generate consistent responses from students.

**iii. Testing**

In this study, this threat referred to the possibility that pretesting subjects might have influenced their post-test scores (Odoh & Chinedum, 2014). A similar set of questions was used for both the study's pre-test and post-test. To mitigate this internal testing threat, the order of the post-test questions was reshuffled and paraphrased.

**iv. Experimental Morality**

In this study, computer science is an elective that students can choose to discontinue at any point if necessary. Consequently, there was a significant risk to experimental integrity. To mitigate this risk, the experiment duration was limited to nine weeks, encompassing only the pretest and posttest phases.

**v. Researcher Bias**

In this study, researcher bias occurred when the researcher provided extra attention and effort to the experimental group in order to verify the module's efficiency. To mitigate this risk, the researcher or anybody close to the researcher did not serve as a teacher in this study. The teacher was selected based on criteria and had no exposure to the SmartAR Module. Therefore, knowledge was able to transfer to students equally without bias.

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### 3.3.2 External Validity Threats

External validity is the validity of a causal connection that can be transferred to other measures, populations, settings, and treatment variables (Cresswell, 2014). A study by Pistone and Isabella (2014) defines external validity as a property that allows research findings to be generalized and questions their relevance. Since this study was conducted in only one school, it considered only one external validity threat.

#### i. Population Validity

To address the external threat of population validity the study ensured a more representative sample by selecting students from diverse such as Malay and Chinese backgrounds within the same educational level. This approach aimed to minimize biases and increase the potential for generalizing the findings.

## 3.4 Research Procedure

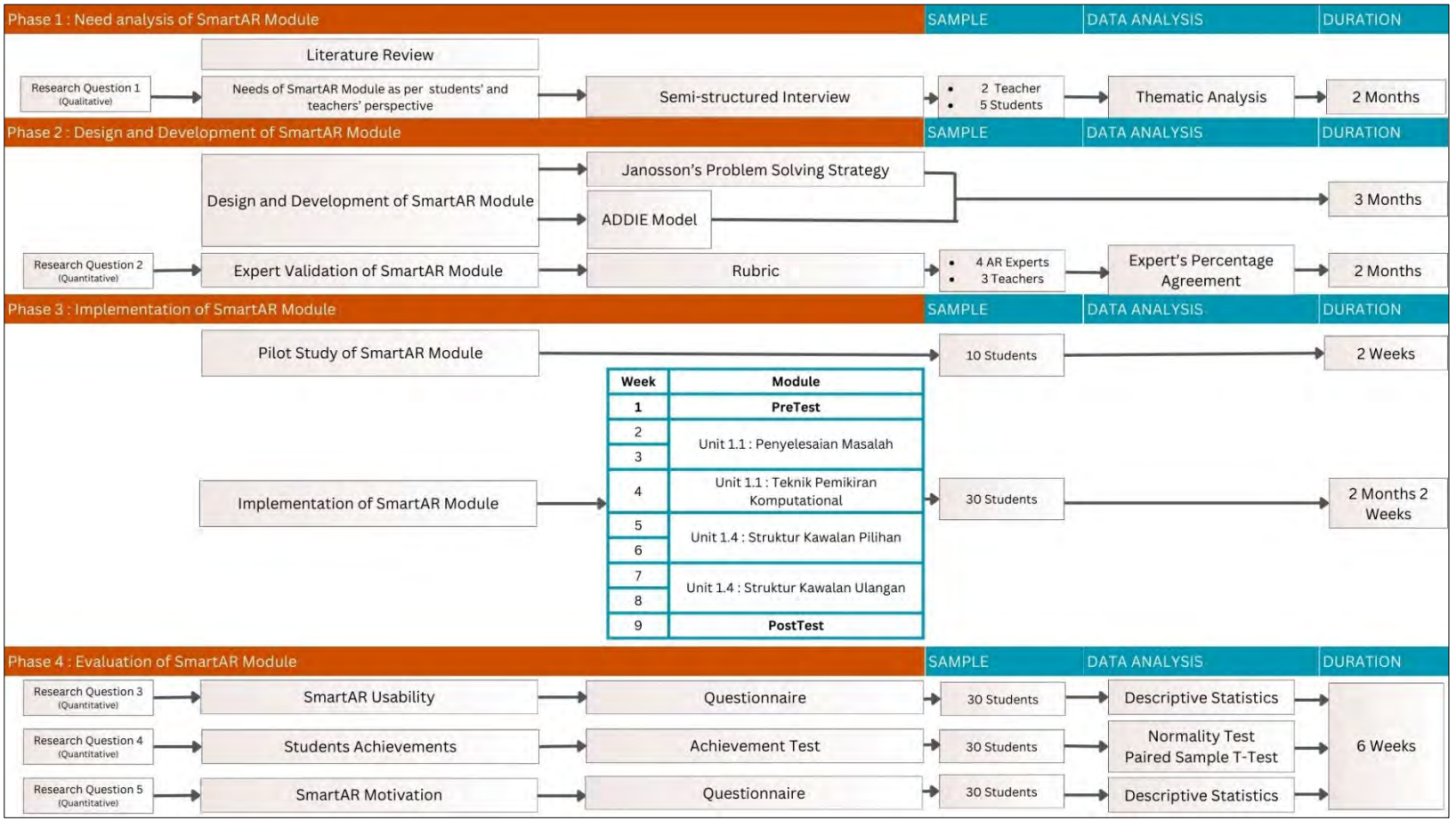
This study contains in four distinct phases such as Phase 1; Needs Analysis of the SmartAR Module, Phase 2; Design and Development of the SmartAR Module, Phase 3; Implementation of the SmartAR Module, and Phase 4; Evaluation of the SmartAR Module. Both quantitative and qualitative data were collected throughout the study to provide a comprehensive analysis. The research procedures followed in this study are illustrated in Figure 3.1.

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**Figure 3.1**

*Research Procedure of SmartAR Modules*






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### 3.4.1 Phase 1: Need Analysis of SmartAR Module

In this study, phase one focuses on gathering the need analysis for the SmartAR Module to address research question one. A comprehensive literature review was conducted on relevant topics prior to the interviews to gather pertinent insights and knowledge. The research instruments of this phase were self-developed according to content of subject to suit the scope of this research. The literature review and the development of instruments took one month. To gather the need analysis for the SmartAR Module, Semi-structured Interviews were conducted with both students and teachers. This phase aimed to answer research question one. The semi structured interview question includes needs of interactive learning material, challenges in learning computer science and programming subject and expectation of SmartAR Module. The findings were analysed using thematic analysis, which identified key themes. Overall, the need analysis phase took two months to complete.

### 3.4.2 Phase 2: Design and Development SmartAR Module

In this study, phase two focused on the design and development of the SmartAR Module. The process was guided by the ADDIE instructional model consists of Analysis, Design, Development, Implementation, and Evaluation. This phase aimed to transform the insights gathered from Phase 1 into a functional and effective learning tool for programming. To begin with design of learning material and mobile application

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draft, this study designed a storyboard using Canva software. The designed includes Janosson's (1977) problem solving learning strategy to designed the five learning activities. Follows the design, this study developed 3Dimensional models, marker, mobile application and final development of SmartAR Module. The module integrated various multimedia includes animation, video, puzzles, assessment and drag and drop activities. The development procedure took three months. After the development of SmartAR Module and research instruments were validated by, seven experts include three content experts and four technological experts. The validation procedure took two months. After the review, the necessary changes were conducted in SmartAR Module and into the application. This phase answered research question two.

### 3.4.3 Phase 3: Implementation of SmartAR Module

In this study, phase three focused on the implementation of the SmartAR Module. Prior to the implementation of SmartAR Module, researcher obtained obtaining the necessary approvals from Educational Research Application System (ERAS) , Research Management and Innovation Centre (RMIC) , *Jabatan Pendidikan Negeri Selangor* (JPN) and *Pejabat Pendidikan Daerah Klang* (PPD). Once got approval, research begin training session for teacher, guiding them on how to use the learning module and the SmartAR application. Following the training, the teachers divided the students into two groups: one for the pilot study, consisting of 10 students, and the other for the main study, consisting of 30 students. The pilot study was conducted over a 2-week period in a classroom.

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Subsequently, the real implementation began. In the first week, a pretest was conducted by the researcher. For the next seven weeks, the teacher used the SmartAR Module to teach programming, and in the final week (week nine), the post-test was administered by the researcher. All activities took place in the classroom setting. The selected subtopics are Problem Solving, Computational Thinking, and Control Structures from Chapter 1 Programming. The implementation phase conducted for two months and two weeks.

### 3.4.4 Phase 4: Evaluation of SmartAR Module

In Phase four, the evaluation of the SmartAR Module focused on the usability of the SmartAR Module, students' achievements, and students' motivation. First, the usability of the SmartAR Module was assessed using the questionnaire by Tuli and Mantra (2020) to address research question three. The data were analyzed using descriptive statistics, such as mean and standard deviation. Next, students' achievements were evaluated based on the scores from the pretest and posttest to address research question four. The data were analyzed using descriptive statistics, a normality test to check for normal distribution, and a paired sample t-test. Finally, students' motivation after using the SmartAR Module was measured to address research question five. The data were analyzed using descriptive statistics, such as mean and standard deviation.

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### 3.4.5 Research Ethics

In this study, obtaining the necessary approvals was crucial before implementing the SmartAR Module in the classroom. After conducted the required amendments from expert validation comment, the researcher applied for approval through the Educational Research Application System (ERAS) via an online web portal. ERAS approval took five working days. Following approval from ERAS, the study then applied approval from the Research Management Innovation Center (RMIC) at UPSI for school visitation. After receiving approval from both ERAS and RMIC, the study applied to JPN Selangor for further authorization, which took 21 working days. Finally, once approval was granted by JPN Selangor, the researcher sought approval from PPD Klang to conduct school visits, which took an additional five days. In total, the approval process lasted approximately two months.

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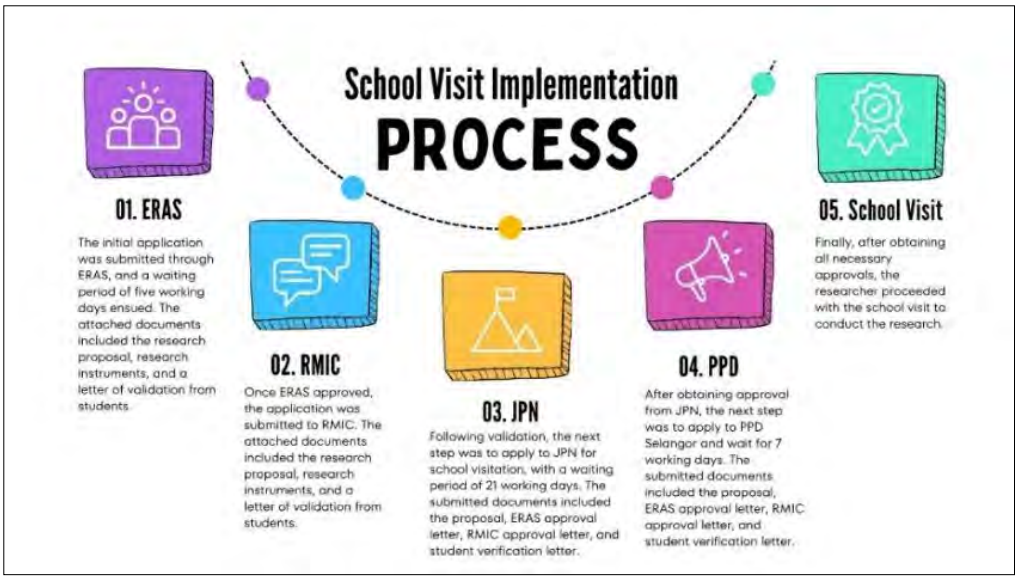
After completing and receiving approval for the entire process, the researcher visited the school to meet with the principal and computer science teacher. During this visit, the researcher obtained their approval and discussed the training dates and times, as outlined in the timeline chart in Figure 3.2 . Appendix A shows ERAS approval to carry out the study in the school meanwhile Appendix B shows the Approval of Human Research Ethics certificate.

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**Figure 3.2**

*Process of School Application to Conduct Research*




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## 3.5 Populations and Samples

This study involved three sets of samples: (1) five students for the needs analysis of the SmartAR Module, (2) two computer science teachers for the needs analysis of the SmartAR Module, and (3) 30 Form 4 students who participated in the study. It is important to note that the five students involved in the needs analysis were different individuals from the 30 students who participated in the study. The samples were chosen using purposive sampling based on specific criteria to ensure relevance and alignment with the study's objectives. Refer to Table 3.2 for the sample summary.

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**Table 3.2**

*Sample Summary table of the study*

| Set | Sample Type | Number of Samples | Research Question |
|---|---|---|---|
| 1 | Computer Science Students | 5 students | One |
| 2 | Computer science teachers | 2 teachers | |
| 3 | Form 4 computer science students | 30 students | Three, Four, Five |

### 3.5.1 Set 1: Computer Science Students

The first set consists of five computer science students selected to analyse the needs of the SmartAR Module, addressing research question one. The students were selected from two different schools to ensure gender diversity and were not involved in either the pilot study or the real experimental study. The criteria for student selection were: (1) must enrolled in the Form 4 computer science subject, and (2) the school must offer computer science as an elective subject, (3) the students age range for Form 4 students (typically 16-17 years old) to ensure the study is representative of the target group. The filled in consent form for participants involved in need analysis of SmartAR Module was provided in Appendix C.

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### 3.5.2 Set 2: Computer Science Teacher

The second set consists of two computer science teachers selected to analyse the needs of the SmartAR Module, addressing research question one. The teachers were chosen from two different schools. The criteria for student selection were: (1) at least five years of teaching experience, (2) a good understanding of logic and algorithms, (3) intermediate experience using educational mobile applications, (4) a basic understanding of Augmented Reality, and (5) self-sufficiency as a fast learner with minimal support. The consent form provided to content experts is attached in Appendix D.

### 3.5.3 Set 3: Secondary School Students

The third sample set consisted of 30 Form 4 Computer Science students who participated in the implementation of the SmartAR Module, addressing research questions three, four, and five. The students were selected from three different classes within a single school using purposive sampling to ensure alignment with the study's objectives and gender diversity. All participants had obtained a grade of B in Computer Science, serving as a moderating variable. Importantly, these students were not involved in the pilot study or the requirement analysis phase. The criteria for student selection were: (1) must be enrolled in the Form 4 computer science subject, and (2) the school must offer computer science as an elective subject, (3) the students must fall

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within the specific age range for Form 4 students (typically 16-17 years old) to ensure the study is representative of the target group. The consent form for participants was provided in Appendix C.

## 3.6 Research Instruments

For this study, three research instruments were employed: semi-structured interview questions to conduct a needs analysis of the SmartAR Module from the perspectives of students and teachers, questionnaires to evaluate usability, achievement test to measure student achievement and questionnaires to evaluate student motivation after using SmartAR Module.

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### 3.6.1 Interview Questions (Students' and Teachers' Perspectives)

In this study, the interview questions for students and teachers aimed at gathering needs analysis data are organized into three sections: Section A focuses on user background and includes three questions, Section B addresses challenges in Computer Science with three questions, and Section C explores needs related to the SmartAR Module with two questions. The interview consists of eight self-developed questions, as presented in Table 3.3.

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**Table 3.3**

*Interview Summary table of the study*

| Section | Topic | Item |
|---|---|---|
| A | Background of User | 3 |
| B | Challenges of Computer Science | 3 |
| C | Needs of SmartAR Module | 2 |

Examples of interview questions for students were detailed in Table 3.4, and Appendix F contains the complete interview question.

**Table 3.4**

*Example of Interview Questions (Students)*

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| Section | Examples of questions |
|---|---|
| Section B: Challenges of Current Learning Approach | What are the challenges you are encountering when studying computer science? Could you please explain why and specify topics that challenge you? |
| Section C: Needs of SmartAR Module | Do you require any additional modernized learning modules to help you improve your programming skillset? |

### 3.6.2 Questionnaire for SmartAR Usability

This closed-ended questionnaire was used to assess the SmartAR Application's usability among 30 students in the experimental group to address research question three. The questionnaire was fully adapted from Tuli & Mantri's (2020) four usability

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principles questionnaire and modified to align with this study's scope. The questionnaire consists of five sections: student demographics, cognition, orientation, design, and support, comprising a total of 23 questions. A five-point Likert scale was employed, as shown in Table 3.5, to ensure respondents could select only one response per item. The complete usability questionnaire is attached in Appendix E.

**Table 3.5**

*Range of Interval Scale Used*

| **Scores** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Category | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

This usability questionnaire comprises a total of 23 items divided into five sections as shown in Table 3.6: Section A (student demographics) contains three items, Section B contains five items, Section C contains five items, Section D contains five items, and Section E contains five items. Section A was self-developed meanwhile section B, C, D and E were adapted from Tuli & Mantri's (2020) four usability principles questionnaire and modified to align with this study's scope.

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**Table 3.6**

*Section of Usability Questionnaire*

| Section | Description | Source | Example of Item | Total Item |
|---|---|---|---|---|
| A | Demographic | Self-developed | | 3 |
| B | Cognition | Adopted from Tuli & Mantri (2020) | SmartAR-Module well designed in achieving the learning objectives | 5 |
| C | Orientation | | The SmartAR-Module design is clear and easy to understand interface. | 5 |
| D | Design | | SmartAR module provide real-life or practical examples to enhance your learning experience | 5 |
| E | Support | | SmartAR requires less physical effort in learning programming | 5 |
| | | Overall | | 23 |

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**i. Section A: Demographic**

Section A, which focuses on demographics, consists of three self-developed questions. The demographic items include gender, class name, and subject stream.

**ii. Section B: Cognition**

In section B which focuses on cognition contains of five items adopted from Tuli & Mantri (2020). The items specifically evaluate content accuracy, task completion efficiency, user-friendliness, and the module's capacity to facilitate active problem-solving approaches.

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**iii. Section C: Orientation**

In section C which focuses on orientation contains of five items adopted from Tuli & Mantri (2020). The items specifically evaluate interface design, learning engagement, real-world programming connections, and the provision of diverse learning modes and challenges.

**iv. Section D: Design**

In section D which focuses on design contains of five items adopted from Tuli & Mantri (2020). These items evaluate the sequential learning flow, marker accessibility, 3D visualization quality, practical example integration, and the module's overall user-friendly design.

**v. Section E: Support**

In section E which focuses on support contains of five items adopted from Tuli & Mantri (2020). These items evaluate system performance, built-in guidance tools, cross-device compatibility, learning resource accessibility, and the module's efficiency in reducing physical learning barriers.

### 3.6.3 Achievement Test (Pre-test and Post-Test)

This achievement test was used to evaluate the student’s achievement before and after using SmartAR Module among 30 students in the experimental group to address research question four. The achievement test was self-developed according DKSP

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Form 4 Computer Science chapter 1 curriculum. The achievement test consists of three sections: student demographics, objective questions, and subjective question, comprising a total of 22 questions. Achievement scores were evaluated according to the Malaysian National Curriculum (KSSM) grading scale, as detailed in Table 3.7. The complete achievement test questions can be found in Appendix F.

**Table 3.7**

*The Grading Scheme of the Malaysian National Curriculum (KSSM)*

| Score | Scale | Grade Description |
|---|---|---|
| 90 – 100 | A + | Highest Excellent |
| 80 – 89 | A | Excellent High |
| 70 – 79 | A – | Excellent |
| 65 – 69 | B + | Highest Good |
| 60 – 64 | B | Good |
| 55 – 59 | C + | Top Honors |
| 50 – 54 | C | Honors |
| 45 – 49 | D | Moderate Pass |
| 40 – 44 | E | Pass |
| 0 – 39 | G | Fail |
| TH | TH | Absent |

The KSSM grading scheme for secondary school students specifies that scores between 100 and 60 represent a "very good" performance, while scores ranging from 59 to 40 indicate a "moderate" achievement level. Scores  39 denote a failing grade, suggesting a need for additional focus on student learning. Additionally, the designation "TH" indicates student absence during examinations. Consequently, the achievement

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test scores in this study were aligned with the KSSM grading scheme. This achievement test comprises a total of 22 question divided into three sections as shown in Table 3.8: Section A (student demographics) contains three items, Section B contains twelve objective question, and Section C contains seven subjective questions.

**Table 3.8**

*Section of Achievement Test*

| Section | Description | Source | Item |
|---|---|---|---|
| A | Demographic | Self-developed | 3 |
| B | Objective | Self-developed | 12 |
| C | Subjective | Self-developed | 7 |
| | | Total | 22 |

### i. Section A: Demographic

Section A, which focuses on demographics, consists of three self-developed questions. The demographic items include gender, class name, and subject stream.

### ii. Section B: Objective

In section B which focuses on objective question contains of 12 questions self-developed. This set of objective questions assesses students' understanding of key concepts in problem-solving, computational thinking, and programming, with a focus on control structures such as loops and decision-making processes. It evaluates students' ability to apply theoretical knowledge to practical scenarios within the context of computer science.

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### iii. Section C: Subjective

In section C which focuses on subjective question contains of seven questions self-developed. These questions are designed to assess students' application of programming concepts and computational thinking strategies in practical scenarios. The questions focus on understanding and implementing loops, identifying effective problem-solving processes, and utilizing techniques for information retention, particularly in the context of programming tasks and real-world problem-solving situations.

Table 3.9 shows the order of selected subtopics and questions for both the pre-test and post-test.

**Table 3.9**

*Chapter, Topic, Pre-Test, and Post-Test Questions*

| Chapter / Topic | Subtopic | Pre-test | Post-Test |
|---|---|---|---|
| *Strategi Penyelesaian Masalah* | *Keperluan Penyelesaian Masalah* | I | II |
| | *Teknik Pemikiran Komputational* | I | II |
| | *Proses Penyelesaian Masalah* | I | II |
| *Struktur Kawalan* | *Bentuk Stuktur Kawalan Pilihan* | II | I |
| | *Bentuk Stuktur Kawalan Ulangan* | II | I |

### 3.6.4 Students Motivation Questionnaire

This closed-ended questionnaire was used to assess the student's motivation after using SmartAR Module among 30 students in the experimental group to address research question five. The questionnaire was adapted from Instructional Materials Motivation Survey (IMMS; Keller, 2010) motivation questionnaire and modified to align with this

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study's scope. The questionnaire consists of two sections: student demographics self-developed and section B adapted from IMMS questionnaire item, comprising a total of 33 questions. A five-point Likert scale was employed, as shown in Table 3.10, to ensure respondents could select only one response per item. To interpret the motivation levels, a scale similar to that used by Zainuddin, Chu, Shujahat, and Perera (2020) was adopted. The scores were categorized as: very low (1.00-1.80), low (1.81-2.60), moderate (2.61-3.40), high (3.41-4.20), and very high (4.21-5.00). The complete student motivation questionnaire is attached in Appendix G.

**Table 3.10**

*Range of Interval Scale Used*

| **Scores** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Category | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

This questionnaire comprises a total of 33 items divided into two sections as shown in Table 3.11: Section A (student demographics) contains three items and Section B contains 30 items.

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**Table 3.11**

*Section of Students Motivation Questionnaire*

| Section | Description | Example Item | Source | Total Item |
|---|---|---|---|---|
| A | Demographic | | Self-developed | 3 |
| B | IMMS | | | 30 |
| | Attention | When I first looked at the programming module, I had the impression that studying from it would be easy for me. | Adopted from Keller, 2010) | |
| | Relevance | It is clear to me how the content of the programming module is related to things I already know. | | |
| | Confidence | As I used the programming module, I was confident that I could learn the content. | | |
| | Satisfaction | It was a pleasure to work on such a well-designed programming module | | |
| | | | Overall | 33 |

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### i. Section A: Demographic

Section A, which focuses on demographics, consists of three self-developed questions. The demographic items include gender, class name, and subject stream.

### ii. Section B: IMMS Questionnaire

In section B which focuses on ARCS motivation question contains of 30 items adopted from Tul Adopted from Instructional Materials Motivation Survey (IMMS) and ARCS (Keller, 2018). The items specifically evaluate areas of Attention, Relevance, Confidence, and Satisfaction to understand how effectively the module captures

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interest, relates to students' needs, builds confidence in learning, and provides a satisfying learning experience.

### 3.7 Validity of Research Instrument

Validity is an important characteristic in measurement, and it aims to assess the extent to which the instrument developed can measure what it is intended to measure Ary, Jacobs, Irvine, & Walker (2019). Therefore, the instrument developed for this study underwent validity testing by selected experts before proceeding to the data collection phase. For this study, the validity of the research instruments was conducted for three instruments, the interview questions, questionnaire and achievement test.

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#### 3.7.1 Validity of Interview Question

In this study, an interview question was developed to gather the need analysis of SmartAR Module in learning programming students and teacher to answer research question one. The interview question was validated by seven experts consist of four technological experts and three content experts as shown in Table 3.12. To ensure that the research instruments were appropriate and well-developed, the self-developed interview questions were validated by seven experts.

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**Table 3.12**

*Expert Criteria for Instrument Validity*

| Experts | Criteria | Number of Experts |
|---|---|---|
| Technological Expert | • University Lecturer with Multimedia Background | 4 Experts |
| | • Expertise in Augmented Reality | |
| | • Expertise in Computer Science | |
| Content Expert | • Teaching computer science for at least 7 years | 3 Experts |
| | • Basic mobile application knowledge | |
| | Overall | 7 |

For technological experts, the study involved four university lecturers with a multimedia background, selected based on their expertise in augmented reality and computer science. These experts were chosen to ensure that the SmartAR Module met high technological standards and incorporated innovative features aligned with advanced multimedia and programming practices. For content experts, the study included three teachers with at least seven years of experience teaching computer science. These experts were selected for their knowledge of computer programming and their basic understanding of mobile applications. These essential for assessing the appropriateness of the SmartAR Module in the educational context.

Several criteria were considered in selecting experts in generally, such as: (i) more than five (5) years of teaching experience, (ii) proficiency in computer programming, (iii) expertise in using mobile applications, and (iv) being a fast learner. The validation form is provided in Appendix H until T, while the expert appointment

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letter is attached in Appendix U.Table 3.13 presents the experts' comments and the corresponding amendments made by the researcher to enhance the validity of the interview questions. Therefore, the questionnaire interview questions used for this study were valid to measure the need of SmartAR Module. The overall comment from experts indicates the interview question are valid.

**Table 3.13**

*Expert Comment on interview Question*

| Comments | | | Amendments by Researcher |
|---|---|---|---|
| **Expert 1** | **Expert 2** | **Expert 3** | |
| Suggested simplifying technical terms in Question 6 for better understanding by students. | Recommended rewording Question 2 to be more focused on learning preferences using mobile apps. | Advised clarifying Question 3 to define "AR" more clearly for participants unfamiliar with it. | Revised Question 6 by breaking down complex terms and giving examples (e.g., algorithm, data structure). Modified Question 2 to ask specifically about educational mobile apps. |

### 3.7.2 Validity of Questionnaire (Usability)

In this study, a usability questionnaire was developed to evaluate the usability of SmartAR Module in learning programming to answer research question three. The usability questionnaire was validated by seven experts consist of four technological experts and three content experts as shown in Table 3.12. To ensure that the research instruments were appropriate and well-developed, the self-developed interview

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questions were validated by seven experts. The requirements for school teachers were (i) having more than five (5) years of teaching experience, (ii) expertise in computer science, and (iii) basic knowledge of mobile applications and augmented reality. The augmented reality experts were expected to (i) possess basic knowledge about education, (ii) have seven (7) years of experience in developing mobile applications, and (iii) demonstrate expertise in marker-based augmented reality. The validation form is provided in Appendix H until T, while the expert appointment letter are attached in Appendix U. Table 3.14 presents the experts' comments and the corresponding amendments made by the researcher to enhance the validity of the usability questionnaire. Therefore, the usability questionnaire used for this study were valid to measure SmartAR Module usability. The overall comment from experts indicates the usability questionnaire are valid.

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**Table 3.14**

*Expert Comment on Usability Questionnaire*

| Comments | | | Amendments by Researcher |
|---|---|---|---|
| **Expert 1** | **Expert 2** | **Expert 3** | |
| Suggested using more student-friendly language in Item 3 (e.g., "encountering obstacles" may confuse younger students) | Noted a grammar error in Item 3 ("helpful is solving" → should be "helpful in solving"). | Check grammar in Item 3 | Reworded Item 3 to "I was able to finish the activities easily without problems."<br><br>Fixed grammar in Item 3. |
| Suggested rephrasing "easily downloadable" (Item 2) to specify where or how students can access markers. | Suggested replacing "robot" with more specific term if possible. | Valid, no changes | Revised Item 2 to "The AR markers in the SmartAR Module are easy to download from the provided website or materials." |

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### 3.7.3 Validity of Achievement Test

In this study, an achievement test was developed to evaluate the student's achievement before and after using SmartAR Module in learning programming to answer research question four. The achievement test was validated by seven experts consist of four technological experts and three content experts as shown in Table 3.12. The requirements for school teachers' experts were (i) having more than five (5) years of teaching experience, (ii) expertise in computer science, and (iii) experience in fabricating and grading test papers. The validation form is provided in Appendix H until T, while the expert appointment letter is attached in Appendix U. Table 3.15 presents the experts' comments and the corresponding amendments made by the researcher to enhance the validity of the achievement test. Therefore, the achievement test used for this study were valid to measure the student's achievement in learning programming using SmartAR Module. The overall comment from experts indicates the achievement test are valid.

**Table 3.15**

*Expert Comment on Achievement test*

| Comments | | | Amendments by Researcher |
|---|---|---|---|
| **Expert 1** | **Expert 2** | **Expert 3** | |
| Please add some images to make interesting | Please add some images and text to easily understand | Please write in 'dwibahasa' easier for students to understand | The achievement test added images and interactive text. Questions written in dwibahasa. |

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### 3.7.4 Validity of Questionnaire (Motivation)

In this study, a motivation questionnaire was developed to evaluate the student's motivation after using SmartAR Module in learning programming to answer research question five. The motivation questionnaire was validated by seven experts consist of four technological experts and three content experts as shown in Table 3.12. To ensure that the research instruments were appropriate and well-developed, the self-developed interview questions were validated by seven experts. The requirements for school teachers were (i) having more than five (5) years of teaching experience, (ii) expertise in computer science, and (iii) basic knowledge of mobile applications and augmented reality. The augmented reality experts were expected to (i) possess basic knowledge about education, (ii) have seven (7) years of experience in developing mobile applications, and (iii) demonstrate expertise in marker-based augmented reality. The validation form was attached in Appendix H until U. The expert selection form was attached in Appendix V. Table 3.16 presents the experts' comments and the corresponding amendments made by the researcher to enhance the validity of the motivation questionnaire. Therefore, the motivation questionnaire used for this study were valid to measure the students motivation after using SmartAR Module. The overall comment from experts indicates the motivation questionnaire are valid.

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**Table 3.16**

*Expert Comment on Motivation Questionnaire*

| Comments | | | Amendments by Researcher |
|---|---|---|---|
| **Expert 1** | **Expert 2** | **Expert 3** | |
| The item is valid and reliable. No changes required | The item is valid and reliable. No changes required | The item is valid and reliable. No changes required | No changes conducted. |

### 3.8 Validity of SmartAR Module

In this study, a validation was conducted to evaluate the SmartAR Module in learning programming to answer research question two. The motivation questionnaire was validated by seven experts consist of four technological experts and three content experts as shown in Table 3.17.

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**Table 3.17**

*Expert Criteria for SmartAR Module Validity*

| Expert | Criteria | | Number of Expert |
|---|---|---|---|
| Technological Expert | i. | University Lecturer with Multimedia Background | 4 Experts |
| | ii. | Expertise in Augmented Reality | |
| | iii. | Expertise in Computer Science | |
| Content Expert | i. | Teaching computer science for at least 3 years | 3 Experts |
| | ii. | Experience in using educational mobile application for teaching and learning | |
| | | Overall | 7 |

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In this study, the SmartAR Module's validity was assessed by seven experts, focusing on three key aspects: (1) content accuracy and relevance, (2) user interface design and navigation, and (3) functionality and effectiveness. The panel consisted of four augmented reality experts and three computer science teachers. The teachers' criteria include five years of teaching experience, expertise in computer science, and basic knowledge of mobile applications and augmented reality. The augmented reality experts' criteria include seven years of experience in mobile application development, and expertise in marker-based augmented reality. The validation form for the achievement test is provided in Appendix H until U.

### 3.9 Pilot Study

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A pilot study was conducted to evaluate the extent to which the instruments used can produce consistent results and to determine how free the instruments are from random errors (Ary, Jacobs, Irvine, & Walker, 2019). Through the pilot study conducted, the researcher was able to assess the reliability of the research instruments. For the pilot study, the researcher selected a group of participants with the same criteria as in the actual study, but with a smaller sample size. This pilot study involved 10 students from one school. After the pilot study, the study used Cronbach's alpha in the Statistical Package for the Social Sciences (SPSS) to obtain the reliability index of the instrument. All items being tested are considered reliable when the Cronbach's alpha value is greater than 0.7 (Tavakol & Dennick, 2011). Table 3.18 illustrates the significant Cronbach's Alpha values used by Tavakol & Dennick (2011). In this study, a pilot study was

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conducted to examine the internal consistent of usability questionnaire and motivation questionnaire.

**Table 3.18**

*Expert Criteria for SmartAR Module Validity*

| Cronbach's Alpha Value | Indicator of Internal Consistency |
|---|---|
| $\alpha \geq 0.9$ | Excellent |
| $0.9 > \alpha \geq 0.8$ | Good |
| $0.8 > \alpha \geq 0.7$ | Acceptable |
| $0.7 > \alpha \geq 0.6$ | Questionable |
| $0.6 > \alpha \geq 0.5$ | Unacceptable |
| $0.5 > \alpha$ | Highly Unacceptable |

## 3.10 Reliability of Instruments

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Reliability is extremely important because evidence of reliability is necessarily the first step in establishing the scientific acceptance and usefulness of a test (Daniel L. Sega, 2018). In this study, reliability of research instrument is important to measure robustness of the study. Therefore, in this study, reliability research was conducted on marking pre-test and post-test scores, and questionnaires.

### 3.10.1 Reliability of Usability Questionnaires

In this study, a pilot study was conducted prior to the actual implementation with 10 students from school one to evaluate the usability of the SmartAR Module. Based on

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the results, the researcher used Cronbach's alpha by Tavakol & Dennick, 2011) in the Statistical Package for the Social Sciences (SPSS) to determine the instrument's reliability index as shown in Table 3.18. Table 3.19 shows the acceptable Cronbach's Alpha values for each section of the usability questionnaire instrument. The Cronbach's alpha for the Cognition section is 0.69 (moderate), indicating a moderate level of internal consistency. The Orientation section achieved a Cronbach's alpha of 0.83 (good), reflecting a high level of reliability. The Design section demonstrated excellent internal consistency with a Cronbach's alpha of 0.90 (good).Meanwhile the Support section also showed a good level of internal consistency with a Cronbach's alpha of 0.84 (good).

**Table 3.19**

*Acceptable Cronbach's Alpha Values for Usability Questionnaire*

| Section | Item Quantity | Cronbach Alpha | Internal Consistency |
|---|---|---|---|
| Cognition | 5 | 0.69 | Moderate |
| Orientation | 5 | 0.83 | Good |
| Design | 5 | 0.90 | Good |
| Support | 5 | 0.84 | Good |
| Total | 20 | 0.815 | Good |

The overall Cronbach's alpha for the entire instrument, which includes all 20 items, was 0.815 (good). This indicates that the instrument has good internal consistency and reliability indicates suitability of this study. Therefore, the questionnaire used in this study is reliable and appropriate for measuring the usability of SmartAR Module.

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### 3.10.2 Reliability of Marking Pre-test and Post-Test (Retest)

The reliability of marking the pre-test and post-test was evaluated using Cohen's Kappa. To ensure impartiality and accuracy, two raters reviewed the questions and marked the pre-test and post-test responses. The results were analysed using IBM Statistical Package for the Social Sciences (SPSS) Statistics software to compute Cohen's Kappa. SPSS, now officially known as "IBM® SPSS® Statistics," is a commercially distributed software suite used for data management and statistical analysis (Felix Frey, 2017). This study kappa value indicator as shown in table 3.20.

**Table 3.20**

*Coen Kappa Indicator*

| Kappa (K) value | Strength of Agreement |
|---|---|
| < 0 | None |
| 0.01 – 0.20 | Slight |
| 0.21 – 0.40 | Far |
| 0.41 – 0.60 | Moderate |
| 0.61 – 0.80 | Substantial |
| 0.81 – 1.00 | Almost perfect |

The reliability assessment of marking the pre-test and post-test with Cohen's Kappa for two raters is detailed in Table 3.21. The reliability of marking the pre-test and post-test was comprehensively evaluated using Cohen's Kappa, revealing a significant progression in rater consistency. During the pretest, the Kappa value of 0.320 indicated a fair agreement between raters, suggesting minimal consistency with only 4-15% of the data considered reliably aligned. In stark contrast, the posttest achieved a remarkable Kappa value of 1.0, representing an almost perfect level of

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agreement with 82-100% of the data showing high reliability. This dramatic improvement from fair to perfect agreement underscores substantial methodological refinements, potentially resulting from more explicit assessment guidelines, targeted rater training, and a more standardized evaluation approach. The progression demonstrates the instrument's potential effectiveness, with the posttest results providing strong evidence that initial methodological challenges were successfully addressed, ultimately yielding a highly reliable assessment tool that researchers and educators can confidently use to measure educational outcomes.

**Table 3.21**

*Reliability of Marking Pre-test and Post-Test*

| Test | Kappa Value |
|---|---|
| Pre-test | 0.320 |
| Post-test | 1.0 |

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### 3.10.3 Reliability of Motivation Questionnaires

In this study, a pilot study was conducted prior to the actual implementation with 10 students from school one to evaluate the student’s motivation after using SmartAR Module. Based on the results, this study used Cronbach's alpha in the Statistical Package for the Social Sciences (SPSS) to determine the instrument's reliability index. Table 3.22 shows the acceptable Cronbach's Alpha values for each section of the instrument. The Cronbach's alpha for the Attention section is 0.79 (good), indicating a good level of internal consistency. The Relevance section achieved a Cronbach's alpha

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of 0.80 (good), reflecting a high level of reliability. The Confidence section demonstrated a Cronbach's alpha of 0.77 (good), indicating satisfactory internal consistency. The Satisfaction section showed the highest level of reliability with a Cronbach's alpha of 0.85 (good).

**Table 3.22**

*Acceptable Cronbach's Alpha Values for Motivation Questionnaire*

| Section | Item Quantity | Cronbach Alpha | Internal Consistency |
|---|---|---|---|
| Attention | 5 | 0.79 | Good |
| Relevance | 5 | 0.80 | Good |
| Confidence | 8 | 0.77 | Good |
| Satisfaction | 12 | 0.85 | Good |
| Total | 30 | 0.80 | Good |

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The overall Cronbach's alpha for the entire instrument, which includes all 30 items, was 0.80 (good). This indicates that the instrument has good internal consistency and reliability, making it suitable for use in this study. Therefore, the questionnaire used in this study is reliable and appropriate in measuring students' motivation after using the SmartAR Module.

### 3.11 Data Analysis

This study gathered qualitative data during the requirement analysis phase and quantitative data to evaluate findings, answer research questions one, two, three, four,

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and five. This study involved four phases of data analysis firstly, thematic analysis, second descriptive statistics third, a normality test and finally a paired sample t-test.

### 3.11.1 Thematic Analysis

In this study, thematic analysis was used to answer the first research questions. Thematic analysis was applied to analyse qualitative data obtained from the interview during analyse the need analysis of SmartAR Module. Thematic analyses (TA) are proposed by Gerald in 1973 and can be used to identify patterns within and across data in relation to participants lived experience, views and perspectives, and behaviour and practices (Clarke, 2016). In this study, thematic analysis will be adopted by Braun and Clarke (2006). Figure 3.3 described six phases contains in Thematic Analysis.

Based on Figure 3.3, Thematic analysis was classified into six phases. The first phase involved familiarization with the data. This included a narrative preparation of the script, rereading the data, and noting down initial ideas. The narrative preparation allowed for the conversion of verbal conversations consisting of audio and emotions into a word transcript. In this study, the recorded interview sessions through OBC were relistened to and transcribed according to the emotions conveyed by students and experts. The first step also facilitated a comprehensive understanding of all the data collected from the interviews. Step two arranged the collected data according to highlighted themes, also known as main points. Following this step, all gathered data

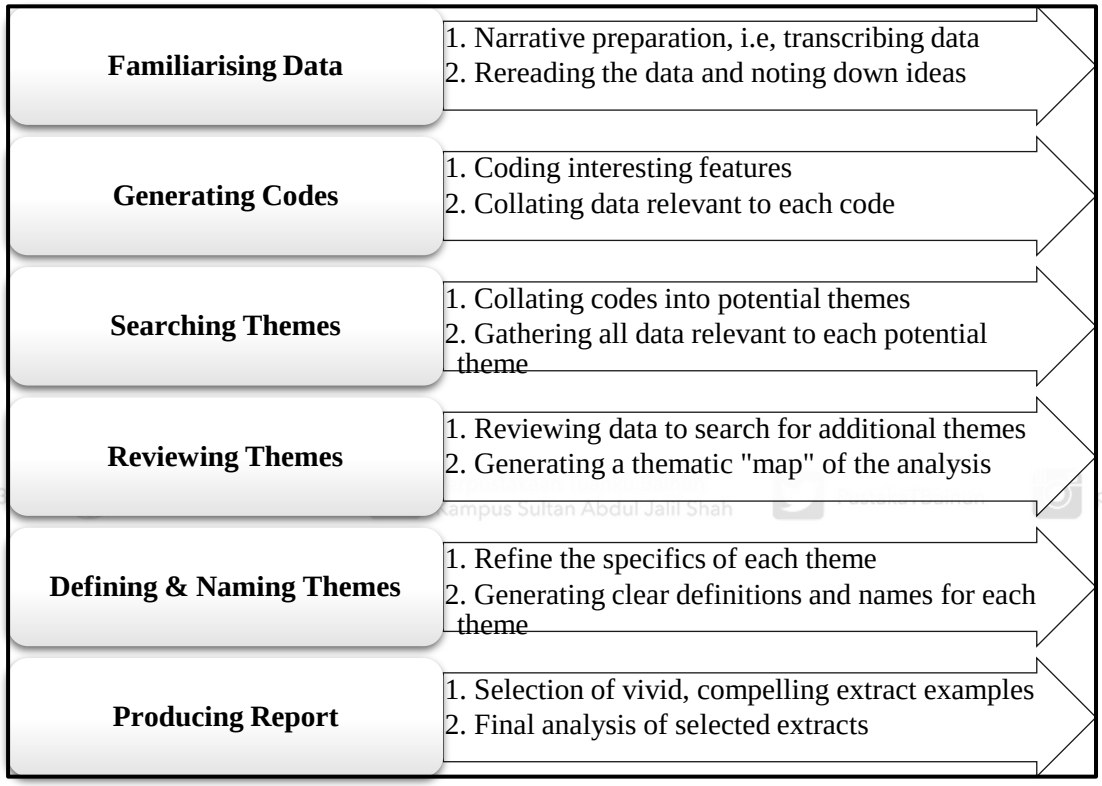
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were categorized into themes and further refined. In the final steps, the write-up contained an introduction, research questions, and aims.

**Figure 3.3**

*Thematic Analysis phases.*




### 3.11.2 Descriptive Statistics

Descriptive statistics offer a summary of the characteristics and distribution of values within one or more datasets (Jay Lee, 2020). In this study, descriptive statistics were employed to address research question three, which aimed to assess SmartAR usability,

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research question four to evaluate student achievement score and research question five, which sought to evaluate student motivation after using the SmartAR Module, by calculating the mean and standard deviations. Table 3.23 shows the interpretation of the mean scores and standard deviation for this study, adapted from Riduwan (2012).

**Table 3.23**

*Scale of Mean Scores and Interpretation*

| Range of Mean Scores | Interpretation of Mean Score | Standard Deviation (SD) |
|---|---|---|
| 1.00 – 1.50 | Very Low | Small SD: Data points are close to the mean, implying consistency. |
| 1.51 – 2.50 | Low | Large SD: Data points are more spread out from the mean, showing variability. |
| 2.51 – 3.50 | Medium | Small SD: Data points are close to the mean, implying consistency. |
| 3.51 – 4.00 | High | Large SD: Data points are widely spread, showing significant variability. |

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### 3.11.3 Normality Test

In this study, normality tests were conducted to analyse student achievement scores and assess whether the data were normally distributed. Normality testing is crucial for evaluating measures of central tendency and dispersion, as well as for determining the appropriate statistical tests (parametric or nonparametric). To perform the normality tests and analyse the data, the Kolmogorov-Smirnov and Shapiro-Wilk tests were employed. These tests were selected based on their widespread use in educational research for assessing data normality (Shapiro & Wilk, 1965; Lilliefors, 1967). This study will follow the indicators outlined Table 3.24 for interpreting the normality test results.

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**Table 3.24**

*Normality Test Indicator*

| Test | Null Hypothesis ($H_0$) | Interpretation | p-value Indicator |
|---|---|---|---|
| Kolmogorov-Smirnov (K-S) | Data is normally distributed | Compares the sample distribution with a normal distribution | $p > 0.05$: Data is normal |
| Shapiro-Wilk | Data follows a normal distribution | Tests the null hypothesis that data is normally distributed | $p > 0.05$: Data is normal |

### 3.11.4 Paired Sample T-Test

In this study, a paired sample t-test was conducted to analyze data collected from students' achievement scores in pretest and posttest phases, addressing research question four. The paired sample t-test was employed to compare pretest and post-test achievement test scores. An indicator of the p-value for statistical significance is often set at $p < 0.05$, which is widely accepted as the threshold for rejecting the null hypothesis and confirming a significant result. Moreover, studies like Tavakol & Dennick (2011) reinforce this threshold in contexts of internal consistency and reliability analysis. These indicating that $p < 0.05$ is the benchmark for significant findings in paired t-tests especially in educational data analysis. Table 3.25 summarized all the research instruments and data analysis according to the research question and research procedure phases.

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**Table 3.25**

*Summary of Research Instruments and Data Analysis*

| Qualitative / Quantitative | Research Objective | Research Questions | Research Instruments | Data Analysis | Sample(s) |
|---|---|---|---|---|---|
| **Qualitative** | RO 1: To analyse the needs for an augmented reality programming learning module in secondary school computer science education, based on students' and teachers' perspectives. | RQ 1: What are the needs for an augmented reality programming module in secondary school computer science education, based on students' and teachers' perspectives? | Semi-Structure interview | Thematic Analysis | Teachers: 2 secondary school computer science teachers<br>Students: Total 5 students |
| **Quantitative** | RO 2: To design and develop the Augmented Reality Programming Module namely SmartAR Module, for learning programming subject in secondary school. | RQ 2: What is the validity of the SmartAR Module according to technological and content experts? | - | Experts Percentage Agreements | Computer Science Teachers: 3 and 4 Augmented Reality Experts (Lecturer) |
| **Quantitative** | RO 3: To evaluate the usability of the SmartAR Module in learning programming in secondary school. | RQ 3: What is the usability of the SmartAR Module for learning programming in secondary school? | Questionnaire adopted by Neha Tuli & Archana Mantri (2020) | Descriptive Statistics<br>• Mean<br>• Standard Deviation | 30 students |



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| | | | | |
|---|---|---|---|---|
| **Quantitative** | RO 4 : To investigate the effect of the SmartAR Module on students' academic achievement. | RQ 4: What is the effect of SmartAR Module on students' academic achievement? | Achievement Test | 1. Pre-test and Post-Test<br>2. Normality Test<br>3. Paired Sample T-Test |
| **Quantitative** | RO 5 : To investigate students' motivation after using the SmartAR Module. | RQ 5: What are students motivated after using the SmartAR Module? | Questionnaire adopted by Instructional Materials Motivation Survey by (IMMS; Keller, 2010). | Descriptive Statistics<br>• Mean<br>• Standard Deviation |



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## 3.12 Summary

This chapter provided an account of the research design utilizing pre-experimental research design, research procedures, populations and samples, research instruments, and the validity of research instruments. Additionally, the chapter elaborated on data analysis, pilot studies, and data analysis of this study. Finally, the chapter explained the software and hardware research application requirements. The following chapter discuss the design and development of the SmartAR Module for learning programming.

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# CHAPTER 4

# THE DESIGN AND DEVELOPMENT OF SMARTAR MODULE

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## 4.1 Introduction

This chapter discussed the design and development of SmartAR learning module and the mobile application using ADDIE Instructional model.

## 4.2 ADDIE

This study used the ADDIE instructional model for design and development SmartAR Module. The acronym ADDIE by Quigley (1970), consist five phases includes analyze,

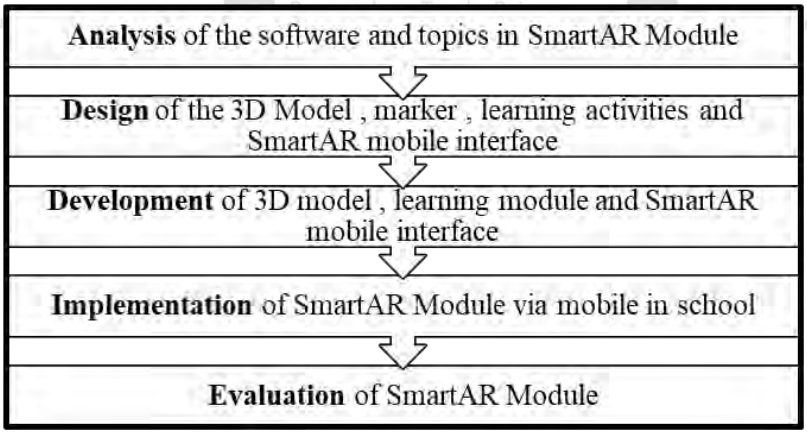
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design, develop, implement, and evaluate. ADDIE represents a dynamic, flexible guideline for building effective training tools that ensure congruence among goals, strategies, and evaluation, resulting in effective instruction in a step-by-step manner (Basu, 2018). Therefore, this SmartAR Module utilized the ADDIE model as a flexible guideline, as illustrated in Figure 4.1. As illustrated in Figure 4.1, this study involved five phases: analysis of software and topics, design of the 3D model, marker, learning activities, and interface, development of the 3D model, learning module, and interface, implementation of the SmartAR Module via mobile in schools, and evaluation of the SmartAR Module.

**Figure 4.1**

*Analysis, design, development, implementation and evaluation (ADDIE)*




### 4.2.1 Analyze

In this study, several analyses were conducted to develop the SmartAR Module. These analyses included identifying students' problems and challenges, determining the needs

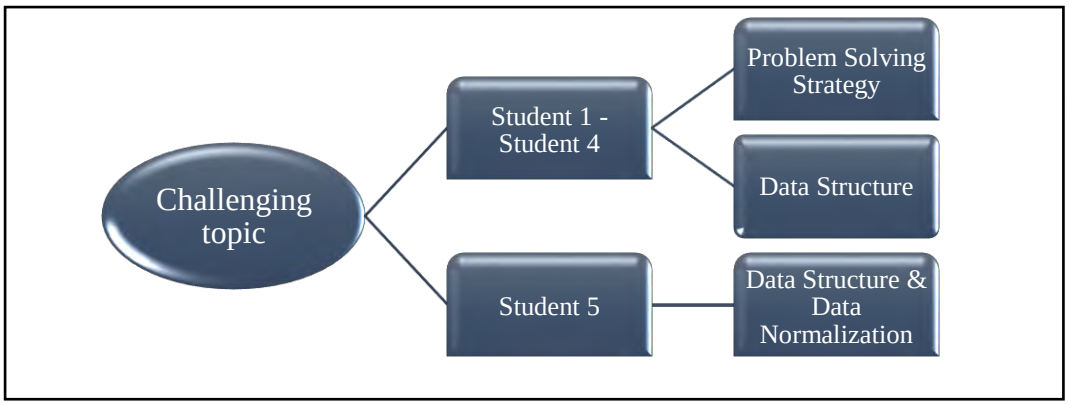
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for the module and topics, and evaluating the hardware and software involved to address research question one. Initially, a semi-structured interview was conducted with 5 Form 4 computer science students and 2 computer science teachers via WhatsApp. The target user of this study is Form 4 secondary school students enrolled to computer science subject. The interview focused on gathering insights into the application's design and content requirements to address research question one. Figure 4.2 presents a subject that students find challenging to learn. A detailed thematic analysis of the interview responses will be discussed in Chapter 5 in the thematic analysis.

**Figure 4.2**

*Challenging topic in learning programming according to students*




Based on the analysis of the interview data, two main topics were chosen from Chapter 1 of programming: problem-solving strategies and data structures. Table 4.1 shows the analyzed learning objectives for each subject according to the '*Dokumen Standard Kurikulum dan Pentaksiran (DSKP)'.*

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**Table 4.1**

*Learning Topic of Form 4 Computer Science Subject*

| Topic | Sub-Topic | DKSP Objective | SmartAR Module Objective | Learning Activities in SmartAR |
|---|---|---|---|---|
| Topic 1.1: Problem Solving Strategies | ***Keperluan Penyelesaian Masalah Teknik Pemikiran Komputational***<br>• Leraian<br>• Peniklasan<br>• Algorithma<br>• Pengencaman Corak | • *Menerangkan keperluan penyelesaian masalah berstrategi* | 1. To introduce problem-solving strategies in computer science | Learning Activity 1 |
| | ***Proses Penyelesaian Masalah*** | • *Menggunakan proses penyelesaian masalah* | 2. To enhance students' understanding of problem-solving | Learning Activity 2 |
| | | | 3. To practice applying problem-solving strategies | |
| Topic 1.4: Control Structures | ***Bentuk Stuktur Kawalan Pilihan***<br>• If Else<br>• If Else If<br>• Switch case | • *Menulis atur cara menggunakan struktur kawalan pilihan* | 1. To introduce control structures in computer science | Learning Activity 3<br>Learning Activity 4 |
| | ***Bentuk Stuktur Kawalan Ulangan***<br>• Loop<br>• Do While Loop<br>• While Loop | • *Menulis atur cara menggunakan sturktur kawalan ulangan yang melibatkan operator* | 2. To familiarize students with different control structures | Learning Activity 5 |
| | | | 3. To practice implementing control structures | |



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In the analysis phase, this study identified challenging topics for students in learning programming, which are problem-solving strategies and control structures. For problem-solving strategies Topic 1.1, the study aimed to introduce strategic problem-solving learning strategy in computer science, enhance students' understanding, and provide practice in applying these strategies. The sub-topics included the necessity of problem-solving, computational thinking techniques, and the problem-solving process. In this study, two learning activities were developed for topic 1.1. Next for control structures Topic 1.4, the objectives were to introduce control structures, familiarize students with different types, and practice implementing them. The sub-topics covered selection control structures (If Else, If Else If, Switch case) and iterative control structures (Loop, Do While Loop, While Loop). In this study, three learning activities were developed for topic 1.4.

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The analyzed learning objectives were aligned with the Dokumen Standard Kurikulum dan Pentaksiran (DSKP) to ensure educational relevance and effectiveness. After analyzing the challenging topics students face in learning programming, this study examined the relevant software to be used in developing the SmartAR Module. Four software applications were selected such as Blender to create 3D objects, Canva to design the Augmented Reality marker and module, Unity to develop the AR application, and Vuforia to store the 3D objects and markers. Additionally, this study utilized two hardware such as Lenovo_MT_82 i5 intel ideapad supported laptop and 5 android mobile application with minimum 23 jellybean android version.

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### 4.2.2 Design

In this study, after analyzing the topics and required software, the subsequent conducted step was designing the 3D model, marker, learning activities, and SmartAR application interface.

#### 4.2.2.1 Designing of Augmented Reality Programming Module

In this study, the learning activities were designed using seven problem-solving learning strategy criteria adapted from Jonassen (1977). Tables 4.2 to 4.6 provide a detailed explanation of each criterion employed in the problem-solving learning strategy for activity 1, activity 2, activity 3, activity 4 and activity 5.

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**Table 4.2**

*The Embedded Online Problem-Solving Learning Strategy in Learning Activity 1*

| Content | Problem-Solving Learning Strategy | Example / Explanation |
|---|---|---|
| *Anda adalah **ahli Kelab Alam Sekitar sekolah.** Anda mendapati terdapat **peningkatan sisa plastik** di sekitar sekolah, yang **menyebabkan pencemaran dan merosakkan alam sekitar tempatan**.*<br><br>*Berdasarkan **prinsip penyelesaian masalah** yang dipelajari sebelum ini, cari cara untuk mengurangkan penggunaan dan pembuangan plastik di sekolah dengan menggunakan konsep dan peraturan yang jelas dan tersusun. Terangkan semua elemen masalah ini dan definisikan masalah dengan penyelesaian yang mungkin. Pastikan penyelesaian tersebut dapat diketahui, menyeluruh, dan mempunyai proses penyelesaian yang lebih disukai dan ditetapkan.* | i) Present all elements of the problem | *"Anda mendapati terdapat peningkatan sisa plastik di sekitar sekolah, yang menyebabkan pencemaran dan merosakkan alam sekitar tempatan."* |
| | ii) Define the problem with a probable solution | *"Berdasarkan prinsip yang dipelajari sebelum ini, cari cara untuk mengurangkan penggunaan dan pembuangan plastik di sekolah..."* |
| | iii) Engage the application of a limited number of rules and principles | *"...dengan menggunakan konsep dan peraturan yang jelas dan tersusun."* |
| | iv) Involve concepts and rules that appear regular and well-structured in a domain knowledge | |
| | v) Possess correct and, convergent answers | *"...cari cara untuk mengurangkan penggunaan dan pembuangan plastik di sekolah..."* |
| | vi) Possess knowable and comprehensive solution | *"Pastikan penyelesaian tersebut dapat diketahui, menyeluruh... "* |
| | vii) Have a preferred and prescribed solution process. | *"...dan mempunyai proses penyelesaian yang lebih disukai dan ditetapkan."* |



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**Table 4.3**

*The Embedded Online Problem-Solving Learning Strategy in Learning Activity 2*

| Content | Problem-Solving Learning Strategy | Example / Explanation |
|---|---|---|
| *Anda adalah seorang pelajar Sarjana yang menghadapi minggu peperiksaan. Dengan* ***tarikh akhir semakin hampir dan banyak tugasan yang belum diselesaikan, anda merasa terlalu banyak bebanan****.*<br><br>*Dalam keadaan ini, anda perlu merancang strategi untuk mengatur masa dan sumber yang anda ada dengan efektif agar dapat menyiapkan semua tugasan dan juga mempersiapkan diri untuk peperiksaan. Sila guna proses penyelesaian masalah untuk menyelesaikan masalah anda.* | i) Present all elements of the problem | *"Anda adalah seorang pelajar Sarjana yang menghadapi minggu peperiksaan. Dengan tarikh akhir semakin hampir dan banyak tugasan yang belum diselesaikan, anda merasa terlalu banyak bebanan."* |
| | ii) Define the problem with a probable solution | *"Dalam keadaan ini, anda perlu merancang strategi untuk mengatur masa dan sumber yang anda ada dengan efektif agar dapat menyiapkan semua tugasan dan juga mempersiapkan diri untuk peperiksaan."* |
| | iii) Engage the application of a limited number of rules and principles | *"Sila guna proses penyelesaian masalah untuk menyelesaikan masalah anda."* |
| | iv) Involve concepts and rules that appear regular and well-structured in a domain knowledge | |
| | v) Possess correct and, convergent answers | |
| | vi) Possess knowable and comprehensive solution | *"Dalam keadaan ini, anda perlu merancang strategi untuk mengatur masa dan sumber yang anda ada dengan efektif agar dapat menyiapkan semua tugasan dan juga mempersiapkan diri untuk peperiksaan."* |
| | vii) Have a preferred and prescribed solution process. | *"Sila guna proses penyelesaian masalah untuk menyelesaikan masalah anda."* |



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**Table 4.4**

*The Embedded Online Problem-Solving Learning Strategy in Learning Activity 3*

| Content | Problem-Solving Learning Strategy | Example / Explanation |
|---|---|---|
| *Pada suatu malam yang gelap di sebuah desa, penduduk mendapati* ***cahaya bulan tidak tersebar merata, menyebabkan beberapa bahagian desa tenggelam dalam kegelapan***.<br><br>*Ahli astronomi desa, yang juga seorang pengaturcara, ingin mencipta satu kod dalam bahasa Java untuk membolehkan bulan berputar agar cahayanya dapat disebarkan dengan lebih merata.*<br><br>*Anda diminta untuk* ***menulis kod tersebut dengan menggunakan pernyataan 'if-else'.*** *Jika syarat tertentu dipenuhi, bulan akan mula berputar dan menyebarkan cahayanya ke seluruh desa; jika tidak, bulan akan kekal dalam keadaan tetap.* | i) Present all elements of the problem | *"Pada suatu malam yang tenang di sebuah desa terpencil, penduduk mendapati bahawa cahaya bulan yang indah tidak tersebar merata di seluruh desa, menyebabkan beberapa kawasan menjadi gelap."* |
| | ii) Define the problem with a probable solution | *"Ahli astronomi desa, yang juga seorang pengaturcara berbakat, memutuskan untuk mencipta satu kod dalam bahasa Java untuk membolehkan bulan berputar dan menyebarkan cahayanya dengan lebih merata di seluruh desa."* |
| | iii) Engage the application of a limited number of rules and principles | *"Sila tulis kod dalam bahasa Java dengan menggunakan pernyataan 'if-else' untuk mencapai matlamat ini.."* |
| | iv) Involve concepts and rules that appear regular and well-structured in a domain knowledge | *"Sila tulis kod dalam bahasa Java dengan menggunakan pernyataan 'if-else"* |
| | v) Possess correct and, convergent answers | *" Jika syarat tertentu dipenuhi, bulan akan berputar dengan anggun dan menerangi seluruh desa; jika tidak, bulan akan kekal dalam kedudukan asalnya.."* |
| | vi) Possess knowable and comprehensive solution | *"Sila tulis kod dalam bahasa Java dengan menggunakan pernyataan 'if-else' untuk mencapai matlamat ini."* |
| | vii) Have a preferred and prescribed solution process. | |



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**Table 4.5**

*The Embedded Online Problem-Solving Learning Strategy in Learning Activity 4*

| Content | Problem-Solving Learning Strategy | Example / Explanation |
|---|---|---|
| ***Sekolah Menengah Harmoni sedang merancang satu acara khas*** *untuk semua pelajar, di mana mereka akan* ***dikelompokkan dalam kategori-kategori yang sesuai untuk aktiviti tersebut.*** *Penyelaras acara, Cikgu Mira, telah memutuskan untuk membahagikan pelajar berdasarkan usia mereka ke dalam tiga kategori supaya setiap kumpulan dapat menikmati aktiviti yang sesuai dengan tahap umur mereka. Kategori tersebut adalah:*<br><br>*< 12 tahun == 'Kanak'-Kanak*<br>*12 -18 tahun == 'Remaja'*<br>*> 18 tahun == 'Dewasa'*<br><br>*Anda diminta untuk menulis kod dalam bahasa Java yang menggunakan pernyataan if-else if untuk mengkategorikan pelajar-pelajar berdasarkan usia mereka.*<br><br>***Sebagai contoh, jika seorang pelajar berusia 15 tahun, dalam kategori usia manakah dia akan ditempatkan?*** | i) Present all elements of the problem | *" Sekolah Menengah Harmoni sedang merancang satu acara khas untuk semua pelajar, di mana mereka akan dikelompokkan dalam kategori-kategori yang sesuai untuk aktiviti tersebut."* |
| | ii) Define the problem with a probable solution | *Anda diminta untuk menulis kod dalam bahasa Java yang menggunakan pernyataan if-else if untuk mengkategorikan pelajar-pelajar berdasarkan usia mereka."* |
| | iii) Engage the application of a limited number of rules and principles | *Tulis kod dalam bahasa Java yang menggunakan pernyataan if-else if untuk mengkategorikan pelajar-pelajar berdasarkan usia mereka."* |
| | iv) Involve concepts and rules that appear regular and well-structured in a domain knowledge | *"Tulis kod dalam bahasa Java yang menggunakan pernyataan if-else if."* |
| | v) Possess correct and, convergent answers | *" Sebagai contoh, jika seorang pelajar berusia 15 tahun, dalam kategori usia manakah dia akan ditempatkan?"* |
| | vi) Possess knowable and comprehensive solution | *"Tulis kod dalam bahasa Java berikut untuk mengkategorikan pelajar dan tentukan kategori untuk pelajar yang berusia 15 tahun."* |
| | vii) Have a preferred and prescribed solution process. | *"Tulis kod dalam bahasa Java yang menggunakan pernyataan if-else if untuk mengkategorikan pelajar-pelajar berdasarkan usia mereka."* |



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**Table 4.6**

*The Embedded Online Problem-Solving Learning Strategy in Learning Activity 5*

| Content | Problem-Solving Learning Strategy | Example / Explanation |
|---|---|---|
| *Anda seorang jurutera program yang bekerja untuk syarikat pembangunan teknologi yang baru sahaja* ***memperkenalkan kereta automatik yang revolusioner****. Kereta ini dapat dikawal dengan mudah melalui antaramuka pintar yang menerima arahan putaran dari pengguna.* ***Setiap arahan putaran (Kanan/Kiri/Atas/Bawah) atau pilihan 'B' untuk berhenti akan mengubah orientasi kereta secara langsung.*** *Tuliskan sebuah program dalam bahasa Java yang memproses input untuk mengubah orientasi kereta seperti berikut:*<br>1. ***Kanan****: Memutar kereta ke kiri.*<br>2. ***Kiri****: Memutar kereta ke kanan.*<br>3. ***Atas****: Mendorong kereta ke atas.*<br>4. ***Bawah****: Menurunkan kereta ke bawah.*<br>5. ***B****: Menghentikan kereta.*<br>*Program ini akan menerima input berulang-ulang dari pengguna hingga pengguna memilih untuk menghentikan kereta dengan memasukkan 'B'. Petunjuk: Gunakan switch statement dalam Java untuk mengatur setiap pilihan arah putaran .* | i) Present all elements of the problem | *"Memperkenalkan kereta automatik yang dikendalikan melalui input pengguna untuk arah putaran."* |
| | ii) Define the problem with a probable solution | *"Tuliskan sebuah program dalam bahasa Java yang memproses input pengguna untuk mengatur arah putaran kereta."* |
| | iii) Engage the application of a limited number of rules and principles | *"Gunakan switch statement dalam Java untuk mengatur setiap pilihan arah putaran."* |
| | iv) Involve concepts and rules that appear regular and well-structured in a domain knowledge | *"Program ini akan menampilkan maklumat tentang setiap arah putaran yang dipilih oleh pengguna dan mengubah orientasi kereta.."* |
| | v) Possess correct and, convergent answers | |
| | vi) Possess knowable and comprehensive solution | *"Gunakan switch statement dalam Java untuk mengatur setiap pilihan arah putaran."* |
| | vii) Have a preferred and prescribed solution process. | *"Program ini akan menerima input berulang-ulang dari pengguna hingga pengguna memilih untuk menghentikan kereta dengan memasukkan 'B'"* |



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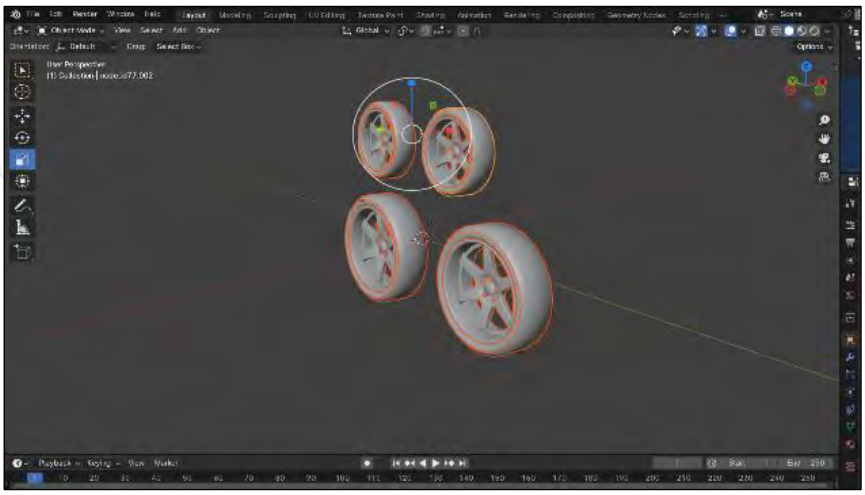
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#### 4.2.2.2 Designing the 3D Model

Next, in this study, various 3D models were created from scratch, including a solar planet, car accessories, a pizza, and more objects. These models were designed using Blender software, as shown in Figure 4.3. The 3D objects were selected based on their relevance to the topic. They were animated using Blender software, and the color materials were imported from Blender.

**Figure 4.3**

*Designing 3Dimensional Object for SmartAR Module*



#### 4.2.2.3 Designing the Marker

Thirdly, this study designed the marker and learning module using Canva software. The module consists of two sets: the first set contains 8 pages, as shown in Figure 4.4, and the second set contains 13 pages, as shown in Figure 4.5, excluding the home pages.

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**Figure 4.4**

*Designing Marker and Learning Module Unit 1 of SmartAR Module*

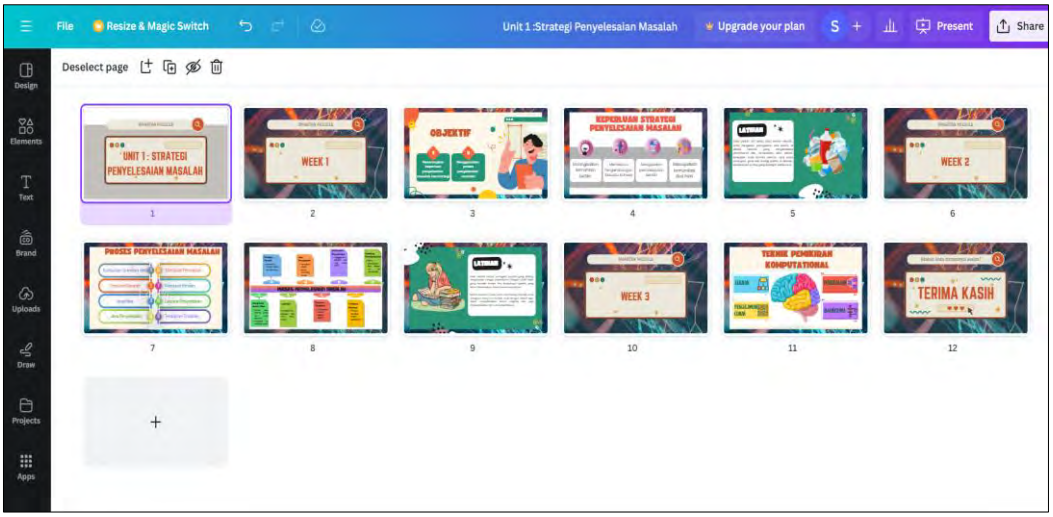
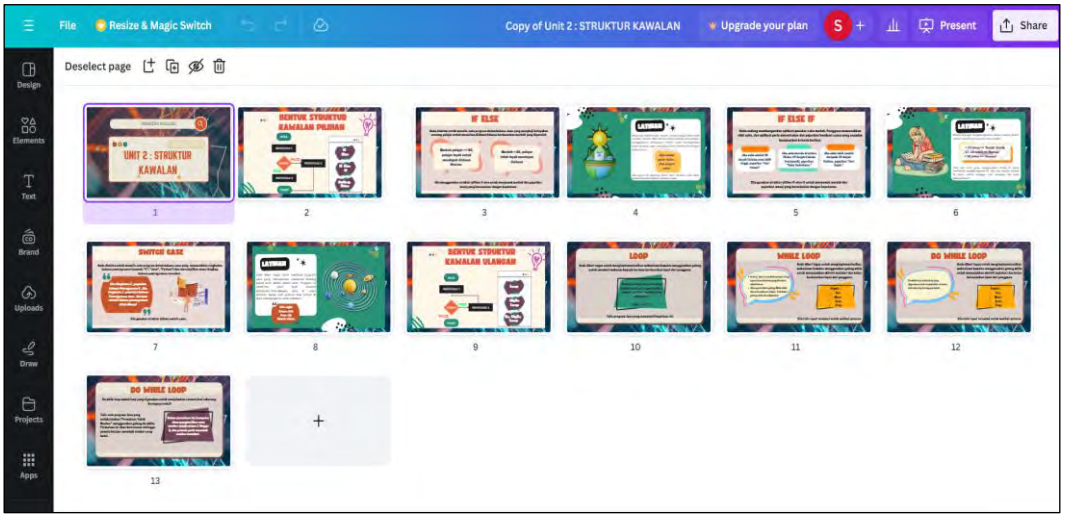



**Figure 4.5**

*Designing Marker and Learning Module Unit 2 of SmartAR Module*




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#### 4.2.2.4 Integration of Connectivism Learning Theory in SmartAR Module Design

The SmartAR Module was intentionally designed to embody key principles of Connectivism Learning Theory (Siemens, 2005), which posits that learning occurs through network formation and pattern recognition across digital, social, and cognitive domains. This theoretical integration manifests in four core dimensions: (i) networked knowledge construction, (ii) situated problem-solving, (iii) dynamic feedback systems and (iv) distributed cognitive tools as shown in Table 4.7.

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**Table 4.7**

The Connectivism Theoretical Integration

| Dimension | Activities |
|---|---|
| 1. Networked Knowledge Construction | *3D Model Design:* The solar planet, car accessories, and pizza models (Figure 4.3) serve as visual nodes that connect abstract programming concepts to tangible representations. For instance, the rotating planet in Activity 3 physically demonstrates how If-Else conditional logic affects system behavior. |
| | *Marker System:* The Canva-designed markers (Figures 4.4-4.5) function as physical-digital bridges, enabling learners to access knowledge networks by scanning real-world triggers. |
| 2. Situated Problem-Solving | *Activity Design*: All of the five learning activities utilize authentic scenarios (See Tables 4.2-4.6) that reflect the contextually framed learning as outlined in Connectivism:<br>a. Environmental Management (Activity 1): Programming in class related to real-life sustainability issues<br>b. Time Management (Activity 2): Personal life having a connection with computational thinking<br>c. Astronomy Simulation (Activity 3): Logic statements that are part of the mechanics of celestial bodies |
| | *Each scenario requires learners to recognize patterns between programming rules (domain knowledge) and practical applications (situated cognition).* |



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| | |
|---|---|
| 3.Dynamic Feedback Systems | *The module implements three-tiered feedback mechanisms:*<br>a. *Immediate Visual Feedback: 3D animations respond to correct code inputs ( Earth rotation in Activity 3)*<br>b. *Error Correction: Drag-and-drop resets and error messages provide corrective networking opportunities*<br>c. *Adaptive Help Systems: Context-sensitive hints (Activity 5's switch statement guidance) offer just-in-time knowledge nodes* |
| 4. Distributed Cognitive Tools | Blender Animations: Complex programming concepts are decomposed into manipulatable 3D objects, enabling learners to externalize mental models<br>Unity AR Interface (Figure 4.7): Creates a "thinking space" where control structures become interactive visual networks rather than abstract syntax |



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Applying the principles of Connectivism in the SmartAR Module leads an interactive learning setting where learners acquire programming skills through a myriad of activities. Grasping knowledge in networks transforms logic encapsulation to 3D models. Students are able to visualize how actual systems execute programmatic constructions. The module enables learners to answer real world problems such as environmental management and astronomy by contextualizing technical concepts, thus helping learners to discover new connections. The multi-layered feedback system strengthens these associations via rapid corrective feedback and adaptive support, reflecting the perpetuated circulation of information within digital systems. In addition, these technological resources permit learners to detach and reconfigure intricate programming frameworks, enabling the formation of higher-level thinking skills needed in the modern world overflowing with information. This approach integrates the concepts of teaching programming and practical connected learning experiences.

### 4.2.3 Development of Augmented Reality Programming Module

In this study, the third phase of the ADDIE model is development. During this phase, the designed 3D models were developed with coloured materials, the Canva module was fully developed, and based on this module, the SmartAR application interface was created.

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#### 4.2.3.1 SmartAR Module

In this study. to create the SmartAR Module an Canva Pro account was utilized to integrate leveraging advanced 3D graphics and premium infographics. The designs were inspired by existing Canva templates, yet the researcher customized the user interface, template colours, and other elements to meet the specific needs of the SmartAR Module. The content for the SmartAR Module was derived from the Malaysian Form 4 computer science curriculum textbook. According to Doe's (2023), educational content needed to be delivered considering the needs of learners, the goals of the course, and the available resources. Consequently, if the content was not well designed, it could easily become a boring event in a vast space for students (Dwivedi et al, 2022). This made it difficult for students to find the resources they needed to succeed in the interactive module. Educators were supposed to provide clear instructions, use interactive activities, and offer opportunities for students to collaborate with each other (Roe, 2023). Therefore, in this study developing an appropriate user interface was crucial for attracting students' interest in learning.

**Figure 4.6:**

*The Canva interface used for designing Unit 1.1*




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Figure 4.6 above illustrates the elements and user interface in Canva for the developed Unit 1.1 Module of the study. The design process encompassed three stages. After developing the marker of this study, also referred to as the SmartAR Module, the file was converted and imported as a PDF, making it convenient for downloading and future use. After developed two learning materials using Canva software, this study employed the Vuforia database to store the chosen markers. Vuforia Engine is a software development kit (SDK) designed for developing Augmented Reality applications (Vuforia, 2024). In this study, Unity will be used to create an augmented reality environment, making the Vuforia database a suitable choice. Since the application is intended for personal use, the study will utilize the free licensing option of the Vuforia database.

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#### 4.2.3.2 SmartAR Mobile Interface

In this study, Unity was used to develop the SmartAR Module. Essential elements such as font design, AR Kit, AR Core setup, basic assets, necessary UI assets, and the marker were imported from the Asset Store before proceeding with the development of the mobile application. The actual development of this study then began, based on the designed learning material, as shown in Figure 4.7.

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**Figure 4.7**

*Setup Unity Software for SmartAR Module*




This study consists of five learning activities, as shown in Table 4.2. Appendix W shows the fully designed and developed SmartAR Module of this study. Meanwhile, table 4.8 the interface of SmartAR Module.

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**Table 4.8**

*The Interface of SmartAR Module*

| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| SmartAR<br><br>Mobile<br><br>Application | The first picture displays the landing page of the SmartAR Mobile application. This landing page features three buttons: one linked to Unit 1, another to Unit 2, and a third to quit the application.<br><br>Following that, the second picture shows the home page of Unit 1. This page consists of a horizontal selection menu with options for *"Keperluan Strategi Penyelesaian Masalah"*, *"Pemikiran Komputasional"* and *"Proses Penyelesaian Masalah"*. | <br> |



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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 1 | The picture displays Learning Activity 1 from Unit 1, which focuses on examining **problem-solving strategies.**<br><br>SmartAR includes an animation video that explains the principles with examples for better student understanding.<br><br>In this activity, students are presented with a scenario as shown in Figure 4.2 and required to scan the question. The interface then prompts students to drag and drop their answers based on the correct principles and steps. If an answer is incorrect, it will revert back to its original position. Correct answers trigger a short animation video. | <br> |



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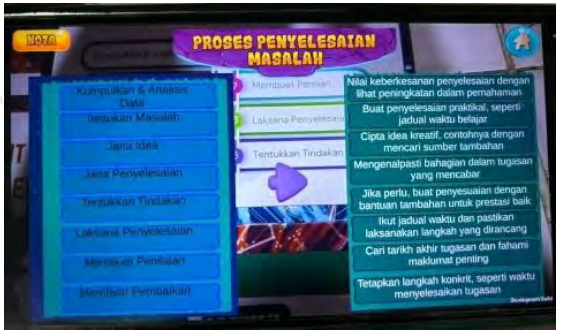
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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 1 | Second topic in Unit 1 is **Teknik Pemikiran Computational**.<br>This subtopic covers four techniques:<br>• Leraian<br>• Peniklasan<br>• Algorithma<br>• Pengencaman Corak<br><br>Each technique includes guidance that consists of animation videos, multimedia, graphics, and text algorithms to keep students engaged and learning effectively.<br><br>Students are required to scan the marker and follow the instructions in the SmartAR application. | <br><br> |



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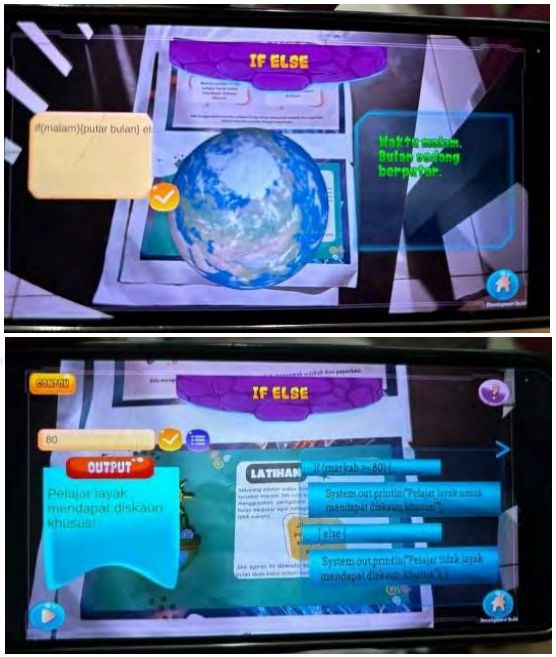
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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 1 | The picture displays Learning Activity 2 from Unit 1, which focuses on examining **Proses Penyelesaian Masalah.**<br>SmartAR includes an animation video that explains the proses penyelesaian masalah with examples for better student understanding.<br><br>In this activity, students are presented with a scenario as shown in Figure 4.3 and required to scan the question. The interface then prompts students to drag and drop their answers based on the correct principles and steps. If an answer is incorrect, it will revert back to its original position. Correct answers trigger a short animation video. | <br> |



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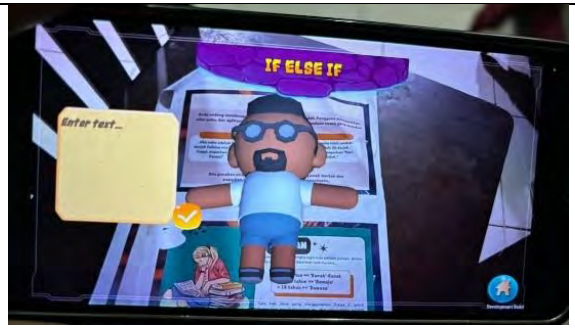
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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The picture displays **Learning Activity 3** from Unit 2, which focuses on examining **If-Else** statements.<br>Before beginning the learning activity, students are given a scenario to explore with an example. For this If-Else scenario, students are required to input marks. If students get stuck, they can click the menu button for help, which provides example code for the scenario.<br>The If-Else interface also includes a help button. When clicked, it shows the formula for If-Else conditions. After practicing the learning activity, students are presented with a scenario as shown in Figure 4.4 and are required to scan the question. The interface then displays a 3D Earth. Students must enter the correct code. If an answer is incorrect, it will display an error message. If the answer is correct, the Earth will rotate. |  |



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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The picture displays **Learning Activity 4** from Unit 2, which focuses on examining **If-Else-If** statements.<br><br>Before beginning the learning activity, students are given a scenario to explore with an example. For this If-Else scenario, students are required to weather Celsius. If students get stuck, they can click the menu button for help, which provides example code for the scenario.<br>The If-Else-If interface also includes a help button. When clicked, it shows the formula for If-Else-If conditions.<br>After practicing the learning activity, students are presented with a scenario as shown in Figure 4.5 and are required to scan the question. The interface then displays a series of 3D human models, ranging from a baby to an elderly person. Students must enter the correct code. If an answer is incorrect, it will display an error message. If the answer is correct, the appropriate middle-aged character will be displayed. | <br> |



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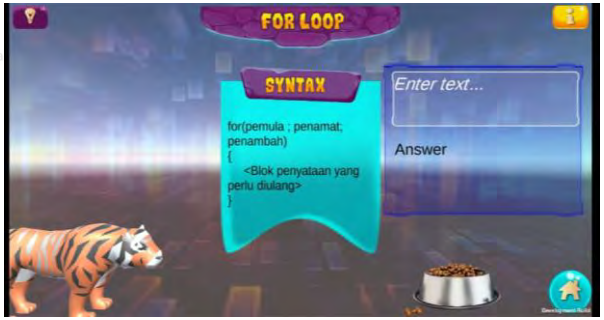
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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The picture displays **Learning Activity 5** from Unit 2, which focuses on examining **Switch Case** statements.<br>In this learning activity, students are required to enter code to move the car as instructed in Figure 4.6. A correct answer will move the car according to the input provided. |  |
| Unit 2 | The first topic in the **Repetitive Control Structure section of Unit 2 is the For Loop**.<br>Initially, the application provides a basic example where students can drag and drop elements based on the questions in the module. After practicing, students can click on the exercise to view a 3D tiger and input the correct code to feed the tiger. Hints are available with the correct formula. | <br> |



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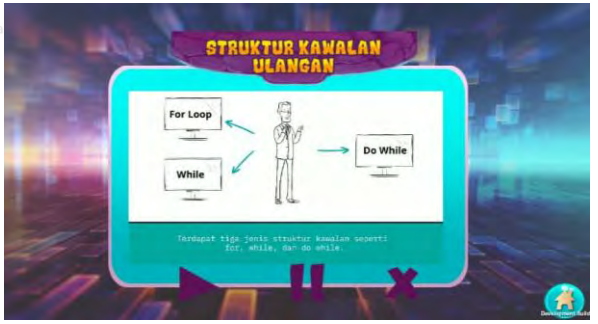
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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The first topic in the **Repetitive Control Structure section of Unit 2 is the For Loop**.<br><br>Initially, the application provides a basic example where students can drag and drop elements based on the questions in the module. After practicing, students can click on the exercise to view a 3D tiger and input the correct code to feed the tiger. Hints are available with the correct formula. | <br> |



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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The second topic in the **Repetitive Control Structure section of Unit 2 is the While Loop**.<br><br>Initially, the application provides a basic example where students can drag and drop elements based on the questions in the module.<br><br>After practicing, students can click on the exercise to view a 3D moon and sun and input the correct code to rotate the object. The object will be rotate based on input by user. Hints are available with the correct formula.<br><br>If students need more detailed information, they can click the info button to access a comprehensive animation video | <br> |



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| Unit | Main Topic / Exercise | Pictures |
|---|---|---|
| Unit 2 | The second topic in the **Repetitive Control Structure section of Unit 2 is the Do While Loop**.<br><br>This is a number guessing game where numbers from one to ten are continuously shuffled. When students enter the current number, the game will stop and display the selected number.<br><br>Hints are provided with the correct formula. If students require more detailed information, they can click the info button to access a comprehensive animation video. |  |



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#### 4.2.3.3 Validation of SmartAR Module

After the development of the SmartAR application, a panel comprising seven experts was formed. This panel included three secondary school computer science teachers, who served as content experts, and four augmented reality experts, who acted as technological experts. The purpose of the panel was to validate the appropriateness of the selected elements and learning materials for the SmartAR Module to answer research question two. Firstly, the technological experts were chosen based on four criteria: (1) a minimum of 3 years' experience in designing and developing augmented reality applications, (2) knowledge of the marker-based Vuforia database engine, (3) intermediate knowledge of academic augmented reality game-based mobile applications, and (4) basic knowledge of programming. The consent form provided to technological experts is attached in Appendix B.

Next, the content experts were chosen based five criteria such as (1) at least five years of teaching experience, (2) a good understanding of logic and algorithms, (3) intermediate experience using educational mobile applications, (4) a basic understanding of Augmented Reality, and (5) self-sufficiency as a fast learner with minimal support. The consent form provided to content experts is attached in Appendix C. The results of the validity test for SmartAR Module content from the experts' perspective (school computer science teachers) are discussed in chapter 5. The complete learning material attached in Appendix W. Therefore, the Smart AR module was valid for use in learning computer science and as a treatment in this study.

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### 4.2.4 Implementation

In this study, after the SmartAR Module was validated by seven experts in technology and content, a preliminary study was conducted to test the SmartAR Module. Following this, the actual implementation of the study was carried out.

#### 4.2.4.1 Preliminary Study

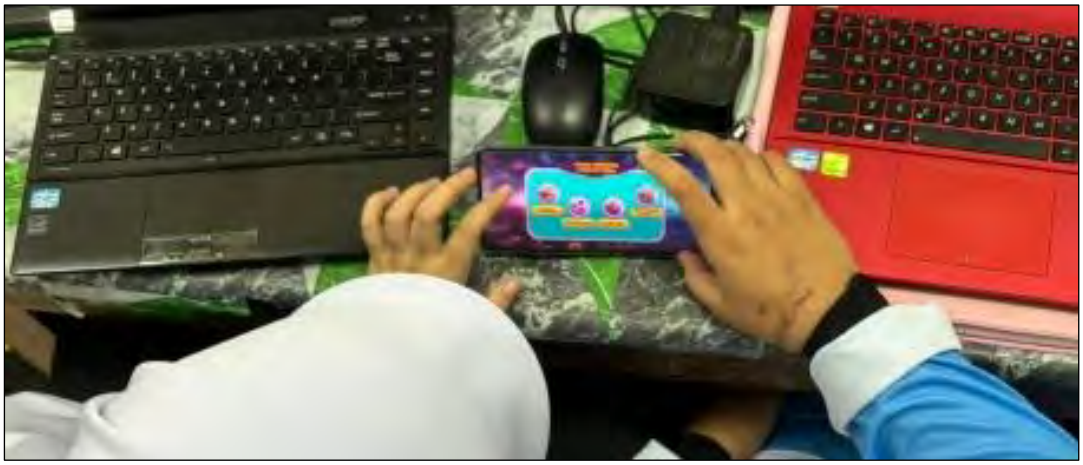
The preliminary study for this study was conducted by the school teacher in a classroom, involving 10 selected computer science students. Creswell (2013) highlighted in his book *Qualitative Inquiry and Research Design*, that a sample size of 10 participants is often adequate for pilot studies as this size allows for an in-depth exploration of experiences without being overwhelming for the researcher to manage.The participants in the preliminary study were not involved in the implementation study; they only took part in the preliminary phase. figure 4.8 displays images taken during the preliminary study. The preliminary study took place in an ICT classroom.

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**Figure 4.8**

*Preliminary Study of SmartAR Module*



### 4.2.4.2 Implementation of SmartAR Module

Following the preliminary study, the implementation of the SmartAR Module commenced. Prior to implementation, the researcher conducted a peer-to-peer consultation session with the computer science teacher to disseminate the research instruments, which included pre-test and post-test assessments, usability and motivation questionnaires, and the SmartAR Module covering Units 1 and 4, along with supplementary learning activities to ensure seamless instruction. The preparation phase involved the configuration of 20 mobile devices, where the researcher installed the SmartAR application via APK files and conducted comprehensive functionality testing on each device. After obtaining approval from the school principal, the computer science teacher began the implementation process by distributing consent forms. This

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was followed by administering the Pre-Test questions in the first week. Subsequently, the implementation was carried out from week two to week eight as outlined in Table 4.9. The images were attached in Appendix X.

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**Table 4.9**

*Implementation of SmartAR Module in School*

| Week /Subject | Unit | Allocated Time | Procedure to implement in classroom |
|---|---|---|---|
| Week 2: Strategi Penyelesaian Masalah<br><br>(19/3/2024)<br>Tuesday | Unit 1.1 | 45 minutes | 1. The class commenced with a 10-minute revision of the previous session by the teacher.<br>2. Following that, the teacher grouped students into six groups and provided each group with an mobile.<br>3. Teacher begin distributed a set of questionnaires to evaluate the students' motivation in using the SmartAR Module, which took 10 minutes.<br>4. Subsequently, the teacher introduced the problem statement and instructed students to watch a 2-minute animation video depicting the problem-solving strategy.<br>5. Then, students were assigned a 10-minute exercise on the mobile application.<br>6. Upon completing the exercise, students proceeded to observe the problem-solving process based on a scenario.<br>7. Finally, after students finished the exercise, the teacher shared an interactive mind map sheet and allotted 10 minutes for them to take revision notes.<br>8. The class dismissed after students finished the question. |



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| Week /Subject | Unit | Allocated Time | Procedure to implement in classroom |
|---|---|---|---|
| Week 3: Computational Learning Technique<br><br>(26/3/2024)<br><br>Tuesday | Unit 1.1 | 45 minutes | 1. A five-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. The students were divided into their previous class groups where each group was asked to investigate four computational techniques for twenty minutes using the SmartAR Mobile Application and Marker, with partial guidance from the teacher.<br>3. At the end of the lesson, the teacher set aside ten minutes for the students to complete practice assessments.<br>4. After the exercise, the teacher presented an interactive mind map sheet and permitted five minutes of revision note-taking.<br>5. The class dismissed after students finished the question. |

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| Week /Subject | Unit | Allocated Time | Procedure to implement in classroom |
|---|---|---|---|
| Week 4:<br>Proses Penyelesaian Masalah<br>(2/4/2024)<br>Tuesday | Unit 1.1 | 45 inutes | 1. A ten-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. The teacher subsequently presented the steps of problem solving and asked the students to pay attention to a 2-minute animation that illustrated the problem-solving process.<br>3. Students were instructed to view another example animation video which lasted for 3 minutes after they had completed the first video.<br>4. In the following step, students were required to complete a 10-minute exercise on the mobile app.<br>5. Students then moved on to watching how a specific scenario is solved, known as the Problem-Solving Process.<br>6. After the students completed the exercises, the teacher provided an interactive mindmap template and instructed them to spend 10 minutes populating the template to create summary notes for revision.<br>7. The class dismissed after students finished the question. |



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| Week /Subject | Unit | Allocated Time | Procedure to implement in classroom |
|---|---|---|---|
| Week 5 : Struktur Kawalan Pilihan (If and Else If ) (4/4/2024) Thursday | Unit 1.4 | 45 minutes | 1. A five-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. The SmartAR Mobile Application and Marker were used by the students from the previous class on '*Stuktur Kawalan Pilihan'* specifically If , If Else subtopic for 20 minutes with a teacher's aide on a one-to-one basis.<br>3. After that, the teacher provided ten minutes for the students to complete the assessment exercises.<br>4. After the exercise, the teacher provided an interactive mind map sheet and reserved five minutes for the students to make revision notes.<br>5. The class dismissed after students finished the question. |
| Week 6 : Struktur Kawalan Pilihan (If Else If and Switch Case) (16/4/2024) Tuesday | | 45 minutes | 1. A five-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. Students were returned to their prior groups with the SmartAR application and Marker where the students were supervised by the teacher while exploring 'Stuktur Kawalan Pilihan' If Else If and Switch Case subtopic for twenty minutes.<br>3. After the teacher assigned the exercises, she provided students with 10 minutes to complete the assessment.<br>4. After the exercise, the interactive mind map sheet was presented by the teacher, and the teacher allowed students to spend 5 minutes taking notes for revisions.<br>5. The class dismissed after students finished the question. |



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| Week /Subject | Unit | Allocated Time | Procedure to implement in classroom |
|---|---|---|---|
| Week 7 : Struktur Kawalan Ulangan (For Loop and While Loop) (23/4/2024) Tuesday | Unit 1.4 | 45 minutes | 1. A five-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. The students were later grouped according to their last class. Each group was expected to use the SmartAR Mobile Application and Marker to learn about 'Struktur Kawalan Ulangan' specifically For Loop and While Loop for 20 minutes, and the teacher provided assistance to each student.<br>3. Afterward, the teacher provided 10 minutes for students to practice self-assessment.<br>4. After the exercise, the teacher distributed an interactive mind map worksheet and allocated 5 minutes for students to record key points.<br>5. The class dismissed after students finished the question. |
| Week 8 : Struktur Kawalan Ulangan (Do while) (30/4/2024) Tuesday | | 45 minutes | 1. A five-minute recap of the last class was conducted by the teacher at the beginning of the lesson.<br>2. Students were then assigned to their respective groups from the previous class, where they were tasked with utilizing the SmartAR Mobile Application and Marker to explore *'Stuktur Kawalan Ulangan'* specifically Do While Loop for 20 minutes, with individual assistance provided by the teacher.<br>3. Following this, the teacher allocated 10 minutes for students to practice assessments.<br>4. Upon completion of the exercise, the teacher shared an interactive mind map sheet and allowed 5 minutes for students to take revision notes.<br>5. The class dismissed after students finished the question. |



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Figure 4.9 shows the image taken during pre-test in Week 1. Meanwhile, Figure 4.10 shows images taken during Weeks 2 to 8. Figure 4.12, captured during Week 9, shows the administration of the post-test, SmartAR Module Usability questionnaire and student motivation questionnaire. On that day, students completed a consent form before proceeding to answer the post-test and student motivation questionnaire.

**Figure 4.9**

*Week 1 of Pre-Test Achievement Test*




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**Figure 4.10**

*Week 2 – 8 of SmartAR Module Implementation*



**Figure 4.11**

*Week 9 of Post-Test Achievement Test*

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### 4.2.5 Evaluation of SmartAR Module

In this study, the evaluation of the SmartAR Module was conducted in three areas: usability, students' achievement, and students' motivation after using the module. Phase one focused on the usability of the SmartAR Module using a usability questionnaire. Phase two evaluated the focused on assessing students' achievement through pre-test and post-test results. Finally, phase three concentrated on examining students' motivation after engaging with the SmartAR Module.

#### 4.2.5.1 Evaluation of Usability Questionnaire

In this study, the usability of the SmartAR Module was evaluated using the Tuli & Mantri (2020) usability questionnaire to answer research question three. During week nine, the researcher distributed 30 sets of the usability questionnaire to students to evaluate the usability of SmartAR Module.

#### 4.2.5.2 Evaluation of Students Achievement

In this study, an achievement test was conducted before and after using the SmartAR Module to answer research question four. During week one, the researcher distributed 30 sets of pre-test questions, prepared by the researcher, to the students. In week nine, the teacher administered the post-test questions.

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#### 4.2.5.3 Evaluation of Students Motivation Questionnaire

In this study, the student's motivation after using SmartAR Module was evaluated using the IMMS and ARCS questionnaire to answer research question five. During week nine, the researcher distributed 30 sets of the motivation questionnaire to examine students' motivation after using SmartAR Module.

## 4.3 Summary

This chapter provided a comprehensive discussion of steps of preliminary and implementation of SmartAR Module. The following chapter began with the analyze the data findings of the SmartAR Module for learning programming.

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# CHAPTER 5

# RESEARCH FINDINGS

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## 5.1 Introduction

In this chapter, the discussion revolves around the research findings based on five research questions of this study. The research findings are discussed in accordance with the sequence of research questions outlined in Chapter One.

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## 5.2 Demographic of respondents

In this study, three groups of respondents were involved to answer the research questions. Firstly, five computer science students and two teachers participated in a virtual semi-structured interview to answer research question one. Secondly, 30 computer science students assessed the usability of the SmartAR Module by completing usability questionnaires to answer research question three. Subsequently, the same group of 30 students participated in pre-test and post-test achievement tests to answer research question four. Finally, the motivation of these 30 students was measured through questionnaires to answered research question five.

### 5.2.1 Demographic of Respondents for Semi-Structure Interview

In this study five Form four secondary school students and two computer science teachers participated in a virtual semi-structured interview to identify the needs analysis of the SmartAR Module to answer research question one. Table 5.1 presents the demographic information of the interview respondents, including gender, daily mobile usage, mobile learning, and augmented reality knowledge.

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**Table 5.1**

*Demographic of Respondents for Interview (Students)*

| Demographic | Category | Frequency (f) |
|---|---|---|
| Gender | Male | 1 |
| | Female | 4 |
| Daily Mobile Usage | Limited time | 2 |
| | four to seven hours | 2 |
| | More than ten hours | 1 |
| Mobile learning | Useful | 2 |
| | Interesting | 2 |
| | Not interested | 1 |
| Augmented Reality Knowledge | Yes | 2 |
| | No | 3 |

In a study involving five students, the gender distribution showed that four were female and one was male. Regarding daily mobile phone usage, the students demonstrated varied patterns: 40% used their mobile phones for a limited time, focusing on specific purposes like learning and current events or using the phone sparingly during school holidays. Another 40% of students used their mobile phones for four to seven hours daily, while 20% reported using their phone for more than ten hours per day. The students' knowledge of augmented reality (AR) was comparatively limited. A minority of 40% had some prior experience with AR, with one student being fascinated by 3D images obtained from scanning cards and another having briefly encountered the technology on TikTok. Conversely, 60% of the students had no prior knowledge of augmented reality. All students were enrolled in Form Four computer science, providing a common educational.

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Besides that, two female secondary school computer science teachers participated in a virtual semi-structured interview to gather user requirements for the SmartAR Module. Both teachers have extensive experience in computer science subjects, with one having 14 years of teaching experience and the other ten years. They both possess prior knowledge of using educational mobile applications and AR. Furthermore, as they hold bachelor's degrees in computer science, they exhibit proficiency in various programming languages, as listed in Table 5.2.

**Table 5.2**

*Demographic of Respondent for Interview (Teachers)*

| Teacher | Experiences in Computer Science | Gender | Educational Mobile Application experience | Programming Knowledge | Level of Syllabus |
|---|---|---|---|---|---|
| Teacher 1 | 14 years | Female | Excellent | Html, Java, JavaScript, C#, C, Python | Form 1 - 5 |
| Teacher 2 | 10 years | Female | Excellent | Java, C | Form 3 - 5 |

### 5.2.2 Demographic of Respondents to Validate SmartAR Module

In this study, two groups of experts, namely technological experts and content experts, participated in validating the SmartAR Module and research instrument to address research question two. Table 5.3 presents the demographic information of the technological experts, including their experience, validation content, augmented reality knowledge, and expertise field. Out of the four technological experts, two were male and two were female.

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**Table 5.3**

*Demographics of Respondent for Validation (AR Experts)*

| Expert | Experiences in Teaching | AR Knowledge | Expertise Field |
|---|---|---|---|
| Expert 1 | 4 years | Expert | Educational Technology and Media (mobile Augmented Reality, Multimedia) |
| Expert 2 | 5 years | Expert | •Augmented Reality<br>•Human Computer Interaction |
| Expert 3 | 15 years | Expert | •Edutainment (e-learning, Serious Games, Augmented Reality, Interactive Teaching/learning Applications, Virtual Reality )<br>•Computer Animation & Multimedia |
| Expert 4 | 10 years | Expert | •Computer Based Learning System<br>•Education Technology and Media Augmented Reality in Education<br>•Multimedia: Augmented Reality |

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Expert 1, with four years of teaching experience, specialized in educational technology and media, particularly mobile augmented reality, instructional technology, and multimedia. Expert 2, with five years of experience, focused on augmented reality and human-computer interaction. Expert 3, boasting 15 years of experience, had expertise in edutainment, virtual reality, computer animation, and multimedia. Lastly, Expert 4, with 10 years of experience, specialized in computer-assisted instruction, education technology and media, multimedia, and e-learning, particularly augmented reality in education and individualized learning. Next, three computer science teachers participated in the validation of the SmartAR Module and the application as shown in Table 5.4.

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**Table 5.4**

*Demographic of Respondents for Validation (Teachers)*

| Teacher | Experiences in Teaching | Education Application Knowledge | Programming Expertise |
|---|---|---|---|
| Teacher 1 | 14 Years | Excellent | Excellent: Html, Java, Javascript, C#, C, Python |
| Teacher 2 | 10 Years | Excellent | Good: Java, C |
| Teacher 3 | 5 Years | Excellent | Excellent: Html, Java, Javascript, C#, C, Python, Csharp |

### 5.2.3 Demographic of Respondents for SmartAR Module Usability, Achievement Test and Motivation Questionnaire

In this study, the third set of respondents comprised 30 computer science students who participated in the implementation. Sample completed a usability questionnaire, achievement tests, and motivation questionnaires to answer research questions three, four, and five, respectively. Table 5.5 shows the demographic information of these respondents, including gender, registration in the computer science subject, prior knowledge of mobile technology, and prior knowledge of augmented reality. In the study of 30 computer science students, 90% were females, while males represented 10% of the total student population. All 100% of the respondents were enrolled in Form 4 computer science subjects.

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**Table 5.5**

*Demographic of Respondent for Motivation Questionnaire and Achievement Test*

| Demographic | Category | Frequency (f) | Percentage (%) |
|---|---|---|---|
| Gender | Male | 3 | 10 |
| | Female | 27 | 90 |
| Register computer science subject | Yes | 30 | 100 |
| | No | 0 | 0 |
| Prior mobile learning knowledge | Yes | 21 | 70 |
| | Neutral | 8 | 26.7 |
| | No | 1 | 3.3 |
| Augmented Reality Knowledge | Yes | 21 | 70 |
| | No | 9 | 30 |

Regarding mobile learning experience, 70% of students had previous experience, 26.7% were neutral, and 3.3% had no prior experience. In terms of augmented reality knowledge, 70% of students were familiar with augmented reality, while 30% were not familiar with the technology. This demographic information reveals the diverse technological backgrounds among the participants, offering insight into the potential receptiveness and prior knowledge base for the SmartAR Module.

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## 5.3 Data Findings of The Needs of SmartAR Module

This study investigated the challenges faced by students and teachers in learning programming, highlighting the need for the SmartAR Module within the Form 4 programming curriculum as an answer to the first research question. Data were collected from five and two teachers from two different schools and analysed using thematic analysis. In this study, the collected data during needs analysis of SmartAR

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module were analysed using thematic analysis specifically, Braun and Clarke (2006) six phases. Table 5.6 shows how the students: Challenges in learning Computer Science data were interpreted using Braun and Clarke (2006) six phases.

**Table 5.6**

*Example of Thematic Analysis Implementation*

| Phases | Descriptions |
|---|---|
| 1. Familiarizing with Data | • Transcribed all interview recordings verbatim<br>• Repeatedly read responses like Student 1's "I struggle to find necessary learning materials..." and Student 5's "*buku teks kadang-kadang boring"* to identify initial patterns |
| 2. Generating Initial Codes | Coded key segments:<br>• *"susah cari nota mudah difahami*" → "Resource accessibility"<br>• "*Syntaxes and logic confusing*" → "Conceptual difficulty"<br>• "*perlu belajar semula coding language*" → "Language transition" |
| 3. Searching for Themes | Grouped codes into preliminary themes:<br>• Learning resource inadequacy (combining resource accessibility and engagement issues)<br>• Conceptual comprehension barriers<br>• Programming skill acquisition demands |
| 4. Reviewing Themes | • Verified themes against full dataset:<br>• Confirmed "Barriers to Effective Programming Learning" as overarching theme<br>• Merged "memorization demands" with "skill acquisition" |
| 5. Defining/Naming Themes | Finalized theme definitions:<br>• "Insufficient Learning Resources": Challenges in accessing engaging, multimedia materials<br>• "Conceptual Comprehension Difficulties": Struggles with syntax, logic, and foundational knowledge |
| 6. Producing Report | • Selected representative excerpts (e.g., Student 3's "*menganalisis masalah"* confusion)<br>• Structured Table 5.6 to illustrate theme prevalence |

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### 5.3.1 Challenges in learning computer science and programming (Students Perspective)

The first section of the interview investigated the challenges faced by five students learning computer science subjects to answer research question one. The study findings show students predominantly challenges in computer science with three interconnected dimensions: insufficient learning resources, conceptual comprehension difficulties, and the demanding nature of programming skill acquisition as shown in Table 5.7.

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**Table 5.7**

*Students: Challenges in learning Computer Science*

| Question | Students | Responses | Challenges in Computer Science | Main Theme |
|---|---|---|---|---|
| What are the challenges you are encountering when studying computer science?<br><br>Do you have any difficulties in learning programming? | Student 1 | "I struggle to find the **necessary learning materials** for my studies, as computer science is one of the hardest subjects. Computer **science is hard because of many syntaxes and I always confuse with terms and logic."** | Insufficient learning resources | Barriers to Effective Programming Learning |
| | Student 2 | "I also frequently have **difficulty finding adequate tutorials and supplementary learning materials** to support my studies. My current buku nota have a lot of exercise but since I have difficulty in understanding concept I can practice by myself." | | |
| | Student 4 | "Selain itu , topik yang mencabar untuk saya pelajari ialah , memguji dan membaiki ralat , algoritma , pengesan nilai pemboleh ubah .Dan sangat sukar untuk cari nota yang mudah difahami" | | |
| | Student 5 | "Selain itu , saya takde nota interactive , buku teks kadang kadang boring. Lepas itu , kadang kadang kitaorg buat coding tulis dalam kertas je . So masa exam nanti susah" | | |



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| Question | Students | Responses | Challenges in Computer Science | Main Theme |
|---|---|---|---|---|
| What are the challenges you are encountering when studying computer science?<br><br>Do you have any difficulties in learning programming? | Student 1 | "I also often face challenges in finding **accessible resources** such as textbooks, **interactive tools**, and online exercises because mostly all in text makes me sleep" | 2. Difficulty Understanding Concepts | Barriers to Effective Programming Learning |
| | Student 2 | "The programming concept is hard for me understand, the learning and syntax is new" | | |
| | Student 3 | "Seperti memahami konsep menganalisis masalah dan struktur kawalan, kadang-kadang saya tidak tahu di mana saya perlu menggunakannya." | | |
| | Student 2 | "To code effectively, I need to understand and remember foundational concepts like using the correct variables, which can be challenging." | Demands robust memorization skills | |
| | Student 3 | "Sains komputer ini **amatla sukar kerana tidak pernah belajar tentang ASK**, jadi **banyak cabaran** yang saya hadapi semasa mempelajari sains komputer untuk faham subtopik – subtopik." | Limited foundational knowledge | |
| | Student 5 | "Waktu di **tingkatan 3 saya belajar menggunakan python tetapi di tingkatan 4 belajar menggunakan online java**. Ini membuatkan saya perlu belajar semula coding language yg baharu." | Transition to different programming languages complicates learning | |



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This study found that insufficient learning resources remain the most significant barrier to learning computer science for all students. Further, all students consented that this barrier was the foremost challenge they faced. In addition, Students 2, 3, and 4 pointed out the relative lack of understanding of fundamental concepts as another major hurdle. This lack of understanding stems from the curriculum lecture notes not being accompanied by sufficient multimedia. Because of lacking foundational knowledge, students find basic exercises increasingly difficult, which in turn makes programming tasks even more difficult. Students 3 and 4 also commented that lacking basic programming skills greatly hinders their ability to learn, resulting in frustration and disinterest in the subject. Apart from these challenges, students highlighted the demand for robust memorization skills, particularly with complex topics such as data normalization. Furthermore, transitioning between different programming languages presents additional difficulties. For example, Student 5 mentioned that while they had learned Python until Form 3, the sudden shift to Java posed a significant challenge to their learning process.

Thus, these issues are consolidated as "Barriers to Effective Programming Learning," theme by describing the lack of relevant content and practical exercises within the learning materials. In order to increase learners' interest in the subject and adequately grasp programming basics, appropriate and helpful materials should be developed. Employing this approach will assist learners in understanding the foundational concepts of programming while also helping them assimilate computational thinking on a deeper and more personal level.

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### 5.3.2 Challenging Topic in learning programming (Students' Perspective)

The second section of the interview investigated the challenging topics among five students face in learning programming to answer research question one. The findings indicate that problem-solving procedures and data structures are perceived as the most challenging topics from the students' perspective, as shown in Table 5.8.

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**Table 5.8**

*Research Findings for Needs Analysis SmartAR (Students: Challenging Topic in Learning Programming)*

| Question | Students | Responses | Challenging Topic in Programming | Main Theme |
|---|---|---|---|---|
| Which subtopic is challenging in learning programming?<br><br>Can you explain in detail please? | Student 1 | "In learning programming, the challenges subtopic for me is **data structure** because **have too many terms and I always confuse when and where to use."** | Data Structure | Challenging Topic |
| | Student 2 | "In my opinion, the most challenging subtopic is **data structure** because I always forget the syntax. As every type has own formula and places to use. "<br>"I often forget the correct place to use and how to write correct code." | | |
| | Student 3 | *"Subtopik yang mencabar dalam pembelajaran pengaturcaraan ialah (5)* ***struktur data dan proses penyelesaian masalah*** *kerana subtopik ini sedikit susah dan kurang faham struktur tatasusanan , aturcara menggunakan tatasusunan , pengumpukan tatasusunan"* | | |
| | Student 4 | "*Pelajaran yang mencabai ialah* ***struktur skawalan dan proses penyelesaian masalah ."*** | | |
| | Student 5 | ***"Struktur data*** *kerana belajar tentang penormalan data. Pada fasa 1nf dan 2nf masih lagi ditahap yang senang untuk difahami . Masalahnya pada 3nf kerana cara menukarkan 2nf ke 3nf agak susah untuk difahami tentang aliran untuk menukarkannya ."* | | |



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| Question | Students | Responses | Challenging Topic in Programming | Main Theme |
|---|---|---|---|---|
| Which subtopic is challenging in learning programming? | Student 3 | *"Subtopik yang mencabar dalam pembelajaran pengaturcaraan ialah (5)* ***struktur data dan proses penyelesaian masalah*** *kerana subtopik ini sedikit susah dan kurang faham struktur tatasusanan , aturcara menggunakan tatasusunan , pengumpukan tatasusunan"* | *Proses Penyelesaian Masalah* | Challenging Topic |
| Can you explain in detail please? | Student 4 | *"Pelajaran yang mencabai ialah* ***stuktur kawalan dan proses penyelesaian masalah ."*** ***Saya rasa amat penting memahai proses penyelesaian masalah to menyelesai masalah strategically . Tetapi saya selalu confuse dengan proses urutan dan tidak dapat jawab soalan dengan betul.*** | | |



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This study found that data structures are the most difficult subtopic within Form 4 Chapter 1 of the programming curriculum, as agreed upon by all students. Student 5 emphasized that data structures are challenging due to the complexity of grasping the structure of arrays, utilizing arrays in programs, and the normalization process in databases, particularly the transition from Second Normal Form (2NF) to Third Normal Form (3NF). Additionally, Students 3 and 4 identified the problem-solving process as a challenging topic, highlighting difficulties in understanding problem-solving methodologies and control structures within programming. These findings underscore the need for targeted instructional support in these areas to enhance programming comprehension.

### 5.3.3 Needs analysis of SmartAR Module (Students' Perspective)

The third section of the interview investigated the needs analysis of the SmartAR Module in learning programming among five students in answer research question one. The findings indicate that the main reason students require the SmartAR Module is that it serves as an educational learning material that can help them engage with learning, making it feel connected and interesting, as explicitly illustrated in Table 5.9.

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**Table 5.9**

*Research Findings for Needs Analysis SmartAR (Students: Needs of SmartAR Module)*

| Question | Students | Responses | Need Of Smart AR Module / Existing Module Problem | Main Theme |
|---|---|---|---|---|
| Do you require any additional modernized learning modules to help you improve your programming skillset? | Student 1 | "Yes, I do. With extra modules, **I can focus on each sample question and review the detailed explanations.** Right now, I find the exercises in my modules pretty hard." | Existing modules are difficult to comprehend | Enhancing Programming Education through Improved Resources and Instruction |
| | Student 2 | "The existing module are boring mostly consist of text and diagrams only. I don't to write code only , I want something interesting ." | | |
| | Student 3 | **"*Ya, sebab nota sekarang tak de hands-on practice. Contoh saya kena tulis kod dalam kertas .*"**<br>**"Digital notes would be more interesting and help me boost my knowledge in learning."** | | |
| | Student 1 | "Modern learning materials **would let me practice hands-on and not just depend on classroom lessons,** helping me understand programming better." | Independent learning | |
| | Student 2 | "Yes I **need additional modernized learning modules to improve my programming skills**. Especially for practicing my programming logic like some real life example that can makes me interested in learning." | Enhance programming skills | |
| | Student 4 | ***"Ya** . Saya memerlukan sebarang modul untuk saya memahami setiap bab yang ada serta **membuat pelbagai latihan untuk memantapkan lagi ingatan saya .**"* | For better understanding | |
| | Student 5 | *"Sejujurnya **saya tidak memerlukan sebarang modul** tambahan pada masa kini. Saya hanya **memerlukan penerangan dari guru dengan jelas dan guru mensertakan lebih banyak contoh programming agar lebih mudah** untuk memahami programing."* | Require clear explanations from the teacher | |



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This study found that students need the SmartAR Module to enhance their interest in learning programming by connecting it to real-life scenarios. As shown in Table 5.5, Student 1 highlighted the need for an additional modernized module because the existing one contains difficult examples and lacks interactive hands-on practices. Other students also agreed and shared similar thoughts. However, Student 5 emphasized that he does not require an additional learning module but needs more examples from teachers to facilitate better understanding. These insights underscore the necessity of enhancing programming education through improved resources and instruction. Therefore, implementing the SmartAR learning module and providing more real-life examples from teachers could significantly improve students' engagement and comprehension in programming.

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### 5.3.4 Needs Analysis of Multimedia Types in the SmartAR Module (Students' Perspective)

The final section of the interview determined the types of multimedia required in the SmartAR Module requires by five students in learning programming to answer the first research question. The findings indicate that students require engaging learning aids, learning aids with clear guidelines, exercises of varying difficulty levels, problem-solving strategies, captivating multimedia aids, and practical exercises. These requirements are illustrated in Table 5.10 .

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**Table 5.10**

*Research Findings for Needs Analysis of Type of Multimedia for SmartAR Module*

| Question | Students | Responses | Multimedia Expectation | Main Theme |
|---|---|---|---|---|
| What types of learning modules are required for programming subjects? Can you go into further details? | Student 1 | **"Easy to understand, simple and focused on answers**.<br>*Maybe kalau* ***nota yang a bit coloring*** *mungkin bole tarik minat pelajar ."*<br>"I want more of animated or informative videos so whenever I am stuck I can see them learn by myself" | Engaging learning aids | Enhancing Learning Experience Through Varied and Engaging Instructional Resources |
| | Student 2 | "The module should have some **note and instruction how to do programming** so it will really help me and other student for understanding in programming. Some character **movement for every activities would be fun . Like walking based on logic ."** | | |
| | Student 2 | "I think the modules question should start from easier to hard exercise so we know how to answer correctly and have problem solving strategy-based learning also coloring notes" | Exercises of varying difficulty levels<br>Problem solving strategy | |
| | Student 3 | "Multimedia such as more interactive daily life learning . real life 3-dimensional maybe ." | Captivating multimedia aids | |
| | Student 4 | *"Dalam bentuk video pon berkesan untuk saya , saya nak something interesting dan mudah difahami."* | | |
| | Student 5 | *"Saya lebih mencadangkan memberikan lebih banyak Latihan practical dan video animasi untuk menjelaskan terminology tersebut."* | Practical exercises | |



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This study found the students expressed a need for multimedia features that enhance learning effectiveness and make programming more interesting. Students proposed that adding colorful captions, teaching through animated or informative videos, and employing interactive materials would assist in explaining difficult subjects. Moreover, students recommended that module questions be structured from simple to more difficult levels and that practical problems to be solved be provided alongside comprehensive instructional guides. Also, students noted the need to develop multimedia resources which relate programming concepts and real world applications to provide learners the freedom to direct their own study. This demonstrates that there is an advanced need for appealing programming education resources and effective marketing strategies focused on multimedia designing to improve programming education for learners.

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Based on the comprehensive analysis of challenges in computer science learning, this study designed and developed an intervention called the SmartAR Module integrated with a problem-solving learning strategy targeting the complex barriers to effective programming education. The SmartAR Module was a multi-dimensional approach focused on interactive learning, multimedia-rich learning resources, creating structured programming language transition modules, and designing diagnostic tools to assess foundational knowledge gaps. By integrating innovative multimedia technologies, supportive learning environments, and adaptive assessment strategies, the study aimed to examine the effect of the SmartAR Module on students' achievement. Additionally, the SmartAR Module was designed and developed by incorporating real-

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life examples to significantly improve students' engagement and comprehension in programming.

### 5.3.5 Challenges in Teaching Computer Science Subject (Teachers' Perspective)

The first section of the interview found the challenges faced by two teachers in teaching computer science, specifically programming to answer research question one. Additionally, this found the difficult topics in teaching programming. The findings show that a lack of fundamental knowledge among students is one of the main challenges for teachers. The study also found that limited learning aids and unattractive lessons tend to make students bored, making it quite challenging for teachers to keep students engaged. According to teachers, the most challenging topic to teach is Data Structures, as shown in Table 5.11 .

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**Table 5.11**

*Research Findings for Challenges in Teaching Computer Science Subject (Teachers' Perspective)*

| Teacher | Question | Responses | Challenges in Teaching Computer Science | Main Theme |
|---|---|---|---|---|
| Teacher 1 | What are the challenges you are overcoming in teaching computer science subjects for Form 4 students? Can the teacher explain in detail? | *"Murid sering* ***tidak menguasai topik asas pengaturcaraan, seperti istilah-istilah coding.*** *Bagi mereka, ini adalah sesuatu yang susah. Selain itu, mereka juga tidak dapat memahami fakta-fakta dalam topik-topik yang terdapat dalam silibus."*<br><br>*"Biasanya,* ***pelajar kurang pengalaman asas****, contohnya* ***tidak pernah membuat coding sebelum ini****, dan* ***pemikiran logic*** *untuk mereka, memahami programming agak susah."* | Student with lack of programming fundamental | Barriers to Effective Programming Education |
| Teacher 2 | | *"Biasanya ,* ***bahan untuk ajar student*** *. Selalu nota semua dalam teks dan gambar . so ia susah untuk saya ajar student dan mereka selalu* ***struggle dengan memahami konsep dan rasa boring."***<br><br>***"Kadang kadang nota itu menyebabkan murid boring , then dia orang hilang fokus dalam kelas."*** | • Limited and unattractive learning aids<br>• Difficulties in understanding | |



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| Teacher | Question | Responses | Challenges in Teaching Computer Science | Main Theme |
|---|---|---|---|---|
| Teacher 1 | Do you have any difficulties in learning programming? | *"ye ..**sbb bg guru untuk menguasainya pun agak sukar apalagi murid**. kita bh menggunakan modul yg mudah serta mengajar yg berkaitan dengan soalan exam.untuk f4 soalan programming bukanlah programming sepenuhnya ".* | Difficulty in understanding programming | Barriers to Effective Programming Education |
| Teacher 2 | | *"i takde masalah , **cubanya kadang kadang murid yang takde basic of programming syntax dan logic mencabar.** To teach them effectively by engaging with real world scenarios without getting bored and easily understanding is a big task ."*<br>***"I always give practical example but not all students have the strong imagination to understand the scope "*** | Student with lack of programming fundamental<br>Logic comprehension<br>Effective teaching tools<br>Limited imagination skills | |



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| Teacher | Question | Responses | Challenges in Teaching Computer Science | Main Theme |
|---|---|---|---|---|
| Teacher 1 | Is that understanding (1) problem solving approach, (2) algorithm, (3) constant variable, manipulated variable, and datatype, (4) structure control, and (5) data structure. Can you explain in detail please? | *"coding , mereka belajar part of coding mcm* ***struktur kwln****, jenis data dall"*<br><br>*"Setakat I tahu ,* ***murid selalu confuse dekat mane kena guna if else , do while , switch case .***" | Data Structure | Challenging Subtopics |
| Teacher 2 | | *"selalunya pelajar akan struggle dua topic sprt problem solving approach, dan structure control. Sebab logic itu agak susah untuk memahami"*<br><br>***"Students often forget the problem-solving process, which basically has eight steps.*** *So, when they tend to forget these steps, the output is also not accurate."* | • Problem Solving Strategy<br>• Data Structure | |



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This study found that the primary challenge faced by teachers in teaching programming in computer science is the students' lack of fundamental knowledge in programming. As students have a very poor understanding of basic programming and logic, it is very challenging, said Teacher 1. This statement was also agreed upon and mentioned by Teacher 2, who added that making students understand the basic concepts is difficult and challenging when they don't have prior knowledge. Additionally, the second challenge for teachers in teaching programming is the lack of attractive learning materials to keep students engaged during lessons, as mentioned by both teachers. Teacher 2 clearly emphasized that, during the lesson, the teacher provides practical examples to help students imagine and understand the concepts. However, since not all students have good imagination skills, some tend to struggle with understanding the concepts clearly.

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Apart from this, other factors that make teaching programming difficult for teachers include the teachers' proficiency in adopting new programming languages and conveying them to students in an effective manner, as well as students' comprehension of programming logic. To overcome these teaching challenges, a SmartAR Module with engaging content is essential for assisting teachers. Moreover, animation videos for basic syntax could support students in understanding and applying programming concepts effectively.

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### 5.3.6 Need analysis of SmartAR Module in Teaching Programming (Teachers' Perspective)

The second section of the interview among two teachers identified the need for a new learning module for teaching computer science, specifically programming in answer research question one. The study found that the current learning approach often leads to student boredom and lack of motivation, as shown in Table 5.12. A new, engaging learning module like the SmartAR Module is needed to make lessons more interesting and to better motivate students.

**Table 5.12**

*Research Findings for Need Analysis for SmartAR Module (Teachers)*

| Teacher | Responses | Need Analysis | Main Theme |
|---|---|---|---|
| T1 | *"**KPM modules and textbooks are what teachers mainly use**, but they can get **a bit dry and don't always grab students' attention."***<br><br>*"I need a new modern module so I can make my learning more engaging with cool AR features and interactive content that would help students understand programming better and keep them interested."* | Necessities of Module | Learning Curve |
| T2 | "*ya , **KPM modules are helpful, but students often find them boring and lose motivation. "*** | | |
| T1 | *"pendapat sy untuk tingkatan 4 modul yg sedia ada dah ok maybe blh dicadangkan"* | Elements of Learning Module | |
| T2 | *"ya mesti kena ada supaya pelajar selalu rasa boring dan kurang motivasi guna Teknik conventional"* | | |

The study determined that KPM modules and textbooks are accessible to teachers; however, most of them struggle to capture student interest and engagement.

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Based on the instructors' insights, most of the available materials are indeed traditional and, therefore, less appealing, which may lead to some students becoming passive or less motivated. To illustrate, one teacher noted that the current Form 4 modules are good but require some changes, while others emphasized the necessity of novel techniques to stop students from becoming unmotivated due to traditional uninspiring methods In response to these problems, the research suggests development of a new augmented reality and interactivity-based module. Such a SmartAR Module could transform the teaching of programming into exciting experiences which could help motivate learners through the journey of their understanding

## 5.4 Data Findings Expert Validation of SmartAR Module

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Following the development of the SmartAR application, a panel of seven experts was formed. This panel consisted of three secondary school computer science teachers as content experts and four augmented reality experts serving as technological experts. This panel was intended to validate the selected elements and learning materials for the SmartAR programming module to address research question two. Firstly, the technological experts were chosen based on four criteria: (1) a minimum of 3 years' experience in designing and developing augmented reality applications, (2) knowledge of the marker-based Vuforia database engine, (3) intermediate knowledge of academic augmented reality game-based mobile applications, and (4) basic knowledge of programming. The consent form provided to technological experts is attached in Appendix B.

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Next, the content experts were chosen based five criteria such as (1) at least five years of teaching experience, (2) a good understanding of logic and algorithms, (3) intermediate experience using educational mobile applications, (4) a basic understanding of Augmented Reality, and (5) self-sufficiency as a fast learner with minimal support. The consent form provided to content experts is attached in Appendix C. The results of the validity test for SmartAR Module content from the experts' perspective (school computer science teachers) are shown in Table 5.13 . Several criteria were evaluated by three experts. All the experts evaluated the content of SmartAR as well-aligned with the existing school curriculum as excellent. Additionally, all experts rated the content of SmartAR Module as well-organized and easy to understand as excellent. Next, all the experts evaluated the content of SmartAR as practical and relevant to students' learning experience as excellent. Two experts evaluated the content in SmartAR as excellent in effectively providing logical skills to enhance students' technical abilities, while one expert assessed it as good. Lastly, two experts evaluated SmartAR Module content as engaging and connected to real-world experience, while one expert assessed it as good.

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**Table 5.13**

*Content Validation by School Teacher Perspective*

| Content | Experts | Marks | | | | | Score /10 | Percentage % |
|---|---|---|---|---|---|---|---|---|
| | | 1-2 Need Improvement | 3-4 Average | 5-6 Fairly Good | 7-8 Good | 9-10 Excellent | | |
| The content in SmartAR is well-aligned with the existing school curriculum. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| The content of SmartAR is well-organized and easy to understand. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| The content in SmartAR is practical and relevant to students' everyday learning experiences. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| The content in SmartAR effectively provides logical skills that enhance students' technical abilities. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | / | | 8 | 97.78 |
| | 3 | | | | | / | 10 | 100 |
| The content in SmartAR engages students and connects well to real-world applications. | 1 | | | | / | | 8 | 93.33 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| The content in SmartAR Module is relative to DKSP Malaysia Form 4 curriculum. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| | | | | | Overall Percentage | | | 99.2 |



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Overall, the SmartAR Module received 99.26% in terms of content validity from the perspective of school computer science teachers. These indicate the module is relevant, effective, and well-structured for the intended educational purpose. Next, the results of the validity test for SmartAR Module from technological experts' perspective' (lecturers) are shown in Table 5.14. Following the results from the validation test on the SmartAR Module from the viewpoint of technology experts (lecturers), it is clear that the module's technological functionality and integration has been validated with overwhelming success. All four experts rated the SmartAR's multi-device and OS functionality as outstanding, verifying accessibility across platforms. Moreover, all experts perceived the design of SmartAR's interface as highly navigable, which indicates that the design greatly improves usability and enhances the user experience.

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**Table 5.14**

*Technological Validation by Lecturer Perspective*

| Content | Experts | Marks | | | | | Score /10 | Percentage % |
|---|---|---|---|---|---|---|---|---|
| | | 1-2 Need Improvement | 3-4 Average | 5-6 Fairly Good | 7-8 Good | 9-10 Excellent | | |
| The SmartAR application is compatible with various devices and operating systems. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| | 4 | | | | | / | 10 | 100 |
| The user interface design of SmartAR is intuitive and easy to navigate. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| | 4 | | | | | / | 10 | 100 |
| The SmartAR application performs reliably without crashes or significant bugs. | 1 | | | | | / | 10 | 100 |
| | 2 | | | | | / | 10 | 100 |
| | 3 | | | | | / | 10 | 100 |
| | 4 | | | | | / | 10 | 100 |

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| | | | | | |
|---|---|---|---|---|---|
| The SmartAR application integrates well with Vuforia marker and easily scan and viewable | 1 | | / | 10 | 100 |
| | 2 | | / | 10 | 100 |
| | 3 | | / | 10 | 100 |
| | 4 | | / | 10 | 100 |
| The responsiveness of the SmartAR application is satisfactory, with minimal lag or delay during use. | 1 | / | | 8 | 97.78 |
| | 2 | | / | 10 | 100 |
| | 3 | | / | 10 | 100 |
| | 4 | | / | 10 | 100 |
| The resolution and graphical quality of the animation videos meet high standards for educational content. | 1 | | / | 10 | 100 |
| | 2 | | / | 10 | 100 |
| | 3 | | / | 10 | 100 |
| | 4 | | / | 10 | 100 |
| The 3D models in SmartAR utilize advanced design techniques for accurate and detailed representations. | 1 | | / | 10 | 100 |
| | 2 | | / | 10 | 100 |
| | 3 | / | | 8 | 97.78 |
| | 4 | | / | 10 | 100 |
| The animation sequences in SmartAR are optimized for smooth playback and visual clarity. | 1 | | / | 10 | 100 |
| | 2 | | / | 10 | 100 |
| | 3 | | / | 10 | 100 |
| | 4 | | / | 10 | 100 |
| | | | Overall Percentage | | 99.45% |

Every expert evaluated the reliability of the SmartAR application, noting that it operates without crashing or major bugs, which is important for providing a seamless learning experience. Additionally, all experts commended the application's interfacing with Vuforia markers and its capability to scan and view content as good, which signifies the system’s reliable technologies. In responsiveness, three experts assessed it as satisfactory, reporting almost no lag while using the system, while one expert rated it as good, which brought the overall figure for this criterion to 97.78%. Similar to other experts, all of them assessed the resolution and graphical quality of the animation videos to be of uttermost excellence, suggesting that the application’s visuals are up to its educational value. In relation to the 3D models within SmartAR, three experts out

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of four considered the models as ‘excellent’ with one considering them as ‘good’, which leads to a weighted average of 97.78%. All experts’ affirmation towards the technical quality of the module was evident as they rated the optimization of animation sequences for smooth playback and visual clarity as excellent. From the validation carried out, it is noted that smartAR module has a 99.45% expert percentage agreement which indicates that from a technological perspective, the module is fully functional, highly sophisticated, and meets the expectations set for a technologically advanced, intuitive educational application. Hence, the assessment conducted validates the claims that SmartAR Module is a mobile application that aids in teaching Form 4 Computer Science content effectively from both content and technological expert perspectives. The complete learning material is attached in Appendix VS.

## 5.5 Data Findings Usability of SmartAR Module

In this study, the usability of the SmartAR Module was investigated among 30 students to answer research question three, using Tuli and Mantra's (2020) four dimensions: cognition, orientation, design, and support.

### i. Cognition of SmartAR

This study conducted a cognitive usability test on the SmartAR application, as indicated in Figure 5.1.

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**Figure 5.1**

*Result of usability questionnaire for Cognition of SmartAR Module*

| Cognition | | | | | |
|---|---|---|---|---|---|
| | The design of the SmartAR module effectively supports the achievement of the learning objectives | The content in the SmartAR module is accurate and aligns well with textbook materials. | I can complete tasks in the SmartAR module efficiently, without unnecessary delays or obstacles. | The SmartAR module is easy to use and intuitive, requiring minimal guidance or training | The SmartAR module helps me recognize answers quickly, promoting effective problem-solving strategies. |
| N Valid | 30 | 30 | 30 | 30 | 30 |
| Mean | 4.97 | 4.93 | 4.93 | 4.97 | 4.83 |
| Std. Error of Mean | .033 | .046 | .067 | .033 | .069 |
| Std. Deviation | .183 | .254 | .365 | .183 | .379 |

The design's support for learning objectives achieved a score of (M = 4.97, SD = .18) indicating strong and consistent user agreement regarding the module's effectiveness in meeting educational goals. Next, content accuracy and alignment with textbook materials scored similarly high with a mean of (M = 4.93, SD = .25) demonstrating strong content validity with relatively low variation in responses. Task completion efficiency also received positive evaluations with a result of (M = 4.93, SD = .36), though showing slightly more variation in user experiences. The module's ease of use and intuitiveness matched the highest ratings with a result of (M = 4.97, SD = .18) suggesting a highly user-friendly interface with very consistent user feedback. The answer recognition and problem-solving support dimension received the comparatively lowest, though still exceptionally high, result of (M = 4.83 SD = .37), showing the highest variation among all dimensions but maintaining an overall strong performance.

Overall, all dimensions fall into the "High" range (3.51 – 4.00) as per Riduwan (2012) mean score and interpretation, indicating excellent performance across all cognitive usability metrics. The standard deviations vary, with some dimensions

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showing consistent responses (small SD) and others showing more variability in user experiences (large SD). These results collectively indicate that the SmartAR Module excels in all cognitive usability aspects, with particularly strong performance in design support and ease of use, while maintaining slightly more diverse user experiences in problem-solving support.

### ii. Orientation of SmartAR

The second usability element evaluate in this study is orientation of SmartAR application, as indicated in Figure 5.2 .

**Figure 5.2**

*Result of usability questionnaire for Orientation of SmartAR Module*

**Orientation**

| | | SmartAR-Module is well designed according to my abilities and preferences in learning programming. | The SmartAR-Module design is clear and easy to understand interface. | The programming learning through My-Smart is more interesting and helpful is solving problems. | SmartAR module effectively establish a connection between virtual content and real-world objects, making it easier for me to relate to real-life programming scenarios | SmartAR module offer different modes and challenges for me to engage with topic. |
|---|---|---|---|---|---|---|
| N | Valid | 30 | 30 | 30 | 30 | 30 |
| Mean | | 4.97 | 4.60 | 4.70 | 4.93 | 4.83 |
| Std. Deviation | | .183 | .498 | .466 | .365 | .379 |

The orientation study of the SmartAR Module was conducted with 30 valid participant responses. The analysis of the module's design alignment with students' abilities and learning preferences showed very high ratings (M = 4.97, SD = .183). Students' evaluation of the interface clarity and understandability received positive

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feedback (M = 4.60, SD = .498). When assessing the interest and helpfulness of programming learning through SmartAR, participants provided favourable responses (M = 4.70, SD = .466). While these areas were positively rated, the larger standard deviations indicate some variability in participants' experiences.

The module's effectiveness in establishing connections between virtual content and real-world programming scenarios was rated highly by students (M = 4.93, SD = .365). The availability of different modes and challenges for topic engagement also received strong ratings from participants (M = 4.83, SD = .379). In summary, the orientation aspects of the SmartAR Module received mean scores ranging from 4.60 to 4.97, with standard deviations between .183 and .498. Overall, all dimensions of the orientation study fall into the "High" range (3.51 – 4.00) as per Riduwan (2012) mean score and interpretation, indicating excellent performance across all orientation metrics. The standard deviations vary, with certain dimensions, such as design alignment with students' abilities and the connection between virtual content and real-world scenarios, showing highly consistent responses (small SD). Meanwhile, dimensions like interface clarity and programming learning interest exhibit slightly more variability (larger SD). These findings collectively suggest that the SmartAR Module is highly effective in engaging students and supporting their orientation to the learning material, with minor opportunities for enhancement in specific areas

**iii. Design of SmartAR**

The third usability element evaluate in this study is design of SmartAR application, as indicated in Figure 5.3.

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**Figure 5.3**

*Result of usability questionnaire for Design of SmartAR Module*

**Design**

| | | SmartAR modules follow a structured flow of programming from basic to problem solving effectively to make me aware of the consequences and solutions. | The marker in SmartAR-Module is well designed and easily downloadable | SmartAR module provide real-life or practical examples to enhance your learning experience | The 3-Dimensional object in My-Smart AR is well designed and attractive while learning | SmartAR Module is less complex and easy to understand |
|---|---|---|---|---|---|---|
| N | Valid | 30 | 30 | 30 | 30 | 30 |
| Mean | | 4.93 | 4.80 | 4.97 | 4.87 | 5.00 |
| Std. Deviation | | .254 | .551 | .183 | .346 | .000 |

The design evaluation of the SmartAR Module included responses from 30 valid participants. The assessment of structured programming flow from basics to problem-solving received strong ratings from students (M = 4.93, SD = .254). The marker design and downloadability of the SmartAR Module was positively evaluated by participants (M = 4.80, SD = .551). Students rated the provision of real-life and practical examples very highly (M = 4.97, SD = .183). The 3-Dimensional object design and its attractiveness during learning received favorable feedback from participants (M = 4.87, SD = .346). Notably, all students unanimously rated the module's complexity level and ease of understanding with the highest possible score (M = 5.00, SD = .000).

Overall, all dimensions of the design evaluation fall within the "High" range (3.51 – 4.00) as per Riduwan (2012) mean score and interpretation, reflecting exceptional performance across all design metrics. The standard deviations indicate a mix of highly consistent responses, such as the module's complexity level and ease of understanding (SD = .000), and some variability, as seen in the marker design and downloadability

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(SD = .551). These results underscore the SmartAR Module's effectiveness in providing a well-structured, visually engaging, and user-friendly learning experience, with outstanding recognition for its seamless complexity level and practical real-life applications.

### iv. Support of SmartAR

The fourth usability element evaluate in this study is support of SmartAR application, as indicated in Figure 5.4.

**Figure 5.4**

*Result of usability questionnaire for Support of SmartAR Module*

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**Support**

| | | Throughout my learning using SmartAR programming Module, I didn't find any errors or glitches | SmartAR module provide hints throughout the programming learning to guide me with the next steps | The help button and robot in SmartAR is helpful for me to complete my assessment and learning programming | The learning materials in SmartAR-Module and AR scanner are support all mobile devices and easily download. | SmartAR requires less physical effort in learning programming. |
|---|---|---|---|---|---|---|
| N | Valid | 30 | 30 | 30 | 30 | 30 |
| Mean | | 4.87 | 4.87 | 4.87 | 4.90 | 5.00 |
| Std. Deviation | | .346 | .346 | .346 | .305 | .000 |

The support evaluation of the SmartAR Module was conducted with 30 valid participants. Students' assessment of the module's error-free and glitch-free operation showed strong positive ratings (M = 4.87, SD = .346). The provision of hints throughout the programming learning process received identical positive feedback from participants (M = 4.87, SD = .346). Similarly, students rated the helpfulness of the help button and robot features in completing assessments and learning programming with

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the same high scores (M = 4.87, SD = .346). The compatibility of learning materials and AR scanner with mobile devices along with download accessibility received very high ratings (M = 4.90, SD = .305). Notably, all participants unanimously gave the highest possible rating regarding the physical effort required in learning programming (M = 5.00, SD = .000).

To summarize, the SmartAR Module support features mean scores between 4.87 and 5.00 with a standard deviation ranging between .000 and .346. According to Riduwan's mean score and interpretation, the support evaluation results tend to fall in the "High" range (3.51 – 4.00) which, in this case, indicates excellent performance on all support metrics. The standard deviations reflect highly consistent feedback, particularly regarding the physical effort required (SD = .000), and minimal variability in other areas (SD = .305–.346). The findings highlights the SmartAR Module's accurateness, availability, user-specific assistance attributes, and order of operations, which facilitate a problem-free learning process. The unanimous high rating for minimal expendable movement shows the SmartAR Module easy to use and well designed.

### 5.5.1 Summary for SmartAR Module Usability Findings

Based on the usability evaluation of the four components of cognition, orientation, design, and support, the SmartAR Module scored excellently overall mean of 4.89 with a standard deviation of 0.3. Riduwan (2012) suggests that the mean scores that fall in the range of 3.51-4.00 are considered "High," which is also notable. The mean scores

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from 4.60 to 5.00 indicates that there was profound agreement concerning the definite effectiveness of the module. While all standard deviations differ, some dimensions seem to present perfect agreement (e.g., SD = .000 for ease of understanding requiring minimal physical effort) and others seem to show more variability (e.g., SD = .551 for marker design and downloadability). These results affirm the SmartAR Module's exceptional usability in supporting cognitive, orientation, design, and support dimensions, ensuring a reliable, accessible, and user-friendly experience for students.

### 5.6 Data Findings of Students Achievement in SmartAR Module

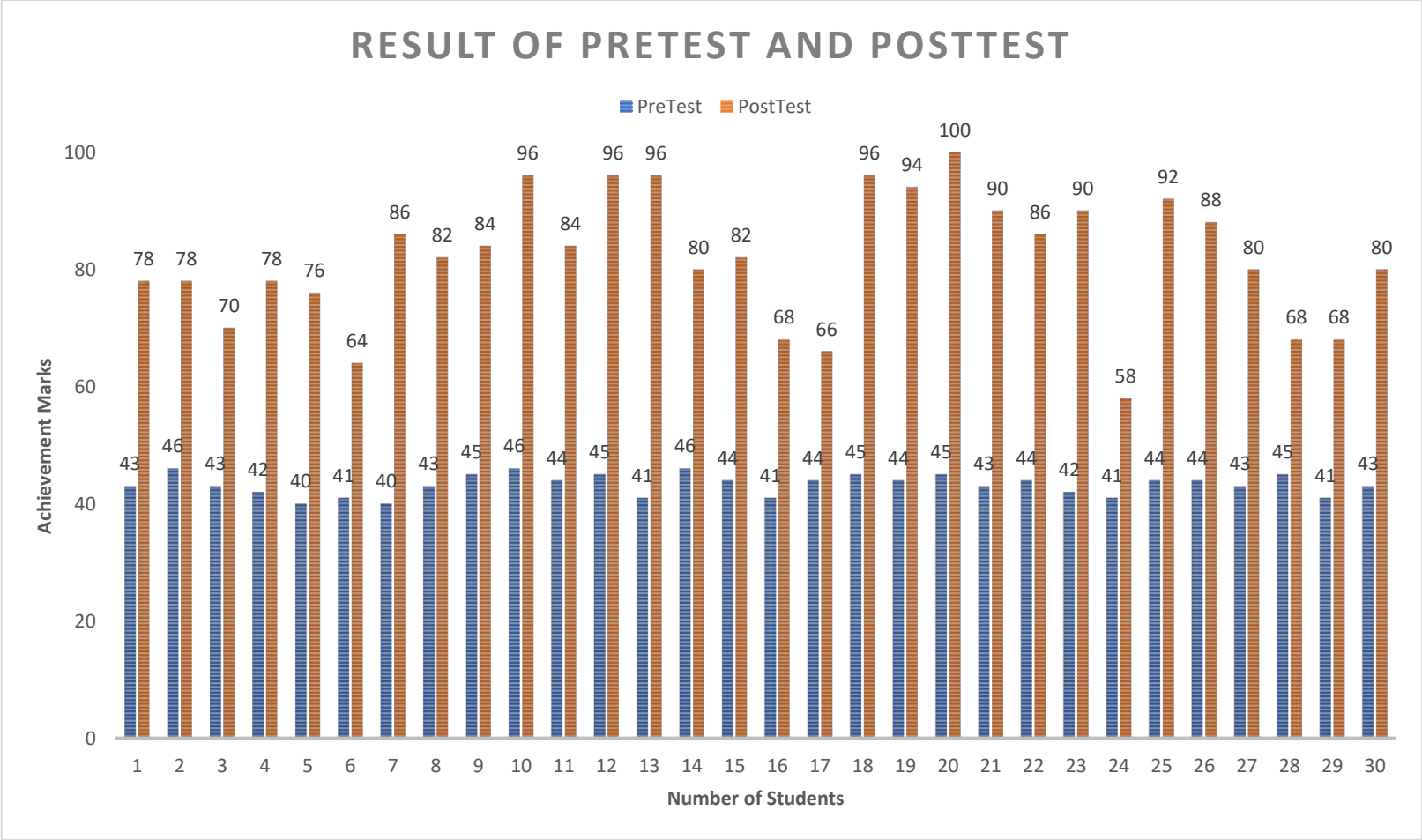
In this study, the evaluation of students' achievement was evaluated using pre-test and post-test achievement tests and the gathered grades were grouped by KSSM curriculum grade to answer research question four. Based on the comparison of pre-test and post-test scores, students' achievement using the SmartAR Module improved on average by 37.7 points, as shown in Figure 5.5. This significant increase suggests that the SmartAR Module effectively enhances students' learning outcomes. To discuss the results statistically, this study calculated descriptive statistics and performed a paired t-test analysis. Before proceeding with the paired t-test, the study conducted normality tests using the Kolmogorov-Smirnov and Shapiro-Wilk tests to ensure that the pre-test and post-test data were normally distributed.

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**Figure 5.5**

*Result of achievement score of Pretest and Post-test*






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Table 5.15 provides a detailed comparison of the pretest and posttest achievement scores and respective grades, highlighting the differences between them.

**Table 5.15**

*Comparison Table of Pretest and Post-test Marks of SmartAR Module*

| Number of Students | Pre-Test Marks | Pre-Test Grade | Post-Test Marks | Post Test Grade | Difference Pre - Post-test |
|---|---|---|---|---|---|
| 1 | 43 | E | 78 | A- | 35 |
| 2 | 46 | D | 78 | A- | 32 |
| 3 | 43 | E | 70 | A- | 27 |
| 4 | 42 | E | 78 | A- | 36 |
| 5 | 40 | E | 76 | A- | 36 |
| 6 | 41 | E | 64 | B+ | 23 |
| 7 | 40 | E | 86 | A | 46 |
| 8 | 43 | E | 82 | A | 39 |
| 9 | 45 | D | 84 | A | 39 |
| 10 | 46 | D | 96 | A+ | 50 |
| 11 | 44 | E | 84 | A | 40 |
| 12 | 45 | D | 96 | A+ | 51 |
| 13 | 41 | E | 96 | A+ | 55 |
| 14 | 46 | D | 80 | A | 34 |
| 15 | 44 | E | 82 | A | 38 |
| 16 | 41 | E | 68 | B+ | 27 |
| 17 | 44 | E | 66 | B+ | 22 |
| 18 | 45 | D | 96 | A+ | 51 |
| 19 | 44 | E | 94 | A+ | 50 |
| 20 | 45 | D | 100 | A+ | 55 |
| 21 | 43 | E | 90 | A+ | 47 |
| 22 | 44 | E | 86 | A | 42 |
| 23 | 42 | E | 90 | A+ | 48 |
| 24 | 41 | E | 58 | C+ | 17 |
| 25 | 44 | E | 92 | A+ | 48 |
| 26 | 44 | E | 88 | A | 44 |
| 27 | 43 | E | 80 | A | 37 |
| 28 | 45 | D | 68 | B+ | 23 |
| 29 | 41 | E | 68 | B+ | 27 |
| 30 | 43 | E | 80 | A | 37 |

In the post-test results, the distribution of grades showed that nine students (30% of the total) achieved an A+ grade, indicating the highest level of excellence. Additionally, ten students (33% of the total) earned an A grade, reflecting a strong

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understanding and performance in the subject matter. Furthermore, five students (20% of the total) received a B+ grade, demonstrating good performance but with some room for improvement. Lastly, one student (3% of the total) attained a C+ grade, indicating a satisfactory but lesser grasp of the material compared to their peers. According to the KSSM grading schema, students achieved 9 A+ (Highest Excellence), 10 A (Excellent High), 5 A- (Excellent), 5 B+ (Highest Good), and 1 C+ (Top Honors). This distribution highlights the overall effectiveness of the SmartAR Module in enhancing students' programming skills, with the majority attaining high grades. The SmartAR Module demonstrated significant educational impact, with 80% of students achieving excellent grades (A+, A, A-) and 96.7% scoring above B+ in their programming assessments, indicating its effectiveness as a learning material for programming education.

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### 5.6.1 Normality Test

To answer research question four, a normality test was conducted to verify the data distribution before proceeding with the paired sample t-Test analysis, as presented in Table 5.16.

**Table 5.16**

*Normality Test*

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| Pretest | .160 | 30 | .049 | .934 | 30 | .062 |
| PostTest | .099 | 30 | .200* | .963 | 30 | .360 |
| *. This is a lower bound of the true significance. | | | | | | |
| a. Lilliefors Significance Correction | | | | | | |

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For the pre-test, the Kolmogorov-Smirnov test statistic was .160 (p = .049, slightly 0.05), indicating a marginal deviation from normality, while the Shapiro-Wilk test statistic was .934 (p = .062, slightly above 0.05), suggesting normality. This presents a borderline case where interpretation may vary depending on the chosen test. For the post-test scores, both tests supported normality, with a Kolmogorov-Smirnov test statistic of .099 (p = .200) and a Shapiro-Wilk test statistic of .963 (p = .360), indicating the post-test data is normally distributed. A previous study by Razali and Wah (2011), published in the Journal of Statistical Modeling and Analytics, titled "Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests" found that the Shapiro-Wilk test is the most powerful normality test, particularly for small sample sizes (n < 50). Their research demonstrated that when dealing with borderline cases where test results differ, the Shapiro-Wilk test's results should be prioritized due to its superior power and reliability for small samples. Based on these results and supported by Razali and Wah's (2011) findings regarding the superior power of the Shapiro-Wilk test for small samples, both the pre-test and post-test scores can be considered normally distributed. Therefore, the assumptions for conducting a paired sample t-test have been met and the analysis can proceed with confidence.

### 5.6.2 Descriptive Statistics

The achievement test score was used to analyse mean and standard deviation of the study as shown in Table 5.6.

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**Figure 5.6**

*Descriptive Statistics of Achievement Test Score*

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|---|
| | | | | | Std. Error | | Std. Error |
| Pretest Score | 30 | 43.27 | 1.780 | -.276 | .427 | -.888 | .833 |
| PostTest Score | 30 | 81.80 | 11.047 | -.304 | .427 | -.688 | .833 |
| Valid N (listwise) | 30 | | | | | | |

The comparison of pretest and post test scores reveals a significant improvement in students' understanding of programming concepts as a result of the SmartAR Module. Prior to the intervention, the average pretest score was relatively low (M = 43.27, SD = 1.78), indicating that students had a limited knowledge of the subject. After using the SmartAR Module, the average posttest score increased substantially (M = 81.80, SD = 11.047), reflecting a marked enhancement in their programming skills. The skewness for the pretest score is -0.276 (SE = 0.427), and for the posttest score, it is -0.304 (SE = 0.427). Both values are negative, indicating that the score distributions are slightly left-skewed, meaning a small number of students scored higher than most of their peers. However, since both values are relatively close to zero, the distributions are approximately symmetric.

The kurtosis for the pretest score is -0.888 (SE = 0.833), and for the posttest score, it is -0.688 (SE = 0.833). Both kurtosis values are negative, which suggests that the distributions are platykurtic (flatter than a normal distribution). This means that the data has fewer extreme outliers or high scores compared to a normal distribution, but the posttest kurtosis is closer to zero, indicating that the posttest score distribution is more normal than the pretest score distribution. The notable increase in the average score, combined with the greater variability in posttest performance (as seen in the

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higher standard deviation), suggests that the SmartAR Module was highly effective in advancing students' understanding of programming concepts. Despite the slight left skewness in both pretest and post-test scores, and the flatness of the distributions (as indicated by the kurtosis values), the substantial improvement from the pretest to the post-test highlights the success of the module in achieving its educational objectives.

### 5.6.3 Paired Sample T-Test

A paired samples t-test was conducted to analyse the effectiveness of the SmartAR Module on student scores by comparing their achievements before and after the treatment, as presented in Table 5.7, to answer research question four.

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**Figure 5.7**

*Paired Sample T-Test*

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | | | One-Sided p | Two-Sided p |
| Pair 1 | PostTest Score - Pretest Score | 38.533 | 10.471 | 1.912 | 34.623 | 42.443 | 20.157 | 29 | <.001 | <.001 |

The paired samples t-test showed students significantly improved from pretest scores (M = 43.27, SD = 1.780) to posttest scores (M = 81.80, SD = 11.047), resulting in an average score difference of 38.533 ($t(29) = 20.157$, $p < .001$). With these results, it strongly showed SmartAR Module has significantly improved students' programming skills, thereby enhancing their learning outcomes. This study supports the findings by Martin-Gutierrez et al. (2015), who analyzed AR learning effectiveness with a similar sample size. As such, this analysis disproves the SmartAR Module's

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hypothesized claim of having no significant effect on students' programming skills and asserts that the module was indeed effective in improving students' learning outcomes. Consequently, this analysis rejects the null hypothesis, which states that there is no significant difference between the pretest and post-test mean scores in students' achievement in learning programming.

### 5.6.4 Effect Sizes

In this study, Cohen's d and Hedges' g to measure the effect size of SmartAR Module on students' outcomes in programming. Cohen's d was used to compute the effect size and the effect noticed was interpreted following Lakens' guidelines (2013). The paired samples effect sizes computed in this study revealed a substantial improvement in the students' achievement score from pretest to posttest as demonstrated in Table 5.8.

**Figure 5.8**

*Paired Sample Effect Sizes*

**Paired Samples Effect Sizes**

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | Standardizer[a] | Point Estimate | Lower | Upper |
| Pair 1 | PostTest Score - Pretest Score | Cohen's d | 10.471 | 3.680 | 2.668 | 4.683 |
| | | Hedges' correction | 10.752 | 3.584 | 2.598 | 4.561 |

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Cohen's *d*, with a point estimate of 3.680 and a 95% confidence interval ranging from 2.668 to 4.683, reflected an exceptionally large effect size, highlighting a significant enhancement in posttest scores compared to pretest scores. Similarly,

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Hedges' *g*, with a point estimate of 3.584 and a 95% confidence interval from 2.598 to 4.561, confirmed this substantial effect while accounting for small sample bias. Both metrics, with their confidence intervals not crossing zero, provide robust evidence that the intervention had a profound and statistically significant positive impact on student performance in learning programming. According to Lakens (2013), effect sizes are categorized as small ($0.20 \leq d \leq 0.50$), medium ($0.50 \leq d \leq 0.80$), and large ($d \geq 0.80$). The observed effect sizes in this study clearly fall into the category of a large effect, proved that the SmartAR Module was large effect on enhancing students' achievement in learning programming.

## 5.7 Data Findings on Student Motivation in Using the SmartAR Application

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This study examined students' motivation after using the SmartAR Module across four dimensions: attention, relevance, satisfaction, and confidence, to answer research question five among 30 students. The motivation questionnaire was employed to assess motivation levels, and a scale adapted from Zainuddin et al. (2020) was used for interpretation. Motivation scores were categorized as follows: very low (1.00–1.80), low (1.81–2.60), moderate (2.61–3.40), high (3.41–4.20), and very high (4.21–5.00).

### 5.7.1 Attention

This study found the students' responses to the attention dimension of the SmartAR Module, revealing high levels of engagement and interest as shown in Table 5.9. The

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mean scores for the various statements related to attention were notably high, with most means around 4.5 or higher. Zainuddin et al. (2020) explained that the average score of attention indicates the students are highly motivated regarding maintaining attention.

**Figure 5.9**

*Student Motivation Mean Score (Attention Perspective)*

**Statistics**

| | The SmartAR-Module mobile application is eye-catching | There was something interesting in the SmartAR-Module mobile application that got my attention. | The quality of the content in the SmartAR-Module mobile application notes helped to hold my attention. | The way that information is presented on the SmartAR-Module mobile application helped keep my attention. | I learned some things that were surprising or unexpected from the SmartAR-Module mobile application. | It was a pleasure to work on such a well-designed mobile application. | The SmartAR-Module mobile application has things that stimulated my curiosity | When using the SmartAR-Module mobile application, there is so much information on the screen that it is irritating. |
|---|---|---|---|---|---|---|---|---|
| Mean | 4.63 | 4.70 | 4.57 | 4.50 | 4.60 | 4.67 | 4.33 | 4.43 |
| Std. Deviation | .490 | .466 | .504 | .509 | .498 | .479 | .479 | .504 |

Specifically, the statement *"Something interesting in the SmartAR module got my attention"* had the highest mean score of (M = 4.70, SD = .466), with nine students (30%) strongly agreeing and 21 students (70%) agreeing. Similarly, *"The SmartAR application is eye-catching"* had a mean score of (M = 4.63, SD = .490), with 11 students (36.7%) strongly agreeing and 19 students (63.3%) agreeing. The quality of the content in the SmartAR module, which helped hold students' attention, received a mean score of (M = 4.57, SD = .504), supported by 13 students (43.3%) strongly agreeing and 17 students (56.7%) agreeing. Additionally, the way information was presented in the SmartAR module kept students' attention, as evidenced by a mean score of (M = 4.50, SD = .509), with equal numbers of students (15 each, 50%) strongly agreeing and agreeing.

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Students also reported that the SmartAR Module stimulated their curiosity (M = 4.67, SD = .479), with 12 students (40%) strongly agreeing and 18 students (60%) agreeing, and that they learned surprising things (M = 4.60, SD = .498), with 14 students (46.7%) strongly agreeing and 16 students (53.3%) agreeing. Although a few students found the amount of information on the screen irritating (M = 4.33, SD = .479), with nine students (30%) strongly agreeing and 21 students (70%) agreeing, overall, students expressed pleasure in using the well-designed mobile application (M = 4.43, SD = .504), with ten students (33.3%) strongly agreeing and 20 students (66.7%) agreeing. Therefore, SmartAR Module effectively captured and maintained students' attention, contributing positively to their learning experience. Based Riduwan's (2012) scale of mean scores and interpretation, the overall summary of students' motivation from the perspective of attention in the SmartAR module is analyzed. The scores obtained reflect a "High" level of motivation, as all mean scores fall within the range of 3.51 – 4.50, accompanied by relatively small standard deviations (SD), indicating consistent responses among students.

### 5.7.2 Relevance

This study found the students' responses to the relevance dimension of the SmartAR Module, revealing high levels of engagement and interest as shown in Table 5.10. The results should that students found the SmartAR module highly relevant to their learning needs with mean above than 4.3. According to Zainuddin et al. (2020), the mean relevance score which is 4.3 indicates that students are very highly motivated in terms of maintaining relevance.

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**Figure 5.10**

*Student Motivation Mean Score (Attention Relevance).*

**Relevance**

| | The content of the SmartAR-Module mobile application will be useful to me | I could relate the content of the SmartAR-Module mobile application to things I have seen, done, or thought about in my own life. | The SmartAR-Module mobile application was not relevant to my needs because I already knew most of it. | The content of the SmartAR-Module mobile application is relevant to my interests. | There were stories, pictures, or examples that showed me how the information in the SmartAR-Module mobile application could be important to some people. |
|---|---|---|---|---|---|
| Mean | 4.57 | 4.60 | 4.37 | 4.40 | 4.80 |
| Std. Deviation | .504 | .498 | .615 | .563 | .407 |

The statement *"The content of the SmartAR-Module mobile application will be useful to me"* received a score of (M = 4.57, SD = .504), with 13 students (43.3%) strongly agreeing and 17 students (56.7%) agreeing. Similarly, *"I could relate the content of the SmartAR-Module mobile application to things I have seen, done, or thought about in my own life"* had a score of (M = 4.60, SD = .498), supported by 12 students (40%) strongly agreeing and 18 students (60%) agreeing. Although one negative aspect, *"The SmartAR-Module mobile application was not relevant to my needs because I already knew most of it,"* received a lower score of (M = 4.37, SD = .615), it still suggests a strong positive perception overall, with no students (0%) agreeing or strongly agreeing with this negative statement. Moreover, the content's relevance to students' interests was confirmed by a score of (M = 4.40, SD = .563), with 13 students (43.3%) strongly agreeing and 16 students (53.3%) agreeing. Additionally, *"There were stories, pictures, or examples that showed me how the information in the SmartAR-Module mobile application could be important to some people"* had the

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highest score of (M = 4.80, SD = .407), indicating a strong agreement, with 24 students (80%) strongly agreeing and six students (20%) agreeing.

Overall, based on Riduwan's (2012) scale of mean scores, which interprets scores of 3.51–4.00 as "High" and scores of 4.01–5.00 as "Very High," the results demonstrate that the SmartAR Module mobile application is perceived as highly relevant and beneficial to students' learning experiences. The majority of mean scores fall within the "Very High" range, with standard deviations indicating consistent responses. Specifically, the high relevance of the content, its alignment with students' interests and prior knowledge, and the inclusion of relatable examples contributed significantly to the positive perceptions.

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### 5.7.3 Confidence

This study evaluated the confidence aspect of students' motivation after the using of the SmartAR Module, indicates strongly positive feedback as shown in table 5.11. In general, students were noted to be high in confidence in a number of statements with most mean values falling between 4.30 and 4.40. Zainuddin et al. (2020) states that the mean confidence scores 4.30 to 4.40 indicates that students are extremely eager in regard to sustaining confidence while learning programming through the SmartAR Module.

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**Figure 5.11**

*Student Motivation Mean Score (Confidence Perspective)*

| Confidence | | | | | |
|---|---|---|---|---|---|
| | I could not really understand quite a bit of material in the SmartAR-Module mobile application | After working with the SmartAR-Module mobile application for a while, I was confident that I would be able to answer programming test. | As I used the SmartAR-Module mobile application, I was confident that I could learn the content. | After downloading the SmartAR-Module application, I felt confident that I knew what I was supposed to learn from the mobile application. | The good organization of the content on the SmartAR-Module programming mobile application helped me be confident that I would learn this material |
| Mean | 4.30 | 4.30 | 4.40 | 4.40 | 4.37 |
| Std. Deviation | .596 | .535 | .498 | .498 | .490 |

The analysis showed the module increased learners' confidence in being able to program. For example, the excerpt "I felt confident that I knew what I was supposed to learn from the mobile application" had a score of (M=4.40, SD=0.498) because 60% of the students, 18 out of 30, agreed while 40%, 12 out of 30, strongly agreed. The same support was found for "As I used the SmartAR-Module mobile application, I was confident that I could learn the content," with the same statistical results, M = 4.40 with SD = 0.498, 60% agreeing and 40% strongly agreeing.

The students' confidence on whether they would successfully answer the programming test questions after interacting with the SmartAR module was captured by a value in (M = 4.30, SD = 0.535) where 17 students, (56.7%), agreed while 13 students (43.3%) strongly agreed. Additionally, the good organization of the content on the SmartAR module, which helped students feel confident that they would learn the material, had a score of (M = 4.37, SD = .490), with 19 students (63.3%) agreeing and 11 students (36.7%) strongly agreeing. On the other hand, the statement *"I could not*

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*really understand quite a bit of material in the SmartAR-Module mobile application"* was strongly disagreed by 29 students (96.7%) and disagreed by one student (3.3%), indicating a high level of comprehension among the students.

In conclusion, based on Riduwan's (2012) scale of mean scores, which interprets scores of 3.51–4.00 as "High" and scores of 4.01–5.00 as "Very High," the results show that the SmartAR-Module mobile application was highly effective in boosting students' confidence. The mean scores predominantly fall within the "Very High" range, demonstrating consistent positive perceptions. The small standard deviations reflect consistent responses, further emphasizing the students' confidence in their ability to learn programming through the well-structured and organized content of the SmartAR Module.

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### 5.7.4 Satisfaction

The study evaluated the satisfaction dimension of students' motivation after using the SmartAR Module, showing strong positive responses as shown in table 5.12. On average, students expressed high levels of satisfaction, with mean scores ranging from 4.30 to 4.73. According to Zainuddin et al. (2020), the mean satisfaction scores 4.73 indicates that students are very highly motivated in terms of maintaining satisfaction in using SmartAR Module.

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**Figure 5.12**

*Student Motivation Mean Score (Satisfaction Perspective)*

| Satisfaction | | | | | | |
|---|---|---|---|---|---|---|
| | When I first looked at the SmartAR-Module mobile application, I had the impression that studying from it would be easy for me. | After working with the SmartAR-Module mobile application for a while, I was confident that I would be able to answer programming test. | The amount of repetition in the SmartAR-Module mobile application caused me to get bored sometimes | I really enjoyed using the SmartAR-Module mobile application. | I enjoyed studying from the SmartAR-Module mobile application so much that I would like to know more about this topic. | Successfully learning from the SmartAR-Module mobile application is important to me |
| Mean | 4.57 | 4.30 | 4.30 | 4.73 | 4.60 | 4.43 |
| Std. Deviation | .568 | .535 | .702 | .450 | .498 | .568 |

The statement *"When I first looked at the SmartAR-Module mobile application, I had the impression that studying from it would be easy for me"* received a score of (M = 4.57, SD = .568), with 11 students (36.7%) agreeing and 18 students (60%) strongly agreeing. *"Successfully learning from the SmartAR-Module mobile application is important to me"* had a score of (M = 4.43, SD = .568), supported by 15 students (50%) agreeing and 14 students (46.7%) strongly agreeing. Additionally, *"I enjoyed studying from the SmartAR-Module mobile application so much that I would like to know more about this topic"* received a score of (M = 4.60, SD = .498), with 12 students (40%) agreeing and 18 students (60%) strongly agreeing. The highest level of satisfaction was shown for the statement *"I really enjoyed using the SmartAR-Module mobile application,"* which had a score of (M = 4.73, SD = .450), with eight students (26.7%) agreeing and 22 students (73.3%) strongly agreeing.

Conversely, the statements *"The content of the SmartAR-Module mobile application is boring"* and *"The amount of repetition in the SmartAR-Module mobile*

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*application caused me to get bored sometimes"* had lower scores, with values of (M = 4.30, SD = .702) and (M = 4.30, SD = .535), respectively. Thirteen students (43.3%) strongly disagreed, and 13 students (43.3%) disagreed that the content was boring, while 10 students (33.3%) strongly disagreed, and 20 students (66.7%) disagreed about the repetition causing boredom. Overall, based on Riduwan's (2012) scale of mean scores, which interprets scores of 3.51–4.00 as "High" and scores of 4.01–5.00 as "Very High," the results indicate that students' satisfaction levels were very high, with mean scores consistently above 4.30. The small standard deviations reflect consistent responses across the group. Students enjoyed not only using the SmartAR-Module mobile application but also felt that it was enjoyable and useful in relation to their learning requirements. The negative critique about the content of the application being uninteresting and dull was, however, very low as most students disagreed or strongly disagreed with that statement.

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### 5.7.5 Overall Data Students Motivation After Using SmartAR Module Findings

The overall mean motivation score across these dimensions was calculated to be 4.57, indicating a "High" level of motivation according to Zainuddin et al. (2020) and mean score based on Riduwan's (2012) mean and standard deviation.These classifies scores between 3.51 and 4.00 as "High" and scores from 4.01 to 5.00 as "Very High." . The relative small standard deviations across the individual dimensions implies uniform responses from students. This means that the SmartAR Module successfully captured the students' attention and increased their willingness to learn programming concepts using augmented reality. This also supports Riduwan's (2012) interpretation of scales

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in which small SDs, proportional to the mean, suggest uniformity and large SDs show a spread in the data, indicating variability. Therefore, the data demonstrates a wide range of student motivations, albeit with some aspects that are more consistent than others.

## 5.8 Summary

This chapter provided a comprehensive information about the demographics of students who participated in the interviews, achievement tests, and motivation and usability questionnaires. It gave average score assessments and analyzed the achievement test scores of the students after using the SmartAR Module. Furthermore, the chapter evaluated the usability of the module on the cognitive, orientation, design, and support aspects and assessed the effects of the module on students' motivation through attention, relevance, confidence, and satisfaction. The results substantiated the effectiveness of the SmartAR Module in the enhancement of programming skills and motivation, given the substantial improvements in post-test scores and received feedback regarding usability and learning experience.

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# CHAPTER 6

# DISCUSSION AND CONCLUSION

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## 6.1 Introduction

This chapter discusses the findings presented in Chapter Five. The discussion is divided into eight sections, covering the study summary, discussion of findings, conclusions, contributions of the study, implications of the study, limitations of the study and recommendations for future research.

## 6.2 Summary of Research Findings

The aim of this study was to investigate the effect of the Augmented Reality programming module, referred to as the SmartAR Module, on the achievement of Form 4 computer science students. In addition, this study evaluated the usability of the

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SmartAR Module using the Augmented Reality (AR) usability questionnaire developed by Tuli and Mantra (2020) and evaluated students' motivation after using the SmartAR Module through the IMMS questionnaire. This study is composed of four phases: Phase I involved conducting a needs analysis for the SmartAR Module on programming with students and teachers; Phase II involved the design SmartAR Module and the learning material; and Phase III involved the development SmartAR Module and the learning material; Phase IV included the evaluation of the SmartAR Module.

In phase one, the needs analysis of the SmartAR Module was gathered using a semi-structured interview among two teachers and five computer science students. The semi-structured interview questions consisted of demographic inquiries, items regarding challenges in learning programming, identification of the most challenging programming topics in the Form 4 syllabus, and expectations for elements in the SmartAR Module. The interviews aimed to gather information on current issues in the computer science subject from both students' and teachers' perspectives, as well as their expectations for presenting information and incorporating attractive elements to make learning more engaging. The gathered data were analysed using thematic analysis.

In the second phase, after completing the needs analysis, the study focused on designing and developing the SmartAR Module based on the gathered requirements. After development was completed, the SmartAR Module was validated by content and technological experts, consisting of three computer science teachers and four augmented reality experts. The gathered data were used to calculate the expert agreement percentage. Following necessary amendments, a two-week pilot study was conducted to examine the usability of the SmartAR Module, as well as to retest and

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evaluate students' motivation after using it. Subsequently, the implementation of the SmartAR Module took place in School A for nine weeks, which included both pre-tests and post-tests.

In phase three, the usability of the SmartAR Module was analyzed using standard descriptive statistics, specifically mean and standard deviation, following the interpretations outlined by Ridzuan (2012). Next, students' achievements were measured before and after the use of the SmartAR Module. First, students' grades were categorized according to the KSSM grade structure. The study then calculated normality tests for both the pre-test and post-test. As a result, since the data were normally distributed, a paired sample t-test was conducted to assess the effect of the SmartAR Module on student performance. Finally, students' motivation was gathered using a questionnaire and analyzed using standard descriptive statistics, including mean and standard deviation, in accordance with Ridzuan's (2012) interpretations. The following discussion is organized according to the research questions of this study.

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## 6.3 Discussion of the needs for an augmented reality programming learning module in secondary school computer science education, based on students' and teachers' perspectives.

This section discusses the needs for an augmented reality programming learning module among secondary school computer science education, based on students' and teachers' perspectives to answer research question one of this study. The discussion is structured into three main themes: barriers to effective programming learning, challenging topics and limited fundamental knowledge. These aspects collectively

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highlight the gaps and opportunities in current programming education, emphasizing the potential of AR technology to enhance learning experiences and outcomes.

### 6.3.1 Barriers to Effective Programming Learning

The analysis of student and teacher perspectives revealed several significant barriers to effective programming learning in secondary schools, with insufficient interactive learning resources emerging as the primary challenge. As evidenced in Tables 5.4 and 5.8, while students have access to mandatory school modules, they lack consistent and engaging learning materials that facilitate effective learning. The impact of inadequate interactive resources directly affects student performance and motivation. According to Qian and Lehman (2019), students who lack access to interactive programming tools show 30% lower completion rates in programming tasks and report significantly lower self-efficacy scores. This finding aligns with previous study by Cheah (2020) emphasised that traditional teaching methods and static materials, such as books and slides, are often ineffective for teaching programming due to the dynamic nature of its concepts. Similarly, Ahmad and Ghazali (2020) highlighted that ineffective textbook-based teaching can hinder the development of programming competency. Recent studies by Wong et al. (2023) and Angraini et al. (2023) identified specific challenges including inadequate lesson delivery, insufficient after-school learning materials, and traditional methods' limitations in developing critical thinking skills.

The quality and design of instructional materials significantly impact learning outcomes. Xinogalos (2016) emphasized the importance of high-quality

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materials that address students' difficulties and misconceptions in computer programming. This aligns with earlier findings by Mow (2008) and Konecki (2014), who highlighted how poor instructional approaches create learning challenges for students. Resource limitations particularly affect rural areas, where schools often lack modern hardware and software infrastructure. Agnello (2019) noted that administrators and instructors struggle to maintain pace with computer programming curriculum requirements due to these limitations. A systematic literature review by Hudin (2023) corroborated these findings, highlighting how limited access to technical equipment and resources forces teachers to rely primarily on theoretical instruction rather than practical, hands-on experiences. Muhamad Yusof et al. (2021) found that limited access to equipment and facilities significantly hinders effective programming instruction. The majority of teachers stated the lack of teaching aids such as robotic sets and appropriate modules caused teachers to use only simulated or virtual robot alternatives. Muhamad Yusof et al. (2021) also stated that the expensive price of robotic sets creates an obstacle for teachers and schools to provide for all students. While, Ali et al. (2018) in their research discovered that according to the majority of teachers, students showed high interest in learning programming activities conducted by teachers. Teaching aids, supportive materials, and facilities are very important in implementing programming education. (Hudin, 2023).

Garcia and Brown (2021) emphasized that the lack of immediate, meaningful feedback in traditional programming environments often leads to frustration and decreased motivation. Similarly, Patel and Wilson (2022) observed that ineffective teaching methods result in low engagement and poor achievement in programming.

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Kadar, et al (2021) emphasized the importance of computational thinking skills in programming, noting that students' struggles often stem from a lack of problem-solving abilities and inadequate guidance. Current learning modules often fail to meet student needs. Interview findings revealed that text-heavy modules contribute to student disengagement, with Students 4 and 5 specifically noting difficulties with exam preparation due to non-interactive notes. This aligns with Dwivedi et al. (2022), who found that poorly designed content directly impacts student engagement. Doe (2023) emphasized the necessity of aligning educational content with learner needs and course objectives, while Sudipa et al. (2022) and Alyusfitria et al. (2024) advocated for incorporating diverse multimedia elements to enhance learning effectiveness. This study also found that existing learning module are not interactive and comprehensive. Robins (2019) noted that object-oriented programming requires enhanced visualization capabilities to help students develop mental models of complex problems. Hwang and Chang's (2021) systematic review suggest that augmented reality technology can address these visualization challenges by providing interactive, three-dimensional representations of programming concepts. These findings collectively suggest a critical need for integrating interactive, multimedia-rich resources into programming education to improve student engagement and understanding.

### 6.3.2 Challenging Topics

In addition to the challenges posed by limited learning resources, this study found students faced difficulties in understanding programming syntax and concepts especially in problem solving strategies and data structures. The challenges identified

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align with previous research by Ahmad and Ghazali (2020) and Kadar et al. (2021), which emphasize that inadequate problem-solving skills among learners exacerbate difficulties in understanding programming concepts. Previous studies also supported the same challenges overcome by students such as hard to understand without visualization of the result (Poonpong et al., 2019) lack of problem-solving skill (Dolgopolovas et al., 2018), no prior knowledge (Cazzola et al., 2016), low motivation (Dasuki, 2015), poor mathematical knowledge (Dolgopolovas et al.,2018), lack of guidance, motivation, time and competence (Humble, 2021), peer influences and lack of future expectation (Kinnunen, 2018).

A recurring issue noted in this study is students' uncertainty in applying abstract concepts, such as problem analysis and control structures. Gomes and Mendes (2007) and Robins (2019) observed that students struggle with creating algorithms and understanding abstract ideas, which are crucial for programming. This lack of consolidation of knowledge and logical reasoning during early learning stages is well-documented (Bosse & Gerosa, 2017; Savage & Piwek, 2019). Furthermore, the need for problem-solving skills remains the most frequently discussed challenge among learners (Cheah, 2020; Medeiros, Ramalho & Falco, 2019; Rahim et al., 2018). Ahmad and Ghazali (2020) emphasized the importance of mastering these skills early to avoid program design failures and confusion with control structures.

Furthermore, Fojcik, Hoyland, and Hoem (2022) emphasize that challenges in learning programming arise from both the structural aspects of programming—such as syntax, interfaces, approaches, experience, and qualifications—and the individual context of the learning situation, which includes the role of the teacher, students'

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motivation, and their expectations. This dual perspective on challenges is critical in understanding the complexities involved in programming education. Students also perceive programming as difficult due to the complexity of algorithms and abstract concepts rather than language syntax (Jamilah et al., 2022). Medeiros et al., (2019) identified that motivation and engagement are critical to overcoming these challenges. Similarly Begum, Hugland , Korhonen , Lonati and Tilantera (2023) found that students encounter challenges with data structures primarily due to fragile knowledge and skills related to prerequisites, as indicated by their incorrect answers on assessment instruments. Many students struggle with program comprehension and often confuse abstract data types (ADTs) with their implementations, leading to difficulties in reasoning about constraints such as array sizes or circularity (Begum et al., 2023).

Apart that, teachers' perspectives highlight that traditional, text-heavy materials often disengage students, with one teacher noting that if educators find programming syntax challenging, students struggle even more. This aligns with Puganesri et al. (2019), who emphasize the pedagogical difficulties in teaching programming effectively. Innovative approaches, such as educational games, have proven beneficial, as shown by Ozturk and Korkmaz (2019), who found games significantly improved academic achievement in social studies. Augmented Reality (AR) applications also enhance engagement, as seen in Totogee's (2023) mobile AR app and Atika et al.'s (2020) robot visualization tool, both of which increased interaction and learning interest. Similarly, Boonbrahm et al. (2019) developed the R Flowchart tool to improve logical thinking, while Chuan et al. (2023) introduced AR Bot for spatial learning, though neither fully measured academic outcomes.

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As, many students struggle due to the complexity of concepts and algorithms (Cheah, 2020). Medeiroset et al., (2019) identified key challenges, including the need for problem-solving skills, motivation, and engagement, with syntax being less of a challenge. Studies have also shown that programming is often perceived as difficult, prompting study into effective teaching strategies to improve comprehension and motivation (Chakraverty & Chakraborty, 2020; Efecan et al., 2020; Huang et al., 2021; Jamilah et al., 2022). Among these challenges, low programming self-efficacy is particularly significant in hindering students from successfully learning programming (Günbatar & Karalar, 2018; Tsai et al., 2019).

Therefore, this study designed and developed an interactive and high usability scored as shown in table 5.1 – 5.4 augmented reality programming module . This study found the difficulties in understanding programming syntax are compounded by limited engagement with learning materials and insufficient problem-solving skills. Addressing these challenges requires a re-evaluation of teaching strategies and the development of more engaging educational resources that cater to students' needs. Thus, this study also used a problem-solving learning strategy to guide students learning systematically.

### 6.3.3 Limited Fundamental Programming Knowledge

The third theme identified in the study's needs analysis highlights a significant challenge: the lack of foundational programming knowledge among students. This finding aligns with recent research emphasizing the difficulties novice programmers face due to limited abstract reasoning skills and high cognitive load. For instance, Lavy

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(2023) discusses how novice programmers struggle with code composition, indicating that the complexity of programming tasks can overwhelm students who lack sufficient foundational knowledge. Similarly, Pontes et al. (2021) found that beginners often find it challenging to combine basic programming concepts effectively, attributing this difficulty to limited foundational knowledge. Furthermore, Othman et al. (2023) explored the cognitive mechanisms underlying the processing of embedded coding structures, shedding light on the challenges novices face when dealing with complex programming constructs.

The challenge of limited foundational knowledge is further complicated by educational transitions. As per students experience of switching from Python in Form 3 to Java in Form 4 exemplifies this complexity, highlighting how changes in programming languages can disrupt the learning continuity. This finding resonates with extensive research in computer science education. Zingaro et al. (2018) documented how misconceptions and insufficient prerequisites significantly impact students' ability to master programming concepts. Similarly, Qian & Lehman (2017) identified that gaps in foundational knowledge create cascading difficulties in understanding algorithms and data structures. These observations are further reinforced by Margulieux et al. (2021), who demonstrated that insufficient mastery of foundational topics creates persistent barriers to advanced learning in computer science.

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### 6.3.4 Summary of Students' and Teachers' Expectations for the SmartAR Module

The findings from the student responses indicate a strong need for modernized learning modules to enhance programming skills. Students expressed that the existing modules are difficult to comprehend, as challenges in understanding exercises and current materials boring due to their reliance on text and diagrams. One common perception among students is that programming is difficult and uninteresting (Aktunc, 2013; Aşkar & Davenport, 2009), which adds to the challenges faced in programming instruction. Students 3 and 4 emphasized the lack of hands-on practice, suggesting that digital notes and interactive elements would improve their learning experience. Overall, students seek engaging, practical, and visually appealing resources that facilitate independent learning and better understanding of programming concepts.

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Teachers emphasized the limitations of traditional modules and textbooks, noting that these resources often fail to engage students effectively. Research supports this perspective, suggesting that user-friendly, interactive environments can make programming concepts more accessible and tangible. Such tools allow students to visualize the effects of commands, test ideas with immediate feedback, and identify errors more efficiently (Kelleher & Pausch, 2005; Koh Lye, 2014). In contrast, a teacher noted that while KPM modules are helpful, they often lead to decreased motivation among students due to their conventional approach. This feedback underscores the need for innovative instructional materials that integrate engaging elements to enhance students' motivation and understanding in programming.

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To effectively cultivate students' ability to solve scientific problems, it is essential to explore both the problem-solving process and the challenges students face in seeking solutions (Zhao, Chang, Shao, Liu, & Liu, 2023). Based on the findings of this study, including the needs analysis and challenges in learning programming at the secondary school level, this study designed and developed an interactive Augmented Reality learning module. The SmartAR Module integrated Jannason's (1977) problem-solving learning strategy to enhance students' programming skills and address identified gaps in their learning experience. By integrating AR technology, the module addresses students' preferences for dynamic, visually engaging, and interactive learning tools, providing immediate feedback and fostering motivation. In alignment with 21st-century learning goals, the SmartAR Module bridges theoretical concepts and practical applications, enabling students to engage in critical thinking, problem-solving, and collaborative learning. Additionally, it aligns with Malaysia's national educational goals of enhancing digital literacy and equipping students with the skills necessary for future technological challenges.

## 6.4 Discussion on the usability of the SmartAR Module in learning programming in secondary school

In this study, the usability of the SmartAR Module was assessed through a usability questionnaire categorized according to Tuli and Mantra's (2020) Augmented Reality (AR) usability principles, which are divided into four dimensions: cognition, orientation, design, and support to answer research question three.

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### 6.4.1 Discussion on the SmartAR Module Usability Principles

The SmartAR Module was specifically designed to address well-documented usability challenges in educational augmented reality systems while leveraging cognitive learning theory to enhance programming education. Traditional AR applications face significant usability barriers that hinder their educational effectiveness, including cognitive overload (Radu et al., 2017), interface inconsistency (Hornbæk, 2005), and tracking instability (Ghazwani & Smith, 2020). These challenges are particularly acute in programming education, where abstract concepts already create substantial cognitive demands (Cheah, 2020; Vinnervik, 2023). The SmartAR Module overcomes these limitations through several key innovations grounded in cognitive learning principles.

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First, the module addresses the cognitive overload problem identified by Radu et al. (2017) by implementing Piaget's (1936) theory of cognitive development through scaffolded content delivery. Unlike previous AR programming tools that presented concepts in isolation (Chuan et al., 2023; Kazanidis et al., 2018), the SmartAR Module uses progressive complexity aligned with students' developmental stages. Concrete operational stage learners (ages 7-11) interact with tangible code blocks, while formal operational thinkers (11+) engage with abstract pattern recognition tools. This developmental approach reduces extraneous cognitive load while optimizing germane processing, directly countering the "strained body postures" and "self-distraction" issues noted in earlier AR systems.

Second, the SmartAR Module solves interface inconsistency problems highlighted by Hornbæk (2005) through Norman's (2002) user-centered design

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principles. Where previous AR applications suffered from cluttered screens and disconnected menus (Ghazwani & Smith, 2020), the SmartAR Module implements a standardized interaction lexicon based on motor development stages. Persistent navigation affordances and context-sensitive UI density regulation maintain consistency while accommodating individual differences in field dependence/independence (Chen, 2020). This addresses the "non-adjustable viewpoints" and "lack of physical feedback" that plagued earlier systems.

Tracking stability, another chronic AR usability challenge (Radu et al., 2017), is enhanced through cognitive-aware marker design and multi-sensory feedback. The module incorporates Fazlina's (2021) elaboration strategies by linking virtual content to physical markers through haptic and audio cues, creating robust spatial anchors that persist even during temporary tracking loss. This represents a significant improvement over earlier marker-based systems like Atika et al.'s (2020) robot visualization tool, which lacked such recovery mechanisms. The SmartAR Module also advances beyond previous AR programming tools in addressing motivation and achievement simultaneously. While Tasdondurena et al. (2022) and Chuan et al. (2023) showed motivational benefits, they failed to demonstrate academic gains. The SmartAR Module bridges this gap by embedding Jonassen's (1977) problem-solving framework within AR interactions, creating what Keller's ARCS principles would term "confidence through competence." Real-time debugging visualization provides immediate satisfaction while reinforcing accurate mental models of program flow - addressing both the usability and pedagogical shortcomings of earlier systems.

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Crucially, the SmartAR module's usability extends beyond technical functionality to encompass pedagogical effectiveness. Where previous frameworks like SUS (Brooke, 1986) or Nielsen's heuristics (1993) evaluated general usability, the SmartAR Module implements Tuli and Mantri's (2020) AR-specific principles through a cognitive learning lens. The cognition dimension is enhanced by metacognitive prompts (Fazlina, 2021), orientation benefits from egocentric spatial mapping, design incorporates dual-coding theory, and support features provide just-in-time scaffolding. This comprehensive approach explains the module's exceptional usability scores while addressing the three critical gaps identified in AR usability frameworks: cognitive load management, pedagogical alignment, and learning curve assessment.

The SmartAR Module usability results demonstrate how Cognitive Learning Theory can meaningfully inform the design of AR-based educational tools. By grounding interaction paradigms in developmental stages rather than merely technical affordances, the module effectively overcomes common usability limitations found in previous systems (Puganesri et al., 2019). This theoretically guided design ensures that learners engage with content in ways aligned with their cognitive capabilities, enhancing both accessibility and comprehension. Moreover, the module's curriculum-aligned content and emphasis on problem-solving directly address the shortage of specialized teaching materials noted by Hudin (2023), while its mobile platform offers an inclusive solution to resource limitations in rural educational settings (Ahmad & Ghazali, 2020).

The cognitive dimension of the SmartAR Module aligns strongly with recent research confirming AR's potential to enhance learning through interactivity and

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responsive feedback. Molina et al. (2022) and Vertesi et al. (2022) demonstrated that digital resources providing timely, clear feedback significantly enhance learners' conceptual understanding. Likewise, Papadopoulou et al. (2022) and Du and Dewitt (2024) found that AR environments reduce cognitive load and promote learner autonomy reflected in how the SmartAR Module encourages independent exploration and mastery of programming concepts. The module's orientation and navigation features are also supported by Avila-Pesantez et al. (2023) and Sodervik et al. (2021), who highlighted AR's contextual guidance as a key factor in facilitating deeper learning.

In terms of design, the SmartAR Module's interactive and visually engaging interface echoes findings by Zingaro et al. (2018) and Avila-Pesantez et al. (2023), who emphasize the importance of user-centered visual design in maintaining student engagement and improving learning retention. De Moraes Rossetto et al. (2023) further validate this approach, highlighting the pedagogical power of immersive technologies in creating meaningful and memorable educational experiences. The SmartAR Module's support features, particularly its provision of real-time feedback and learner guidance, align with Sodervik's (2021) emphasis on scaffolding learning through timely and targeted interventions. This ensures students remain on track in their learning journeys while fostering a sense of self-regulation and motivation.

Additionally, this cognitive-based approach to AR usability carries significant implications for the future development of educational technology. The SmartAR Module exemplifies how effective AR solutions must go beyond technical novelty, embedding learning theory into their core design. As programming education

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increasingly focuses on cultivating computational thinking (Angeli & Valanides, 2020), the need for usability-conscious, theoretically grounded tools becomes even more critical. The SmartAR Module contributes a new paradigm for AR in education one where usability is not merely judged by technical metrics, but by measurable cognitive development and learning outcomes.

## 6.5 Discussion on the Effect of the SmartAR Module in Learning Programming

The findings revealed significant improvements in students' programming achievement after using the SmartAR Module, demonstrating its effectiveness as a learning module in learning programming for Form 4 Computer Science students. This positive impact aligns with previous studies on Augmented Reality (AR) Programming modules in educational contexts (Tsai & Cheng, 2022; Chuan et al., 2023; Yi-Ming et al., 2023; Cevahir et al., 2022; Totogee, 2023). Consistent with the findings of Cevahir et al. (2022), who demonstrated that students exposed to animation-based augmented reality (AR) worked examples achieved significantly higher academic performance compared to those using traditional paper-based materials, the SmartAR Module capitalized on the visualization affordances of AR to enhance learners' comprehension of abstract programming concepts. This approach directly addresses a prevalent issue in programming education, wherein students often struggle to conceptualize abstract programming structures. Such difficulties hinder the development of accurate mental models, which are essential for effective problem-solving and debugging (Kara & Gungor, 2024).

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The improved achievement can be attributed to several key features of the SmartAR Module. First, by transforming abstract programming constructs into interactive 3D visualizations, the module addressed one of the primary challenges identified by Thompson and Lee (2023) and Chen et al. (2022): students' difficulty visualizing abstract programming concepts such as loops, functions, and variables. This visualization capability directly addresses what Vinnervik (2023) identified as cognitive barriers in programming education. Furthermore, the SmartAR Module's effectiveness reflects Yi-Ming et al.'s (2023) findings that highly interactive AR environments lead to better academic performance compared to traditional methods. The module's interactivity allowed students to manipulate programming components directly, providing a concrete representation of abstract concepts that reduced cognitive load a significant barrier highlighted by Cheah (2020) and Vinnervik (2023).

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In contrast to previous studies such as Chuan et al. (2023), which reported no significant difference in academic achievement between students in AR-based and traditional learning environments despite increased motivation, the SmartAR Module demonstrated the ability to translate heightened engagement into tangible learning gains. This distinction may be attributed to the pedagogical design of the SmartAR Module, which was deliberately aligned with the Malaysian Form 4 Computer Science curriculum and underpinned by the principles of Connectivism. Furthermore, expert validation reinforced the module’s relevance and effectiveness; a panel of seven experts comprising four experts in augmented reality and three subject matter experts in computer science confirmed that the SmartAR Module was well-aligned with curriculum requirements and appropriate for student learning.

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The integration of Connectivism Learning Theory (CLT) was central to the design and success of the SmartAR Module in enhancing secondary school students' programming achievement. CLT, as articulated by Siemens (2004) and Downes (2007), frames learning as a networked process, where knowledge is distributed across connections between people, technology, and information sources. This theoretical perspective was operationalized in the SmartAR Module through four core principles: autonomy, connectedness, diversity, and openness. Autonomy was fostered by allowing students to navigate the module at their own pace, select programming challenges that matched their interests, and make independent decisions about their learning journey. This aligns with Downes (2012) and Tschofen (2012), who emphasized that learner agency and self-direction are foundational to connectivist environments. Connectedness was embedded by encouraging collaboration and teamwork, enabling students to form learning networks, share solutions, and engage in peer-to-peer learning, which mirrors the knowledge flow described by Downes (2012) and supported by the collaborative nature of AR environments in previous studies (Techakosit & Wannapiroon, 2015; Jeny, 2024).

The observed improvements in student achievement further validate Alsomali's (2023) claim that AR applications enable active and immersive engagement with learning content. This finding is consistent with previous studies (Bursali & Yilmaz, 2019; Chen et al., 2020; Boediono, Aulia, & Maulana, 2023) that reported AR's ability to enhance learning outcomes, reduce cognitive overload, and boost motivation. By bridging the gap between abstract programming theory and tangible practice, the SmartAR Module supported students in overcoming challenges such as syntax comprehension, debugging difficulties, and conceptual understanding of loops and

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decision statements issues previously identified by Olipas (2022) and echoed by Cheah (2020) and Thompson & Lee (2023). This immersive approach aligns with earlier efforts like those of Patel (2017) and Cevahir et al. (2022), but uniquely addresses curriculum-specific gaps by delivering a mobile-based, interactive learning experience tailored to the Malaysian Form 4 Computer Science syllabus.

Furthermore, the integration of problem-solving skills within the SmartAR Module played a pivotal role in addressing the cognitive and practical challenges commonly faced by secondary students in programming education. Grounded in Jonassen's (1977) problem-solving learning strategy, the module was designed around seven essential criteria: presenting all elements of the problem, defining it alongside a probable solution, applying relevant rules and principles, incorporating well-structured domain knowledge, guiding students toward convergent answers, supporting comprehensive solutions, and prescribing a preferred solution process. By embedding these criteria into each learning activity, the module scaffolded students through a systematic approach to problem-solving, echoing the cognitive phases identified by Omar (2022) and Rahman (2019). This structure enabled students to deconstruct complex programming tasks into manageable components, fostering logical reasoning and critical thinking skills fundamental to both academic success and real-world problem-solving (Rahman, 2019; Harefa & Purba, 2019).

Moreover, the use of authentic, context-rich scenarios in the SmartAR Module enhanced student engagement and facilitated deeper learning. For instance, students were tasked with solving real-life problems such as environmental pollution, time management during exam preparation, and algorithmic challenges using Java. These

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scenarios were carefully crafted to align with Jonassen's criteria, requiring learners to define problems clearly, devise and test solutions, and apply specific programming concepts. This approach reflects the theoretical foundations of problem-solving learning, which advocate for situating learning within meaningful contexts to nurture higher-order thinking and metacognitive awareness (Rahman, 2019; Harefa & Purba, 2019).

Jonassen's problem solving learning strategy (1970) has been widely recognized for promoting deep learning and self-regulation, particularly when integrated with interactive digital tools (Tang et al., 2020; Ajani, 2024). Within the SmartAR Module, the integration of these criteria enabled students to visualize abstract programming concepts, explore multiple solution paths, and receive real-time feedback. This iterative process of problem-solving and reflection not only improved programming competence but also increased students' confidence and self-efficacy in addressing unfamiliar challenges. By systematically embedding problem-solving strategies, the SmartAR Module effectively mitigated common barriers in learning programming such as difficulties with logic and syntax, limited prior exposure, and inadequate problem-solving techniques (Latih et al., 2020; Zainaf, Robiah, & Habibah, 2019). The AR-based environment provided a low-risk, interactive space for learners to repeatedly practice and refine their skills, supporting the gradual development of independent, competent problem-solvers.

The synergistic integration of problem-solving strategies and Connectivism Learning Theory (CLT) in the SmartAR Module significantly enhanced students' programming achievement by addressing key learning barriers. Structured problem-

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solving techniques, grounded in Jonassen's (1977) framework, enabled students to systematically decompose complex tasks, apply knowledge to real-world scenarios, and refine solutions through iterative feedback reducing cognitive load while fostering critical thinking. Simultaneously, CLT principles (Siemens, 2004) promoted autonomous, networked learning by encouraging collaboration and self-directed exploration within the AR environment. This dual approach not only improved comprehension of abstract programming concepts but also increased engagement and metacognitive skills, translating into measurable academic gains. The study underscores the efficacy of combining pedagogical theory with interactive technology to transform programming education.

Additionally, the results found in this study are supported by the student achievements as a result of enhanced mental processing and problem-solving skills using the Cognitive Learning Theory. The intellectual requirements of programming aligns with Piaget's theory at the stage of formal operational (11 years and older) with advanced reasoning and methodical approach to problem solving which are used in the SmartAR Module's interactive challenges. Fazlina (2021) with her metacognitive strategies of comprehension monitoring and elaboration defined within the module's instructions helped students solve complex challenges through programming by relating relevant real-life situations and iteratively improving solutions. This cognitive scaffolding offers learners a way to reduce extraneous load to working memory as suggested by Ginns & Leppink (2019) while nurturing critical thinking and self-regulated learning (Qu & Shi, 2022), encouraging the Aprilia (2024) and Harahap (2024) findings on the role of cognitive strategies on technical and analytical skills development. The SmartAR Module provides a solution to the issues related to the

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superficial nature of programming while fostering deeper student knowledge integration through metacognitive theories attempting students use learned concepts in real life. Bridging the gap between theoretical understanding and practical achievement.

### 6.6 Discussion on the students' motivation after using the SmartAR Module

The SmartAR Module significantly enhanced student motivation across all dimensions of the ARCS principles (Attention, Relevance, Confidence, and Satisfaction). It demonstrated the effectiveness as an innovative module for computer science subject. The high motivation levels align with findings from Kul and Berber (2022), who observed similar motivational gains when using AR in science education, suggesting that immersive technologies universally boost engagement regardless of subject matter. Crucially, the module addressed a critical gap identified by Jdaitawi et al. (2023): while AR has proven effective in subjects like biology and vocational training (Wong et al., 2023; Pujiastuti et al., 2023), its application in programming education particularly for secondary students remained underexplored. By leveraging AR's interactive 3D visualizations, the SmartAR Module captured attention through dynamic representations of abstract concepts includes loops, variables, directly tackling the disengagement challenges noted in traditional programming instruction (Dasuki, 2015; Humble, 2021).

The integration of Self-Determination Theory (SDT) into this study provides a deeper psychological rationale behind the motivational outcomes measured through the IMMS questionnaires. While the IMMS questionnaires and ARCS principle model

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focuses on immediate instructional strategies such as gaining attention, building confidence, and ensuring satisfaction. Meanwhile SDT offers a broader understanding of why these strategies are effective by addressing the psychological needs that drive intrinsic motivation. According to Deci and Ryan (2000), SDT identifies three basic psychological needs includes autonomy, competence, and relatedness that must be fulfilled to foster sustained motivation. In the context of this study, the SmartAR Module supports autonomy by allowing students to explore the learning content at their own pace and make decisions about their learning path, thereby increasing their sense of control. It enhances competence through scaffolded programming tasks and immediate feedback, which help learners feel successful and capable in completing coding challenges (Cheah, 2020; Raposo et al., 2020). The sense of relatedness is also promoted through collaborative features and interactive content that enable peer discussions and shared problem-solving experiences (Frederic, 2022). As suggested by Lee and Tsai (2022), combining the ARCS principle with SDT creates a more holistic motivational design, aligning practical teaching strategies with the psychological mechanisms that support long-term engagement and learning success. Therefore, the motivational gains observed in this study can be explained not only by the structured instructional elements of the ARCS principles but also by the intrinsic satisfaction derived from meeting students' psychological needs as outlined in SDT.

The SmartAR Module design also ensured relevance by contextualizing programming within real-world problems environmental simulations, echoing Chai et al.'s (2019) finding that AR's applicability to authentic scenarios fosters deeper motivation. This approach mitigated the abstractness barrie pervasive in programming education (Kara & Güngör, 2024), as students recognized the practical utility of their

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coding tasks. Furthermore, the module cultivated confidence through scaffolded problem-solving activities, which reduced cognitive overload (Cheah, 2020) and allowed incremental mastery key to sustaining motivation (Raposo et al., 2020). Notably, the satisfaction dimension was reinforced by immediate feedback and gamified elements, paralleling Rawan et al.'s (2023) success with gamification in C++ modules. However, unlike C huan et al. (2023), whose AR Bot failed to translate motivation into academic gains, the SmartAR Module's alignment with curriculum-specific objectives ensured motivational improvements correlated with achievement.

While prior studies highlighted AR's motivational benefits in STEM fields (Kaur et al., 2019; Valarmathie et al., 2016), this study extends the evidence base to programming education, addressing limitations observed in earlier AR programming tools. For instance, Tsai and Cheng (2022) reported motivational gains but lacked depth in advanced concepts, while Abidin and Zawawi (2020) noted technical flaws in 3D rendering. The SmartAR Module overcame these pitfalls through rigorous teacher-expert collaboration, ensuring pedagogical soundness and usability factors critical for motivation (Ivan, 2020). By systematically integrating ARCS principles with AR's immersive capabilities, this study not only validates AR's role in programming motivation but also provides a replicable framework for future innovations in the field.

Additionally, the SmartAR Module advances beyond current AR programming tools by systematically addressing four key limitations identified in prior research while retaining their validated benefits. Like Tsai & Cheng's (2022) system, it successfully captures attention through AR visualizations, but crucially extends this to secondary-level programming concepts rather than being limited to elementary logic blocks. This

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addresses the programming depth gap noted in their study, where advanced concepts were omitted. The module's curriculum-aligned design validated by both AR experts and computer science teachers ensures pedagogical rigor that was lacking in applications like Abidin & Zawawi's (2020) OOP-AR, which suffered from content coverage issues and rendering errors.

Furthermore, Chuan et al.'s (2023) AR Bot failed to convert motivation into achievement gains, the SmartAR Module bridges this gap through its integrated assessment system and connectivism based collaborative features. This demonstrates that AR's motivational benefits well-established by Cevahir et al., (2022) and Yi-Ming et al., (2023) can indeed translate to academic gains when combined with sound pedagogical design. The module's multi-platform accessibility also resolves the hardware limitations seen in Totogee's (2023) payment-dependent model and Tsai & Cheng's (2022) platform restrictions. Building upon these comparisons, the SmartAR Module introduces three key innovations that further set it apart from prior AR programming modules. Firstly, the problem-solving scaffolding incorporates Jonassen's (1977) framework more systematically than the ad-hoc approaches in Tasdondurena & Korucu (2022) or Atika et al.'s (2020) robot visualization tool. Second, unlike Yi-Ming et al.'s (2023) finding that "AR alone is not enough," the module embeds interactivity within a structured learning progression rather than treating it as an isolated feature. Third, it is the first AR solution specifically designed for secondary programming education that aligns with national curriculum standards a critical need identified by Puganesri et al. (2019) but unaddressed in previous AR implementations.

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The SmartAR Module success in overcoming visualization barriers (Poonpong et al., 2019) and cognitive overload (Mary, 2018) stems from its unique combination of three research-backed features: (1) progressive complexity in AR visualizations matching Vygotsky's ZPD, (2) contextualized real-world problem scenarios as recommended by Rahman (2019), and (3) immediate debugging feedback shown by Cevahir et al. (2022) to enhance retention. However, the SmartAR Module's advancements must be contextualized within persistent field-wide challenges. Like all AR solutions, it faces implementation barriers regarding teacher training (Puganesri et al., 2019) and infrastructure requirements. Its focus on secondary education leaves open questions about scalability to university-level programming, where abstraction challenges intensify (Kara & Güngör, 2024).

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Therefore, the SmartAR Module has demonstrated a significant positive impact on student motivation after using SmartAR Module to learn programming. The findings of this study contribute significantly to understanding of AR's role in educational motivation, particularly in programming education. The consistently high motivation scores across all ARCS dimensions suggest that AR technology, when properly implemented, can bridge the traditionally challenging gap between abstract programming concepts and student engagement. This study not only validates the effectiveness of AR in educational contexts but also opens new avenues for investigating how immersive technologies can be leveraged to enhance motivation in complex technical subjects. In conclusion, the SmartAR Module has demonstrated compelling evidence of its positive impact on student motivation in programming education. Through IMMS questionnaire and comprehensive integration of AR

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technology, the module has successfully addressed the fundamental challenges of maintaining student motivation in programming education.

## 6.7 Conclusion of the study

This chapter has comprehensively discussed the findings of this study. The needs analysis identified critical challenges in programming education, including a lack of interactive learning materials and difficulties in understanding complex programming concepts. The SmartAR Module successfully addressed these needs by providing an interactive, AR enhanced learning environment that made abstract programming concepts more tangible and engaging for students. The usability evaluation demonstrated exceptional performance across all four dimensions of Tuli and Mantra's framework includes cognitive, orientation, design, and support - validating its effectiveness as an educational tool.

The evaluation of the SmartAR Module among Form 4 students from a secondary school demonstrated significant improvements in academic achievement, with students showing marked improvement in their programming assessments after using the module. This improvement was particularly notable in their understanding and application of complex programming concepts, indicating that the AR-enhanced learning environment effectively bridged the gap between theoretical knowledge and practical application. The module's implementation also resulted in enhanced student motivation, as measured through the ARCS principles, with notably high scores across attention, relevance, confidence, and satisfaction dimensions.

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These findings suggest that the integration of Augmented Reality technology can effectively address the fundamental challenges students face in understanding programming concepts, leading to increased motivation, and academic performance. The consistent positive results across usability, achievement, and motivation metrics provide strong evidence that AR technology can successfully overcome traditional barriers in programming education. Educators and curriculum developers are encouraged to adopt such innovative tools to enhance the learning experience, as the success of the SmartAR Module provides a compelling case for the integration of AR technology in secondary school programming education.

## 6.8 Contributions of the study

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This study makes several significant contributions to the field of programming education. Firstly, it identifies existing programming challenges and difficult topics from both students' and teachers' perspectives. Through comprehensive interviews, this study gathered insights into specific areas where students struggle, such as understanding abstract programming concepts and applying theoretical knowledge to practical situations. By analysing these challenges, study can propose improvements in learning outcomes through the use of multimedia resources, interactive learning materials, real-life problem scenarios, and effective assessment strategies. This targeted approach ensures that educational interventions are relevant and tailored to meet the diverse needs of learners.

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Secondly, the SmartAR Module represents a pioneering contribution as an interactive learning tool in secondary school programming education. This innovative module integrates augmented reality technology to create an immersive learning environment, addressing the critical need for interactive and engaging educational resources. The module's unique features include 3D visualization of programming concepts, real-time feedback mechanisms, and interactive problem-solving scenarios that enhance student engagement. This technological advancement demonstrates how emerging technologies can be effectively integrated into traditional classroom settings to create more dynamic and effective learning experiences. These findings illustrate that the SmartAR Module not only facilitates deeper comprehension and retention of knowledge through hands-on AR experiences but also significantly boosts student achievement in programming by bridging the gap between theoretical concepts and practical application.

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Thirdly, the study provides empirical evidence of the effectiveness of AR-enhanced learning in programming education. The SmartAR Module has demonstrated significant improvements in student achievement, particularly in their ability to understand and apply complex programming concepts. Through hands-on AR experiences, students were able to bridge the gap between theoretical understanding and practical application, leading to enhanced learning outcomes. The module's success in improving student motivation and engagement provides a valuable model for future educational technology implementations. Next, this study enhances the educational Connectivism, Cognitive Learning Theory, and Self Determination Theory (SDT) approaches. Through the SmartAR Module, connectivism principles are operationalized through Augmented Reality integration, peer feedback, problem-

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solving, networking, and real-world problems. From a cognitive theory, the SmartAR Module's scaffolding and 3D visualization mapping is aligned with Piaget's (1936) formal operational stage, allowing students to thinking in programming tangibly, such as loops and functions. Also, the Smart Module mitigates common motivational drops in programming education by infusing autonomy, competence, and relatedness into the experience, fostering intrinsic motivation.

Reinforcing national policy objectives, this study contributes to the Malaysia Digital Education Policy (DPDM). This study provides a practical model for incorporating immersive technologies into classrooms. The SmartAR Module serves as a case illustration for DPDM's requisites on educational innovation with technology (MOE Malaysia, 2021). This study also promotes equitability through its design which is mobile-based, offline-capable, and tailored for resource-limited schools. Moreover, the troubleshooting learning activity within the module aligns with the 21st century skills framework in conjunction with DPDM and the Malaysia Education Blueprint (2013-2025). In addition, the study employed ADDIE Instructional model (Analysis, Design, Development, Implementation, Evaluation) was utilized as a systematic instructional design framework to ensure comprehensive development of the SmartAR Module. Additionally, Janassen's (1977) problem-solving learning strategy guided the instructional design process and problem-solving skills through interactive learning experiences. This methodological rigor supports the effectiveness of the SmartAR Module in achieving educational objectives and addressing identified challenges in programming education.

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Lastly, the research methodology employed in this study consisted of four distinct phases: (1) identifying the need for the Smart AR module, (2) designing and developing the Smart AR module, (3) implementing the Smart AR module, and (4) evaluating the Smart AR module through a comprehensive and systematic approach. This comprehensive methodology represents a significant contribution of the study, ensuring rigor and coherence throughout the research process.

## 6.9 Implication of the study

This study developed a Smart AR module and evaluated it in terms of validity, usability, student achievement, and motivation. The findings of this study are expected to have several impacts on various stakeholders, including students, teachers, secondary schools, and the Ministry of Education.

### 6.9.1 Students

The SmartAR Module demonstrated significant implications for student learning. The module improved students' skills in programming, logical reasoning, and their overall computational thinking abilities. The students were able to relate better to the material as it embraced real-world problem-solving situations, improving their grasp of the problem-solving strategies. This helped in sharpening the students' programming logic and allowed them to internalise techniques to help them in examination prep without needing devices. The interactivity of the module, such as learning modules, drag-and-

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drop exercises, marker scanning, animation-based videos, augmented programming content and, consequently, student engagement towards the content, was enhanced. Though designed for self-paced learning, the activities are far-reaching and cover extensive ground, evidenced by five activities and two question sets covering one lesson and comprehensive topic coverage. The application of Bloom's Taxonomy in the module was also very effective and enabled learners to acquire skills for the 21st century, thereby enhancing their achievement in programming.

### 6.9.2 Teachers

For secondary school computer science teachers, the SmartAR Module provided comprehensive instructional support and guidance by integrate augmented reality in problem-based scenarios. The learning material reduced preparation time for teaching materials and tutorials. The validation of module elements and contents by experts ensured alignment with the DKSP curriculum structure. These helps facilitating easier adoption of the learning materials. Teachers were able to effectively organize independent learning activities and leading to enhanced teaching quality with 21st-century learning approaches.

### 6.9.3 Secondary School

The study's one-group pretest-posttest research design provided valuable insights into the effectiveness of augmented reality applications in programming education. This

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methodological approach established clear cause-and-effect relationships between the module, augmented reality implementation, and programming problem-solving skills. The pre-experimental research design strengthened the internal validity of the findings, offering schools evidence-based support for implementing innovative teaching and learning aids.

### 6.9.4 The Ministry of Education

The implementation of the SmartAR Module aligns closely with the objectives of Dasar KPM and Dasar Pendidikan Digital. Its integration into school settings demonstrated how immersive technology can enhance student achievement, motivation, and higher-order thinking in programming education. The module supported digital learning initiatives by promoting computational thinking, creativity, and equitable access through its mobile and offline features. These outcomes directly contribute to the Ministry of Education's efforts to advance immersive digital tools, develop 21st-century skills, and strengthen teacher capacity in line with national education policies.

## 6.10 Limitation of the study

Throughout this study, several limitations were encountered. These limitations relate to the student engagement, interview depth and topic coverage.

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### 6.10.1 Student Engagement

This student does not effectively evaluate student engagement during the learning processes implemented with the SmartAR Module. While students assessed the usability of the module, achievement, and motivation after using the SmartAR Module, their overall engagement and motivation with the study might have been affected by various factors, such as pre-existing knowledge of the technology, interest in its programming, as well as other contextual distractions. Consequently, these variations in engagement may affect the reliability of the results regarding student achievement and motivation after using the SmartAR Module.

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### 6.10.2 Limited Interview Depth

A significant limitation was the restricted scope of the qualitative data collection. This study conducted semi-structured interviews only with five students and two teachers. This small sample size may not have captured the full range of experiences and perspectives regarding the SmartAR Module's implementation.

### 6.10.3 Limited Topic Coverage

The study focused on only two subtopics from the Form 4 computer science programming curriculum, which limited the generalizability of findings across the

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entire programming syllabus. While this focused approach allowed for detailed examination of the SmartAR Module's effectiveness in teaching specific programming concepts, it may not fully represent how the module would perform across all programming topics. The selected topics might have been more conducive to AR implementation compared to other programming concepts, potentially affecting the overall assessment of the module's effectiveness in comprehensive programming education.

## 6.11 Recommendation for future study

Based on the limitations discussed above, several recommendations can be provided as guidance for future researchers.

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### 6.11.1 Enhancement of Student Engagement Measurement

Future studies recommended to implement more comprehensive methods to measure and track student engagement with the SmartAR Module. Researchers should consider incorporating continuous assessment tools, engagement analytics, and detailed tracking mechanisms to monitor student interaction patterns. Additionally, implementing controls for variables such as prior technology experience and programming interest would provide more accurate insights into the module's effectiveness. Future research could also explore the development of personalized learning paths within the module

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to address varying engagement levels and maintain consistent motivation throughout the learning process.

### 6.11.2 Expansion of Qualitative Research Scope

For future studies recommended to significantly expand their scope beyond the current limited interview process. A more robust approach would involve conducting in-depth interviews with a larger sample of at least 15-20 students and 5-10 teachers, complemented by focus group discussions to capture collaborative insights. Implementing longitudinal interview approaches would also be valuable in tracking perception changes over time, while including perspectives from school administrators and curriculum developers would provide a more comprehensive understanding of the module's impact across different educational stakeholders. The integration of mixed-method approaches would further strengthen the research findings through data triangulation.

### 6.11.3 Comprehensive Topic Coverage

For future studies, it is recommended to extend the implementation of the SmartAR Module across a broader range of programming topics within the Form 4 computer science curriculum. This expansion should include testing the module's effectiveness across all six subtopics, developing and evaluating AR implementations for various programming concepts, and conducting comparative studies to identify which concepts

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are most effectively taught using AR technology. Additionally, research should focus on creating adaptive content that can accommodate different programming concepts with varying levels of complexity, while also investigating the scalability of the AR approach across different programming languages and paradigms. These comprehensive recommendations aim to address the current study's limitations and provide deeper insights into the effectiveness of AR technology in programming education.

## 6.12 Summary

This chapter discusses the findings of the study investigating the usability and effectiveness of the SmartAR Module for enhancing programming education among Form 4 computer science students. The chapter is structured into several sections, including a summary of research findings, challenges faced by students, and the implications of the study. The research employed a four-phases: needs analysis through semi-structured interviews with students and teachers, the design of the SmartAR Module based on identified needs, and development of the SmartAR Module and an evaluation phase that included usability testing and achievement assessments. Results indicated significant challenges in learning programming, such as insufficient resources, difficulties with programming syntax, and limited foundational knowledge. The usability assessment revealed high scores across cognitive, orientation, design, and support dimensions, demonstrating that the SmartAR Module effectively meets educational needs while providing an interactive platform for skill development. The findings underscore the importance of modernized, interactive learning resources that

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enhance student motivation and comprehension in programming education, highlighting the potential of augmented reality to transform traditional teaching methods. Additionally, the module has a strong positive effect on student motivation, increasing their interest and willingness to learn the subject. These findings indicate that the SmartAR module is a valuable instructional tool for promoting more effective and interactive learning in the classroom.

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# APPENDIX A

# APPROVAL OF ERAS

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(17668)
**Tarikh :** 10 Oktober 2023

**SALINI A/P KRISHNA PILLAI**
**NO. KP : 971109106696**

NO 15 , JALAN JATI 4, TAMAN JATI
SUNGAI JANGGUT , JERAM 45800 KUALA SELANGOR
SELANGOR

Tuan,

**KELULUSAN BERSYARAT UNTUK MENJALANKAN KAJIAN :**
**THE EFFECT OF AUGMENTED REALITY PROGRAMMING MODULE ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT**

Perkara di atas adalah dirujuk.

2. Sukacita dimaklumkan bahawa permohonan tuan untuk menjalankan kajian seperti di bawah telah diluluskan dengan syarat :

**" KELULUSAN INI BERGANTUNG KEPADA KEBENARAN PENGARAH JPN DAN PERTIMBANGAN PENTADBIR SEKOLAH. PENGUTIPAN DATA TIDAK BOLEH MENGGANGGU AKTIVITI PENGAJARAN DAN PEMBELAJARAN MURID. PENYELIDIK MESTI MENDAPATKAN KEBENARAN BERTULIS DARIPADA IBU BAPA MURID YANG DILIBATKAN DALAM KAJIAN INI. PIHAK PENTADBIR SEKOLAH PERLU MENELITI KESESUAIAN MODUL YANG DIBANGUNKAN SEBELUM DIGUNAKAN OLEH MURID. "**

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 **11 Oktober 2023** hingga **7 April 2024**

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 Penolong Pengarah Kanan
Sektor Penyelidikan dan Penilaian Dasar
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pendidikan Malaysia

salinan kepada:-

JABATAN PENDIDIKAN PERAK
JABATAN PENDIDIKAN SELANGOR

* SURAT INI DIJANA OLEH KOMPUTER DAN TIADA TANDATANGAN DIPERLUKAN *

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**APPENDIX B**

# APPROVAL OF HUMAN RESEARCH ETHICS COMMITTEE

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 6000 / 450 6661
FAKS : + 605 4582776
EMEL: ccd@upsi.edu.my

PUSAT PENGURUSAN PENYELIDIKAN DAN INOVASI

Rujukan Tuan : *Your Reference*
Rujukan Kami : UPSI/PPPI/PYK/ETIKA(M)/Jld. 16 (196) *Our Reference*
Tarikh : 1 November 2023
17 Rabiulakhir 1445H

**Salini A/P Krishna Pillai**
**Faculty of Computing and Meta Technology**
**Sultan Idris Education University**

Dear Sir/ Madam,

**APPROVAL OF HUMAN RESEARCH ETHICS COMMITTEE SULTAN IDRIS EDUCATION UNIVERSITY**

| | | |
|---|---|---|
| **Reference number** | : | **2023-0196-01** |
| **Date of Approval** | : | **30 October 2023 – 29 October 2024** |
| **Research Title** | : | **The Effect of Augmented Reality Programming Module on Secondary School Student's Achievement** |

With all due respect I refer to the above matter.

2. Please be informed that the Research Ethics Committee Meeting No. 10/2023 held on 30 October 2023 has **approved** your application for the proposed research activities.

3. The approved research period is valid until **29 October 2024**. The Research Ethics Committee must be informed for any changes made on the research. However, the implementation of the research activities is subject to the decision by the Ministry of Higher Education (KPT) from time to time based on the latest development of COVID -19 in the country.

4. In this regard, the University congratulates and hopes that you will be able to conduct research in accordance with established research ethics.

Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours sincerely,

**(PROFESSOR DR. NUR IKHWAN BIN MOHAMAD)**

s.k. Deputy Vice-Chancellor (Research and Innovation)
Director of Research and Innovation Management Center
Deputy Dean (Research and Innovation) Faculty
Researcher Files



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## APPENDIX C

## CONSENT FORM FOR STUDENTS

**7. WILL THE INFORMATION THAT PARTICIPANTS PROVIDE AND PARTICIPANTS IDENTITY REMAIN CONFIDENTIAL?**
YES.

**8. WHO SHOULD PARTICIPANTS CONTACT IF PARTICIPANTS HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?**
THE LEADER OF THE RESEARCH (DR. NOOR HIDAYAH CHE LAH)

**9. CONSENT**

I nur fatin alya Identity Card No. 070403100350
address lot 93B,lorong indah 10B,kampung sri indah B, 47000,sungai buloh,selangor hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse effects and complications (as written in the Respondent's Information Sheet). I understand that I have the right to withdraw from this research at any time without giving any reason whatsoever. I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.

I* wish / do not wish to know the results related to my participation in the research

I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* delete where necessary

Signature ..... (Respondent)
Date : 17/10/2023

Signature MAGES (Witness)
Name : MAGESWARY
I/C No. : 710801105440

I confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date 18/10/2023
Signature SALINI (Researcher)

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## APPENDIX D

## CONSENT FORM FOR COMPUTER SCIENCE

**7. WILL THE INFORMATION THAT PARTICIPANTS PROVIDE AND PARTICIPANTS IDENTITY REMAIN CONFIDENTIAL?**
YES.

**8. WHO SHOULD PARTICIPANTS CONTACT IF PARTICIPANTS HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?**
THE LEADER OF THE RESEARCH (DR. NOOR HIDAYAH CHE LAH)

**9. CONSENT**

I PUAN ANIS AFIZA BINTI ABDUL RAZAK Identity Card No. 791217-06-5088
address SMK RANTAU PANJANG KLANG
.....hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse effects and complications (as written in the Respondent's Information Sheet). I understand that I have the right to withdraw from this research at any time without giving any reason whatsoever. I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.

I* wish / do not wish to know the results related to my participation in the research

I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* delete where necessary

Signature ..... (Respondent)
Date : 30/10/2023

Signature Mages (Witness)
Name : Mageswary Paramasivan
I/C No. : 710801-10-5440

I confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date 30/10/2023
Signature Salini (Researcher)

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**APPENDIX E**

**NEED ANALYSIS INTERVIEW QUESTION (STUDENTS & TEACHERS)**

The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement

I am Salini Krishna Pillai, from the Faculty of Computing and Meta Technology, University Pendidikan Sultan Idris. Currently, I am pursuing my Master of Education (Multimedia Education) in research mode. Hence, I am proposing a marker-based augmented reality programming module, namely the SmartAR Module, and measuring its effect on students' achievement in learning programming towards Malaysian secondary schools.

The purpose of this study is to develop an interactive learning module for computer science students in order to improve their problem-solving skills in programming.

Therefore, I need your earnest cooperation in participating in this interview and answering all of the questions honestly. The collected data will be analyzed, and the SmartAR Module will be designed accordingly. All information obtained during the interview will be kept confidential and protected. If you have any questions, please contact us at 012-539 2709 or salinikrishnapillai@gmail.com.

These semi-structured interviews questions self-developed according to the programming subject .

**THANK YOU**

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## TEACHERS' INTERVIEW QUESTION

| QUESTION | ANSWERS |
|---|---|
| **Section A: BACKGROUND OF USER** | |
| 1. Do you own a smartphone? If yes, how frequently do you utilize your mobile at home? | |
| 2. Are you frequently using any available mobile applications or YouTube to watch learning tutorials? Do you enjoy practicing mobile assessment? If yes, kindly state what features excites you in learning. | |
| 3. Augmented reality allows for a more realistic picture of 3-D objects. Have you heard of augmented reality before? If yes, would you mind sharing your AR experience with us? | |
| **Section B: CHALLENGES OF COMPUTER SCIENCE** | |
| 4. What are the challenges you are encountering when studying computer science? Could you please explain why and specify topics that challenge you? | |
| 5. Do you have any difficulties in learning programming? | |
| 6. Which subtopic is challenging in learning programming? Is that understanding (1) problem solving approach, (2) algorithm, (3) constant variable, manipulated variable, and datatype, (4) structure control, and (5) data structure. Can you explain in detail please? | |
| **Section C: THE NEEDS OF MODULE** | |
| 7. Do you require any additional modernized learning modules to help you improve your programming skillset? | |
| 8. What types of learning modules are required for programming subjects? Can you go into further details? | |

## STUDENTS' INTERVIEW QUESTION

| Question | Answers |
|---|---|
| **Section a: background of user** | |
| 1. Do you own a smartphone? If yes, how frequently do you utilize your mobile at home? | |
| 2. Are you frequently using any available mobile applications or youtube to watch learning tutorials? Do you enjoy practicing mobile assessment? If yes, kindly state what features excites you in learning. | |

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| | |
|---|---|
| 3. Augmented reality allows for a more realistic picture of 3-d objects. Have you heard of augmented reality before? If yes, would you mind sharing your ar experience with us? | |
| **Section b: challenges of computer science** | |
| 4. What are the challenges you are encountering when studying computer science? Could you please explain why and specify topics that challenge you? | |
| 5. Do you have any difficulties in learning programming? | |
| 6. Which subtopic is challenging in learning programming? Can you explain in detail please? | |
| **Section c: the needs of module** | |
| 7. Do you require any additional modernized learning modules to help you improve your programming skillset? | |
| 8. What types of learning modules are required for programming subjects? Can you go into further details? | |

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# APPENDIX E

## QUESTIONNAIRE FOR USABILITY

The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement

I am Salini Krishna Pillai, from the Faculty of Computing and Meta Technology, University Pendidikan Sultan Idris. Currently, I am pursuing my Master of Education (Multimedia Education) in research mode. Hence, I am proposing a marker-based augmented reality programming module, namely the SmartAR Module, and measuring its effect on students' achievement in learning programming towards Malaysian secondary schools.

The purpose of this study is to develop an interactive learning module for computer science students in order to improve their problem-solving skills in programming.

Therefore, I need your earnest cooperation in participating in this interview and answering all of the questions honestly. The collected data will be analysed, and the SmartAR Module will be designed accordingly. All information obtained during the interview will be kept confidential and protected. If you have any questions, please contact us at 012-539 2709 or salinikrishnapillai@gmail.com.

This questionnaire will be adopted by Tuli & Mantri (2020) four augmented reality mobile application usability principles such as (1) Cognition, (2) Orientation, (3) Design and (4) Support. This questionnaire is self-developed comprises five (5) sections such as Demographic (3 questions) and experimental session (20 questions).

THANK YOU

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**APPENDIX E (Continued)**

**SECTION A: DEMOGRAPHIC**

1. GENDER:
   - MALE
   - FEMALE
2. CLASS:
   - CLASS A
   - CLASS B
   - CLASS C
3. STREAM:
   - COMPUTER SCIENCE
   - SCIENCE STREAM
   - ARTS

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**SECTION B: Cognition**

Note: In this questionnaire, the question should be answered on 5-point Likert scale as follows:

| Scores | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Category | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

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**APPENDIX E (Continued)**

1. Please respond to the following questions regarding the SmartAR Module's cognitive aspects using a scale ranging from "Strongly Disagree" to "Strongly Agree." Remember to round your answers as necessary.

| No | (Read out one statement at a time and record the responsefor the same) | Rating Scale | | | | |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1 | SmartAR-Module well designed in achieving the learning objectives | 1 | 2 | 3 | 4 | 5 |
| 2 | The content in SmartAR Module is accurate to text book contents. | 1 | 2 | 3 | 4 | 5 |
| 3 | I able to complete tasks within the SmartAR module efficiently, without wasting time or encountering unnecessary obstacles. | 1 | 2 | 3 | 4 | 5 |
| 4 | SmartAR module easy to use and intuitive, requiring no special training or extensive guidance | 1 | 2 | 3 | 4 | 5 |
| 5 | SmartAR module effectively assist you in recognizing answers immediately in effective problem-solving strategy, rather than relying on memory recall | 1 | 2 | 3 | 4 | 5 |

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**APPENDIX E (Continued)**

**SECTION C: Orientation**

2. Please respond to the following questions regarding the SmartAR Module's orientation aspects using a scale ranging from "Strongly Disagree" to "Strongly Agree." Remember to round your answers as necessary.

| No | (Read out one statement at a time and record the response for the same) | Rating Scale | | | | |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1 | SmartAR-Module is well designed according to my abilities and preferences in learning programming. | 1 | 2 | 3 | 4 | 5 |
| 2 | The SmartAR-Module design is clear and easy to understand interface. | 1 | 2 | 3 | 4 | 5 |
| 3 | The programming learning through My-Smart is more interesting andhelpful is solving problems. | 1 | 2 | 3 | 4 | 5 |
| 4 | SmartAR module effectively establish a connection between virtual content and real-world objects, making it easier for me to relate to real-life programming scenarios | 1 | 2 | 3 | 4 | 5 |
| 5 | SmartAR module offer different modes and challenges for me to engage with topic. | 1 | 2 | 3 | 4 | 5 |

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**APPENDIX E (Continued)**

**SECTION D: Design**

3. Please respond to the following questions regarding the SmartAR Module's design aspects using a scale ranging from "Strongly Disagree" to "Strongly Agree." Remember to round your answers as necessary.

| No | (Read out one statement at a time and record the response for the same) | Rating Scale | | | | |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1 | SmartAR modules follow a structured flow of programming from basic to problem solving effectively to make me aware of the consequences and solutions. | 1 | 2 | 3 | 4 | 5 |
| 2 | The marker in SmartAR-Module are well designed and easily downloadable | 1 | 2 | 3 | 4 | 5 |
| 3 | SmartAR module provide real-life or practical examples to enhance your learning experience | 1 | 2 | 3 | 4 | 5 |
| 4 | The 3-Dimensional object in My-Smart AR is well designed and attractive while learning | 1 | 2 | 3 | 4 | 5 |
| 5 | SmartAR Module is less complex and easy to understand | 1 | 2 | 3 | 4 | 5 |

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**APPENDIX E (Continued)**

**SECTION D: Support**

4. Please respond to the following questions regarding the SmartAR Module's support aspects using a scale ranging from "Strongly Disagree" to "Strongly Agree." Remember to round your answers as necessary.

| No | (Read out one statement at a time and record the responsefor the same) | Rating Scale | | | | |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1 | Throughout my learning using SmartAR programming Module, I didn't find any errors or glitches | 1 | 2 | 3 | 4 | 5 |
| 2 | SmartAR module provide hints throughout the programming learning to guide me with the next steps | 1 | 2 | 3 | 4 | 5 |
| 3 | The help button and robot in SmartAR is helpful for me to complete my assessment and learning programming | 1 | 2 | 3 | 4 | 5 |
| 4 | The learning materials in SmartAR-Module and AR scanner are support all mobile devices and easily download. | 1 | 2 | 3 | 4 | 5 |
| 5 | SmartAR requires less physical effort in learning programming . | 1 | 2 | 3 | 4 | 5 |

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**APPENDIX F**

**ACHIEVEMENT TEST**

The Effect of Augmented Reality Programming Module On Secondary School Students' Achievement

The objective of this study is to devise an interactive learning module for computer science students, enhancing their problem-solving skills in programming. This testing phase is designed to fulfil the requirements of research question objective 5, which seeks to evaluate the impact of the SmartAR Module on students' achievement.

I am seeking your participation to complete this test, which will require approximately 30 minutes of your time, and ask for your honest responses. The feedback collected will be instrumental in analyzing and refining the SmartAR Module. Rest assured, all responses will be kept confidential and used solely for the purposes of this study. If you have any questions, please contact us at 012-539 2709 or salinikrishnapillai@gmail.com.

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The test will be divided into two parts, consisting of 12 objective questions and 7 subjective questions.

**THANK YOU**

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**APPENDIX F (Continued)**

**SECTION A: DEMOGRAPHIC**

1. GENDER:
   - MALE
   - FEMALE
2. CLASS:
   - CLASS A
   - CLASS B
   - CLASS C
3. STREAM:
   - COMPUTER SCIENCE
   - SCIENCE STREAM
   - ARTS

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**ACHIEVEMENT TEST QUESTIONS (Pretest & PostTest)**

**SOALAN OBJEKTIF**

1. Antara berikut, manakah ciri-ciri penyelesaian masalah yang berkesan? [ /2 Marks]

i. Kos
ii. Jadual
iii. Sumber
iv. Masa

| A | B | C | D |
|---|---|---|---|
| i, ii, iii | i, ii, iv | ii dan iv | i, iii dan iv |

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**APPENDIX F (Continued)**

2. Apakah tujuan utama teknik pemikiran komputasional leraian dalam menyelesaikan masalah? [ /2 Marks]

A. Menjadikan masalah lebih kompleks.

B. Memecahkan masalah kompleks kepada bahagian yang lebih kecil.

C. Menggabungkan masalah yang tidak berkaitan menjadi satu masalah yang lebih besar.

3. Apakah tujuan utama langkah "Membuat Penilaian" dalam proses penyelesaian masalah? [ /2 Marks]

A. Menyusun jadual kerja.

B. Mengenal pasti kesan penyelesaian yang telah dijalankan.

C. Mengukur keberkesanan penyelesaian yang telah dilaksanakan.

4. Siti mempunyai sejumlah data yang perlu dianalisis untuk mencari corak penggunaan tenaga elektrik di rumahnya sepanjang setahun. Nyatakan kaedah pemikiran komputasi yang paling sesuai digunakan dalam menganalisis data tersebut. [ /2 Marks]

a. Teknik leraian

b. Pengecaman corak

c. Peniskalaan

d. Algoritma

5. Apakah langkah terakhir dalam proses penyelesaian masalah? [ /2 Marks]

A. Membuat tindakan

B. Mengumpulkan & menganalisis data

C. Membuat pembaikan

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**APPENDIX F (Continued)**

6. Kajian data mengenai peningkatan gejala ponteng sekolah murid Tingkatan 4 menunjukkan ramai pelajar yang menghabiskan masa di kafe siber. Berikut manakah cara penyelesaian yang tidak sesuai? [ /2 Marks]

A. Memperbanyakkan kemudahan ICT di sekolah: Murid akan lebih tertarik untuk ke sekolah kerana kemudahan komputer yang mencukupi.

B. Mewajibkan guru membawa pelajar ke makmal komputer dua kali seminggu: Ini akan memberikan peluang yang lebih banyak kepada murid supaya dapat menghidari daripada menghabiskan masa di kafe siber.

C. Membuka Pusat Akses Kendiri atau makmal komputer untuk diakses oleh murid: Hal ini secara tidak langsung akan membantu mengurangkan gejala ponteng sekolah apabila murid-murid dapat mengakses komputer pada bila-bila masa.

7. Apakah jenis gelung yang digunakan untuk menjalankan sesuatu kod sekurang-kurangnya sekali, walaupun syaratnya tidak dipenuhi? [ /2 Marks]

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A. Gelung Do-While

B. Gelung While

C. Gelung For

8. Apakah jenis gelung yang sesuai jika anda ingin menjalankan sesuatu kod selagi syarat tertentu dipenuhi? [ /2 Marks]

A. Gelung Do-While

B. Gelung While

C. Gelung For

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**APPENDIX F (Continued)**

9.Apa yang akan berlaku jika syarat dalam gelung While tidak dipenuhi pada permulaan? [ /2 Marks]

A. Kod dalam gelung tidak akan dijalankan.

B. Kod dalam gelung akan dijalankan berulang kali.

C. Kod dalam gelung akan dijalankan sekali.

10. Berapa kali kod di atas akan berulang?

```
int y = 10;
do {
   System.out.print(y + " ");
   y -= 2;
} while (y >= 2);
```

A. 4 kali

B. 10 kali

C. 5 kali

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11. Tentukan output untuk kawalan ulangan yang berikut. [ /2 Marks]

```
for(n = 150;n<=40;n-=15) {

System.out.println(n + "   ");

}
```

A. 1 2 3 4 5

B. 5 4 3 2 1

C. Tiada Output

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**APPENDIX F (Continued)**

12. Anda mempunyai satu program yang memerlukan pengesahan umur pengguna sebelum memberikan akses kepada fungsi tertentu. Anda telah menetapkan umur pengguna sebagai 16 tahun. Pilih jawapan yang betul berdasarkan umur yang telah ditetapkan: [ /2 Marks]

```
public class Main {
    public static void main(String[] args) {
        int umurPengguna = 16;

        if (umurPengguna < 18) {
            System.out.println("Pengguna di bawah 18 tahun.");
        } else if (umurPengguna == 18) {
            System.out.println("Pengguna berumur 18 tahun.");
        } else {
            System.out.println("Pengguna berumur lebih dari 18 tahun.");
        }
    }
}
```

a. Di bawah 18 tahun - Tidak layak untuk mengakses fungsi.

b. 18 tahun - Layak untuk mengakses fungsi.

c. Lebih dari 18 tahun - Layak untuk mengakses fungsi

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**APPENDIX F (Continued)**

**SOALAN SUBJEKTIF**

1. For the subjective questions, provide detailed responses based on your understanding and experiences with the SmartAR Module.
2. Write clearly and concisely, ensuring that your answers reflect your thoughts and insights regarding the module's effectiveness in enhancing your learning experience.

| SOALAN & JAWAPAN |
|---|
| 1. Apakah output yang akan dicetak oleh kod di atas?<br><br>`for (int i = 2; i <= 8; i += 2) {`<br>`System.out.print(i * i + " "); }`<br><br>**Jawapan :** [ /4 Marks] |
| 2. Bagaimana anda akan menulis kod dalam gelung For untuk mencetak nombor genap dari 2 hingga 10?<br><br>**Jawapan :** [ /4 Marks] |
| 3. Berapa kali kod di atas akan berulang?<br><br>`int y = 12;`<br>`do {`<br>`System.out.print(y + " ");`<br>`y -= 3;`<br>`} while (y >= 3);`<br><br>**Jawapan :** [ /2 Marks] |
| 4.Teknik komputasional yang manakah yang paling sesuai untuk membantu pelajar mengingati formula matematik? |

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Situasi : Seorang pelajar sedang menghadapi kesulitan dalam mengingat formula matematik untuk ujian esok.

**Jawapan :** [ /4 Marks]

5. Anda telah diberi tugas untuk menyediakan kek coklat untuk majlis hari jadi. Apakah langkah pertama yang anda akan ambil mengikut proses menyelesaian masalah ?




**Jawapan :** [ /5 Marks]

6. Senaraikan empat teknik pemikiran komputasional menggunakan i-Think

7.Apakah ciri-ciri penyelesaian masalah yang berkesan?

Jawapan : [ /4 Marks]

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**APPENDIX G**

**QUESTIONNAIRE FOR STUDENT MOTIVATION**

The Effect of Augmented Reality Programming Module On Secondary School Students' Achievement

I am Salini Krishna Pillai, from the Faculty of Computing and Meta Technology, University Pendidikan Sultan Idris. Currently, I am pursuing my Master of Education (Multimedia Education) in research mode. Hence, I am proposing a marker-based augmented reality programming module, namely the SmartAR Module, and measuring its effect on students' achievement in learning programming towards Malaysian secondary schools.

The purpose of this study is to develop an interactive learning module for computer science students to improve their problem-solving skills in programming.

Therefore, I need your earnest cooperation in participating in this interview and answering all of the questions honestly. The collected data will be analyzed, and the SmartAR Module will be designed accordingly. All information obtained during the interview will be kept confidential and protected. If you have any questions, please contact us at 012-539 2709 or salinikrishnapillai@gmail.com.

This questionnaire will consist of three (2) section such as Demographic (3 questions), 30 Questions contains of ARCS Attention, Relevance, Confidence, Satisfaction adopted from Instructional Materials Motivation Survey (IMMS) by Keller (2010).

THANK YOU

**SECTION A: DEMOGRAPHIC**

**1. GENDER:**

- MALE
- FEMALE

**2. CLASS:**

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- CLASS A
- CLASS B
- CLASS C

**3. STREAM:**

- COMPUTER SCIENCE
- SCIENCE STREAM
- ARTS

**SECTION B: ARCS Questionnaire**

**ARCS Questionnaire for Module (Experimental Group)**

Note: In this questionnaire, the question should be answered on 5-point Likert scale as follows:

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| Scores | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Category | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

1. One Scale of Strongly disagree – Strongly agree answer the following questions regarding SmartAR-Module visibility. Please round at the necessary field.

| No | (Read out one statement at a time and record the response for the same) | Rating Scale | | | | |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 1 | When I first looked at the programming module, I had the impression that studying from it would be easy for me. | 1 | 2 | 3 | 4 | 5 |
| 2 | There was something interesting in the programming module that got my attention. | 1 | 2 | 3 | 4 | 5 |
| 3 | The content of the programming module was | 1 | 2 | 3 | 4 | 5 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | more difficult to understand than I would like for it to be. | | | | | |
| 4 | After downloading the programming module, I felt confident that I knew what I was supposed to learn from the mobile application. | 1 | 2 | 3 | 4 | 5 |
| 5 | It is clear to me how the content of the programming module is related to things I already know. | 1 | 2 | 3 | 4 | 5 |
| 6 | The programming module had so much information that it was hard to pick out and remember the important points. | 1 | 2 | 3 | 4 | 5 |
| 7 | The programming module is eye-catching | 1 | 2 | 3 | 4 | 5 |
| 8 | There were stories, pictures, or examples that showed me how the information in the programming module could be important to some people. | 1 | 2 | 3 | 4 | 5 |
| 9 | Successfully learning from the programming module is important to me | 1 | 2 | 3 | 4 | 5 |
| 10 | The quality of the content in the programming module helped to hold my attention. | 1 | 2 | 3 | 4 | 5 |
| 11 | The content in the programming module is so abstract that it was hard to keep my attention on it. | 1 | 2 | 3 | 4 | 5 |
| 12 | As I used the programming module, I was confident that I could learn the content. | 1 | 2 | 3 | 4 | 5 |
| 13 | I enjoyed studying from the programming module so much that I would like to know more about this topic. | 1 | 2 | 3 | 4 | 5 |
| 14 | The programming module looks dry and unappealing | 1 | 2 | 3 | 4 | 5 |
| 15 | The content of the programming module is relevant to my interests. | 1 | 2 | 3 | 4 | 5 |
| 16 | The way that information is presented on the programming module helped keep my attention. | 1 | 2 | 3 | 4 | 5 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | Using the programming module was too difficult. | 1 | 2 | 3 | 4 | 5 |
| 18 | The programming module has things that stimulated my curiosity | 1 | 2 | 3 | 4 | 5 |
| 19 | I really enjoyed using the programming module. | 1 | 2 | 3 | 4 | 5 |
| 20 | The amount of repetition in the programming module caused me to get bored sometimes | 1 | 2 | 3 | 4 | 5 |
| 21 | I learned some things that were surprising or unexpected from the programming module. | 1 | 2 | 3 | 4 | 5 |
| 22 | After working with the programming module for a while, I was confident that I would be able to answer programming test. | 1 | 2 | 3 | 4 | 5 |
| 23 | The programming module was not relevant to my needs because I already knew most of it. | 1 | 2 | 3 | 4 | 5 |
| 24 | The content of the programming module is boring. | 1 | 2 | 3 | 4 | 5 |
| 25 | I could relate the content of the programming module to things I have seen, done, or thought. about in my own life. | 1 | 2 | 3 | 4 | 5 |
| 26 | When using the programming module, there is so much information on the screen that it is irritating. | 1 | 2 | 3 | 4 | 5 |
| 27 | The content of the programming module will be useful to me | 1 | 2 | 3 | 4 | 5 |
| 28 | I could not really understand quite a bit of material in the programming module | 1 | 2 | 3 | 4 | 5 |
| 29 | The good organization of the content on the programming module helped me be confident that I would learn this material | 1 | 2 | 3 | 4 | 5 |
| 30 | It was a pleasure to work on such a well-designed programming module | 1 | 2 | 3 | 4 | 5 |

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**APPENDIX H**

**VALIDATION FORM OF TECHNICAL EXPERT 1**

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SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR QUESTIONNAIRE (STUDENTS MOTIVATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the interview questions of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS:

Question no 6: Double barrel question. Choose 1 statement only, either 'hard to pick up' or 'remember'
Question No 21: Either suprising/unexpected, dont use both

The rest is relevant to context.

Signature : 

Name : Dr Nur Nabihah Mohamad Nizar

Qualification : PhD in Education

Date : 16 November 2023

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**APPENDIX I**

**VALIDATION FORM OF TECHNICAL EXPERT 1**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR QUESTIONNAIRE (ACHIEVEMENT TEST)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the interview questions of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS:

Question 8: Peniskalaan should be translate in english or that is the only term used? (Same comment for question 6, 11 in section B)

The rest relevant to the context

Signature : 

Name : Dr Nur Nabihah Mohamad Nizar

Qualification : PhD in Education

Date : 16 November 2023

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**APPENDIX J**

**VALIDATION FORM OF TECHNICAL EXPERT 1**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR QUESTIONNAIRE (SmartAR-Module)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the interview questions of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS:

Sect A, Question 2: No need to mentioned about Youtube.
Appendix B: Researcher mentioned question will be answered on 5 point Likert Scale, but in questionnaire only 4 scale.

Avoid double barraled question. Please check the items carefully. Avoid ask 2 questions or s tatements in one sentences, it will reduce the accuracy of the data.

Signature :

Name : Dr Nur Nabihah Mohamad Nizar

Qualification : PhD in Education

Date : 16 November 2023

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**APPENDIX K**

**VALIDATION FORM OF TECHNICAL EXPERT 2**

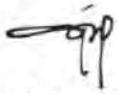
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**VALIDATION FORM FOR QUESTIONNAIRE (ACHIEVEMENT TEST)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the interview questions of the SmartAR-Module are relevant and intended to answer the respective research objective.

| | |
|---|---|
| COMMENTS: | The instrument is suitable and can be utilized for data collection in the study after corrections have been made in accordance with the suggestions provided in the comments section of the document. |

Signature : 

Name : DR CHE SAMIHAH BINTI CHE DALIM

Qualification : PhD (Computer Science)

Date : 15 December 2023

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi


**APPENDIX L**

**VALIDATION FORM OF TECHNICAL EXPERT 2**

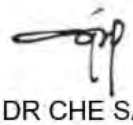
UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR QUESTIONNAIRE (SmartAR-Module)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the interview questions of the SmartAR-Module are relevant and intended to answer the respective research objective.

| | |
|---|---|
| COMMENTS: | The instrument is suitable and can be utilized for data collection in the study after corrections have been made in accordance with the suggestions provided in the comments section of the document. |

Signature : 

Name : DR CHE SAMIHAH BINTI CHE DALIM

Qualification : PhD (Computer Science)

Date : 15 December 2023

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX M**

**VALIDATION FORM OF TECHNICAL EXPERT 3**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONTENT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the content of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS: The chosen content within the SmartAR-Module is thoughtfully tailored to complement the study's exploration of programming modules and aligned with the syllabus/curriculum of secondary school, ensuring its relevance and suitability for students.

Signature :

Name : Ts DR DANAKORN NINCAREAN A/L EH PHON

Qualification : PhD in Educational Technology

Date : 23/2/2024

TS DR DANAKORN NINCAREAN A/L EH PHON
FACULTY OF COMPUTING,
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDUL
26600 PEKAN, PAHANG.
MALAYSIA

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX N**

**VALIDATION FORM OF TECHNICAL EXPERT 3**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيۏرسيتي ڤندидيقن سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONSTRUCT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the construct of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS: Overall, the smart AR mobile application sets a high standard for AR integration, providing students with immersive and compelling experiences that demonstrate the potential of augmented reality technology in learning programming

Signature :

Name : Ts DR DANAKORN NINCAREAN A/L EH PHON

Qualification : PhD in Educational Technology

Date : 23/2/2024

TS DR DANAKORN NINCAREAN A/L EH PHON
FACULTY OF COMPUTING,
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH
26600 PEKAN, PAHANG,
MALAYSIA

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX O**

**VALIDATION FORM OF TECHNICAL EXPERT 4**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيورسيتي ڤندidikan سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONTENT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the content of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS: I have checked it and I am satisfied with it.

Signature :

Name : ASSOCIATE PROFESSOR DR. AMIRRUDIN KAMSIN
Department of Computer System & Technology
Faculty of Computer Science & Information Technology
Universiti Malaya
50603 Kuala Lumpur
MALAYSIA

Qualification : PHD IN COMPUTER SCIENCE

Date : 25.3.2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX P**

**VALIDATION FORM OF TECHNICAL EXPERT 4**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيۏرسيتي ڤندидikan سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONSTRUCT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the construct of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS: I have checked it and I am satisfied with it.

Signature :

ASSOCIATE PROFESSOR DR. AMIRHUDIN KAMSIN
Department of Computer System & Technology
Faculty of Computer Science & Information Technology
University Malaya
50603 Kuala Lumpur
MALAYSIA

Name :

Qualification : PHD IN COMPUTER SCIENCE

Date : 25.3.2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi


**APPENDIX Q**

**VALIDATION FORM OF CONTENT EXPERT 1**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيۏرسيتي ڤنديديقن سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONTENT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the content of the SmartAR-Module are relevant and intended to answer the respective research objective.

| | |
|---|---|
| COMMENTS: | Tahniah atas usaha menghasilkan modul SmartAR. Mohon sertakan penerangan spesifik tentang keperluan strategi penyelesaian masalah beserta contoh. |

Signature :

Name : SITI HADIJAH BINTI SUPIAN

Qualification : GAB

Date : 22 Februari 2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi


**APPENDIX R**

**VALIDATION FORM OF CONTENT EXPERT 1**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONSTRUCT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the construct of the SmartAR-Module are relevant and intended to answer the respective research objective.

| COMMENTS: | Terdapat konstruk terminologi, fakta, urutan dan kriteria |
|---|---|

Signature : 

Name : SITI HADIJAH BINTI SUPIAN

Qualification : GAB

Date : 22 Februari 2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi


**APPENDIX S**

**VALIDATION FORM OF CONTENT EXPERT 2**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONTENT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the content of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS:
- Isi kandungan yang mudah difahami
- sesuai dan menepati standard pembelajaran

Signature :

Name : Sara Hanim Binti Johar

Qualification : Guru Sains komputer

Date : 22 Feb 2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi


**APPENDIX T**

**VALIDATION FORM OF CONTENT EXPERT 2**

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيۏرسيتي ڤنديديقن سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

**VALIDATION FORM FOR SMART-AR MOBILE APPLICATION (CONSTRUCT VALIDATION)**

The Effect of Augmented Reality Programming Modules on Secondary School Students' Achievement

I hereby certify and validate that the construct of the SmartAR-Module are relevant and intended to answer the respective research objective.

COMMENTS:
- ISI menepati standard yang ditetapkan oleh KPM
- sesuai digunakan dalam proses PdPc

Signature :

Name : Sara Hanim Binti Johar

Qualification : Guru Sains Komputer

Date : 22 Feb 2024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U**

# TECHNOLOGICAL EXPERTS' APPOINTMENT LETTER (EXPERT 1)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

INSTITUTE OF GRADUATE STUDIES

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

Ts. Dr. Danakorn Nincarean Eh Phon
Universiti Teknologi Malaysia,

UTM Johor Bahru,

81310 Skudai
Johor

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

# TECHNOLOGICAL EXPERTS' APPOINTMENT LETTER (EXPERT 2)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

INSTITUTE OF GRADUATE STUDIES

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

Professor Dr. Amirrudin Kamsin
Universiti Malaya

Jabatan Sistem dan Teknologi Komputer

50603 Kuala Lumpur
Wilayah Persekutuan Kuala Lumpur

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

# TECHNOLOGICAL EXPERTS' APPOINTMENT LETTER (EXPERT 3)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

NUR NABIHAH BINTI MOHAMAD NIZAR
University Malaya,

UM

50603 Kuala Lumpur
Wilayah Persekutuan Kuala Lumpur

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

# TECHNOLOGICAL EXPERTS' APPOINTMENT LETTER (EXPERT 4)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

INSTITUTE OF GRADUATE STUDIES

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

Che Samihah Binti Che Dalim
Universiti Tun Hussein Onn Malaysia,

Pagoh Higher Education Hub,

84600 Pagoh
Johor

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

## CONTENT EXPERTS' APPOINTMENT LETTER (EXPERT 1)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

INSTITUTE OF GRADUATE STUDIES

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

SARA HANIM BINTI JOHAR
Sekolah Menengah Kebangsaan Undang Jelebu

Km 3 Jalan Petaling, 71600,

71600 Kuala Klawang,
Negeri Sembilan

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

## CONTENT EXPERTS' APPOINTMENT LETTER (EXPERT 2)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

TEL: +605 450 5482
FAX: +605 459 4649
EMAIL: ips@upsi.edu.my

INSTITUTE OF GRADUATE STUDIES

Ref. No. : UPSI/IPS-3/475.5
Date : 09 December 2024

PUAN ANIS AFIZA BINTI ABDUL RAZAK
SMK Rantau Panjang Klang

Lot 111, Jalan Genting

42100 Klang
Selangor

Prof./Assoc.Prof./Dr./Mr./Mdm.,

**APPOINTMENT AS ASSESSOR FOR INSTRUMENT VALIDATION**

With reference to the above matter.

2. Please be informed that the student as stated below is under the supervisory of Dr. Noor Hidayah binti Che Lah, Sultan Idris Education University (UPSI) :

| | | |
|---|---|---|
| Name | : | **Salini A/P Krishna Pillai** |
| Matric | : | **M20221000103** |
| Faculty | : | **FACULTY OF COMPUTING AND META-TECHNOLOGY** |
| Research | : | **The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement** |

3. Thus, we need your expertise in assisting the research to be more significant and relevant. Herewith the related document for your further action. Any enquiry or inconvenience, you may contact the researcher at **0125392709** or email to **salinikrishnapillai@gmail.com**

Your coorperation regarding this matter is highly appreciated. Thank you.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN"**

Yours Sincerely,

**(PROFESSOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dean, Institute Of Graduate Studies
c.c Student's : M20221000103
: UPSI/IPS-3/475.5

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi



**APPENDIX U (Continue)**

## CONTENT EXPERTS' APPOINTMENT LETTER (EXPERT 3)

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

35900 TANJONG MALIM
PERAK DARUL RIDZUAN, MALAYSIA

FAKS: + 605 4582776
EMEL: ccd@upsi.edu.my

INSTITUT PENGAJIAN SISWAZAH

Ruj. Kami : UPSI/IPS-3/475.5 Jilid 36
Tarikh : 6 November 2023
22 Rabiulakhir 1445H

Siti Hadijah Binti Supian
Guru Komputer Sains
SMK Bandar Baru Sungai Buloh
Jalan BRP 1/10 A, Bandar Baru Sungai Buloh
47000 Selangor Darul Ehsan.

YBhg.Prof./Prof.Madya/Dr./Tn./Pn.,

**PELANTIKAN SEBAGAI PAKAR SMART-AR AUGMENTED MOBILE APPLICATION.**

Dengan segala hormatnya perkara di atas adalah dirujuk.

2. Adalah dimaklumkan bahawa pelajar seperti butiran di bawah merupakan pelajar Program Pengajian Siswazah Sarjana Pendidikan (Multimedia), Universiti Pendidikan Sultan Idris (UPSI):

| | | |
|---|---|---|
| Nama | : | **Salini A/P Krishna Pillai** |
| No. Matrik | : | **M20221000103** |
| Fakulti | : | **Fakulti Komputeran dan Meta Teknologi** |
| Tajuk Kajian | : | ***The Effect of Augmented Reality Programming Module on Secondary School Students' Achievement.*** |

3. Sehubungan itu, saya ingin memohon khidmat kepakaran YBhg.Prof./Prof.Madya/Dr./Tn./Pn. dalam membantu penyelidikan beliau supaya ia lebih signifikan dan relevan. Bersama-sama ini disertakan dokumen berkaitan untuk tindakan dan perhatian YBhg.Prof./Prof.Madya/Dr./Tn./Pn. selanjutnya. Sebarang pertanyaan atau kesulitan boleh menghubungi penyelidik di talian **0125392709** atau alamat emel ke **salinikrishnapillai@gmail.com.**

4. Kerjasama dan kesudian pihak YBhg.Prof./Prof.Madya/Dr./Tn./Pn. berhubung perkara ini amatlah dihargai dan didahului dengan ucapan ribuan terima kasih.

Sekian.

**"MALAYSIA MADANI"**
**"BERKHIDMAT UNTUK NEGARA"**
**"PENERAJU KEBITARAAN PENDIDIKAN'**

Saya yang menjalankan amanah,

**(PROFESOR DR. RAJA NOR SAFINAS BINTI RAJA HARUN)**
Dekan, Institut Pengajian Siswazah
05-4505487



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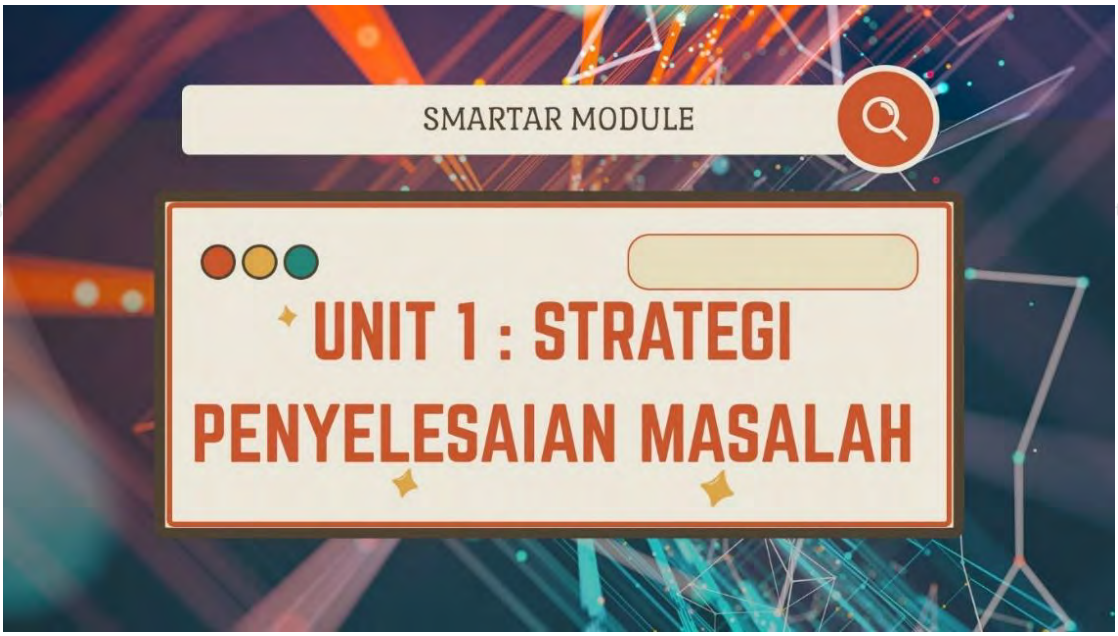
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**APPENDIX V**

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**SMARTAR MODULE**

**UNIT 1**




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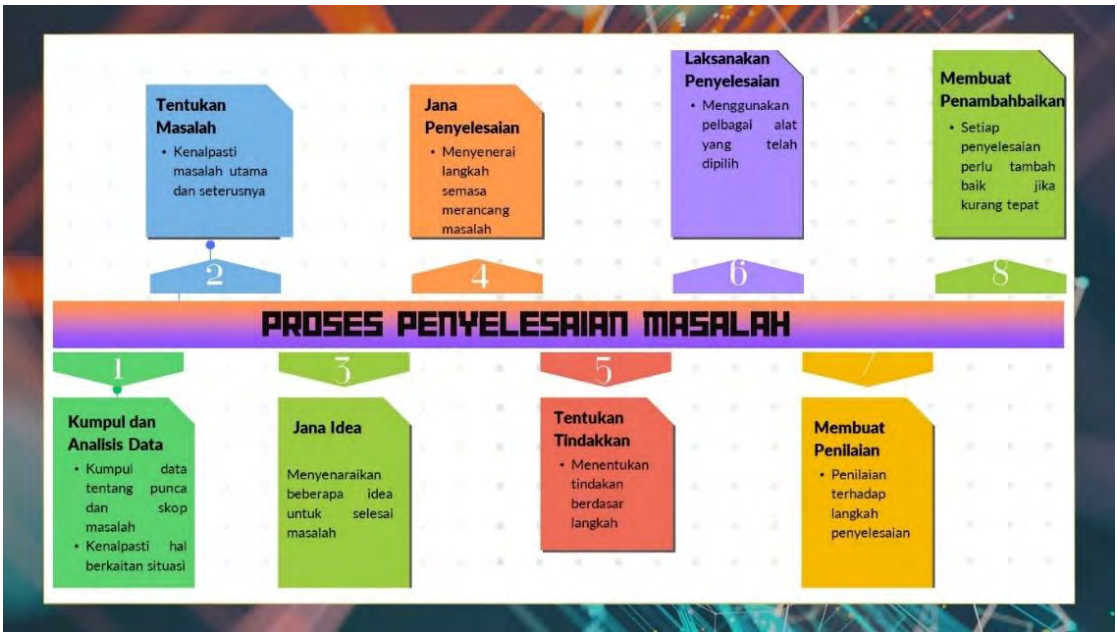







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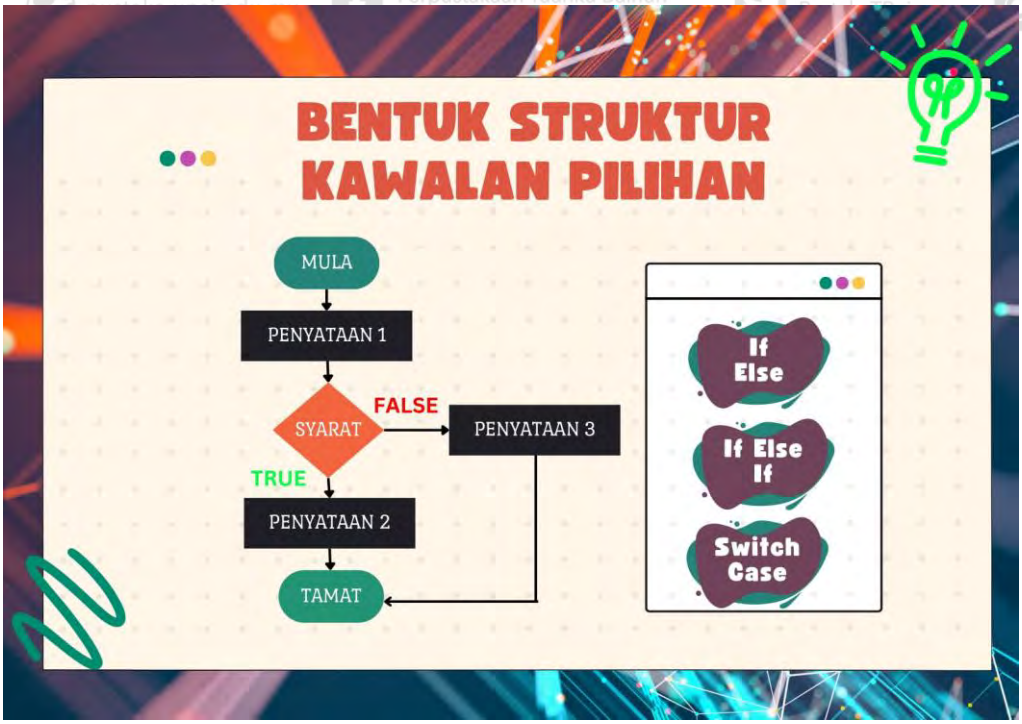

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**UNIT 2**




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# IF ELSE IF

**Anda sedang membangunkan aplikasi penukar suhu mudah. Pengguna memasukkan nilai suhu, dan aplikasi perlu menentukan dan paparkan keadaan cuaca yang sepadan berdasarkan kriteria berikut:**

**Jika suhu adalah 30 darjah Celsius atau lebih tinggi, paparkan "Hari Panas!"**

**Jika suhu berada di antara 20 dan 29 darjah Celsius (termasuk), paparkan "Suhu Sederhana."**

**Jika suhu lebih rendah daripada 20 darjah Celsius, paparkan "Hari Sejuk."**

**Sila gunakan struktur pilihan if-else-if untuk menyemak markah dan paparkan mesej yang bersesuaian dengan keputusan.**




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# SWITCH CASE

**Anda diminta untuk menulis satu program dalam bahasa Java yang memasukkan singkatan bahasa pemrograman (contoh: "C", "Java", "Python") dan menampilkan nama lengkap bahasa pemrograman tersebut..**

**Jika Singkatan C , paparkan Bahasa Pemrograman C .Jika singkatan J , paparkan Bahasa Pemrograman Java . Ataupun default Bahasa pemrograman tidak dikenal**




**Sila gunakan struktur pilihan switch-case .**

# LATIHAN

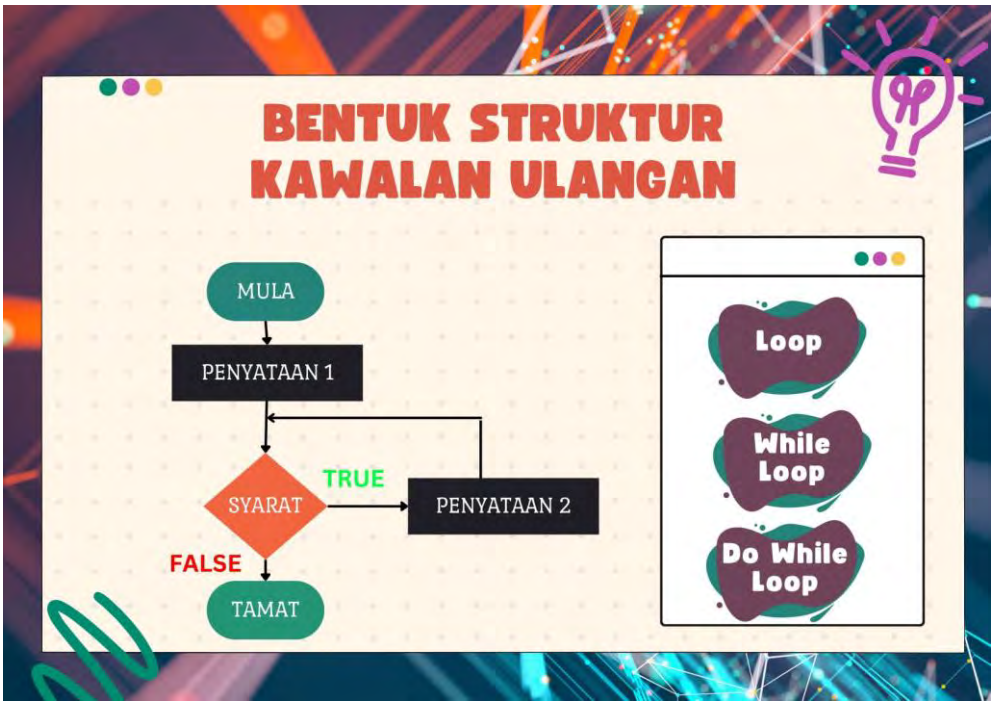
Anda seorang jurutera program yang bekerja untuk syarikat pembangunan teknologi yang baru sahaja memperkenalkan kereta automatik yang revolusioner. Kereta ini dapat dikawal dengan mudah melalui antaramuka pintar yang menerima arahan putaran dari pengguna. Setiap arahan putaran (Kanan/Kiri/Atas/Bawah) atau pilihan 'B' untuk berhenti akan mengubah orientasi kereta secara langsung.
Tuliskan sebuah program dalam bahasa Java yang memproses input untuk mengubah orientasi kereta seperti berikut:

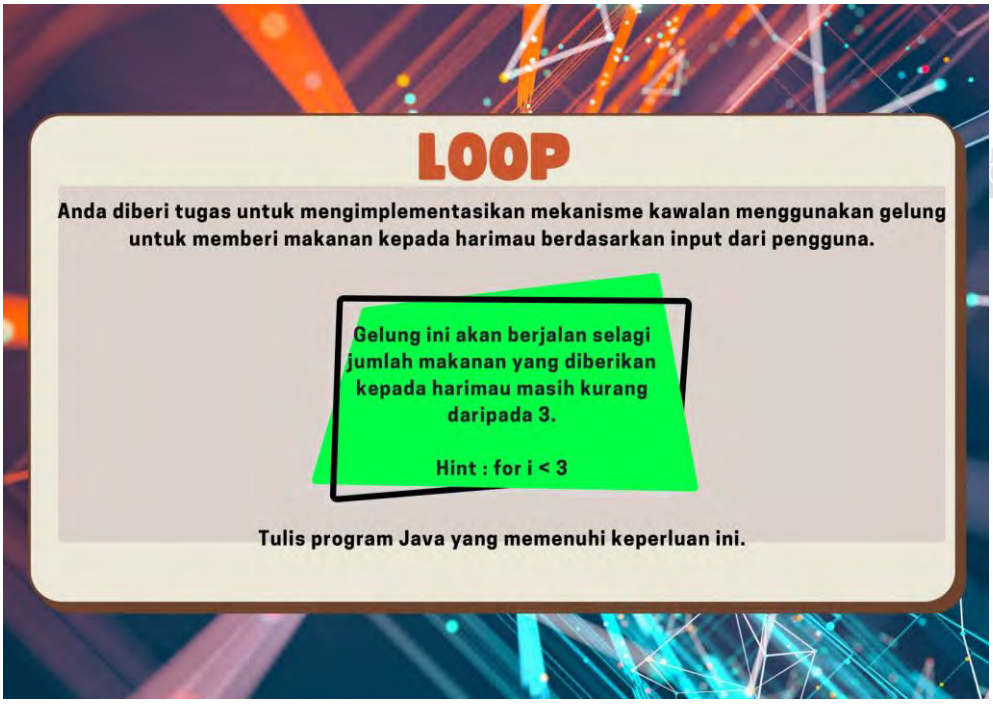
**Kiri : right**
**Kanan : left**
**Atas : Up**
**Bawah : Down**

Program ini akan menerima input berulang-ulang dari pengguna hingga pengguna memilih untuk menghentikan kereta dengan memasukkan 'B'.

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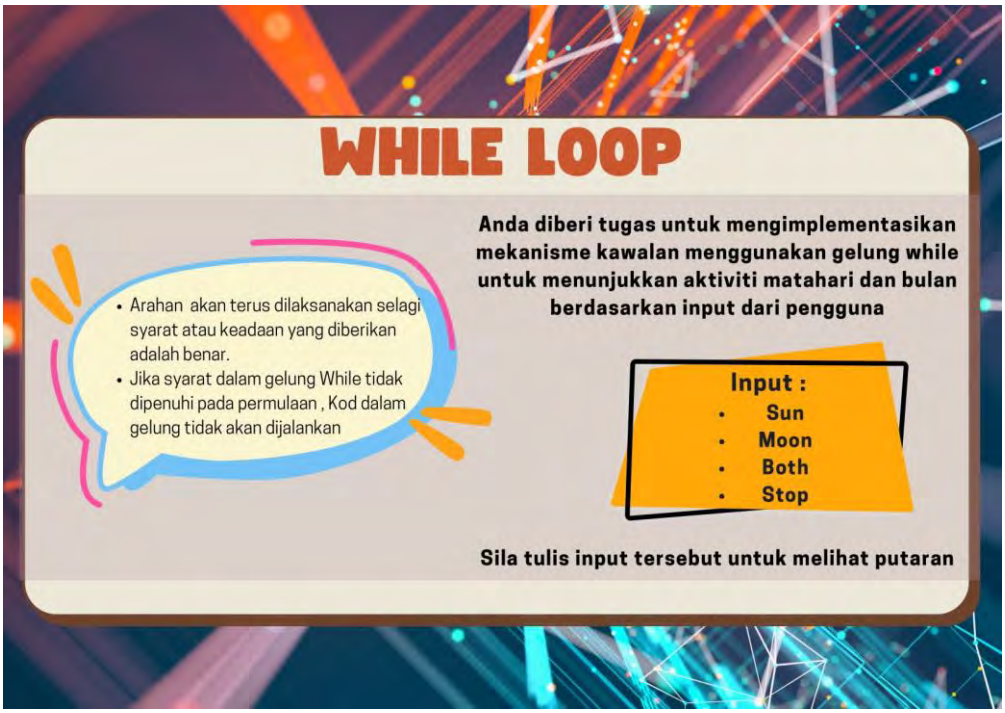
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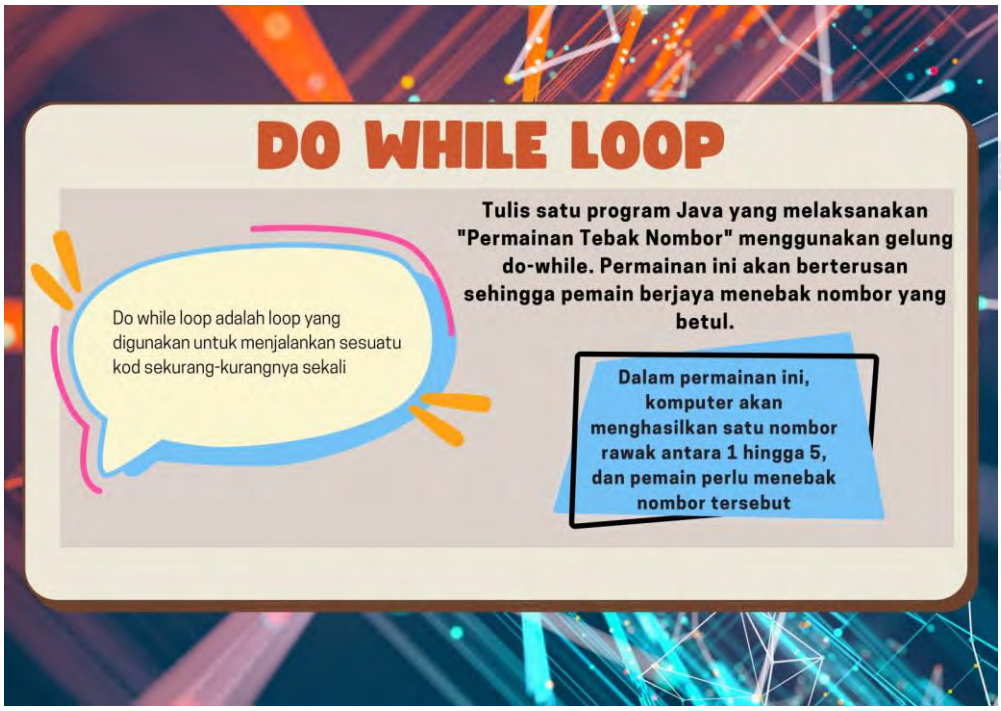




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**APPENDIX W**

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**IMPLEMENTATION OF SMART AR MODULE IN SCHOOL**



Student using SmartAR Module to learn programming

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Pre-preparations of Implementing SmartAR Module in School



Student using SmartAR Module to learn programming

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Student answering SmartAR Module Usability and Motivation Questionnaire

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Group Picture of Students participated in the SmartAR Module Study

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