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

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I, SALINI A/P KRISHNA PILLAI (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled THE EFFECT OF AUGMENTED REALITY MODULE ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT AND MOTIVATION IN LEARNING PROGRAMMING is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

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5/6/2025

Date

Signature of the Supervisor

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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.

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

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, 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).

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.

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 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 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 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.

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) 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 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 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 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.

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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 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).

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 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.

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 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.

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 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:

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

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?

1.6 Hypothesis

The hypothesis in this study as below:

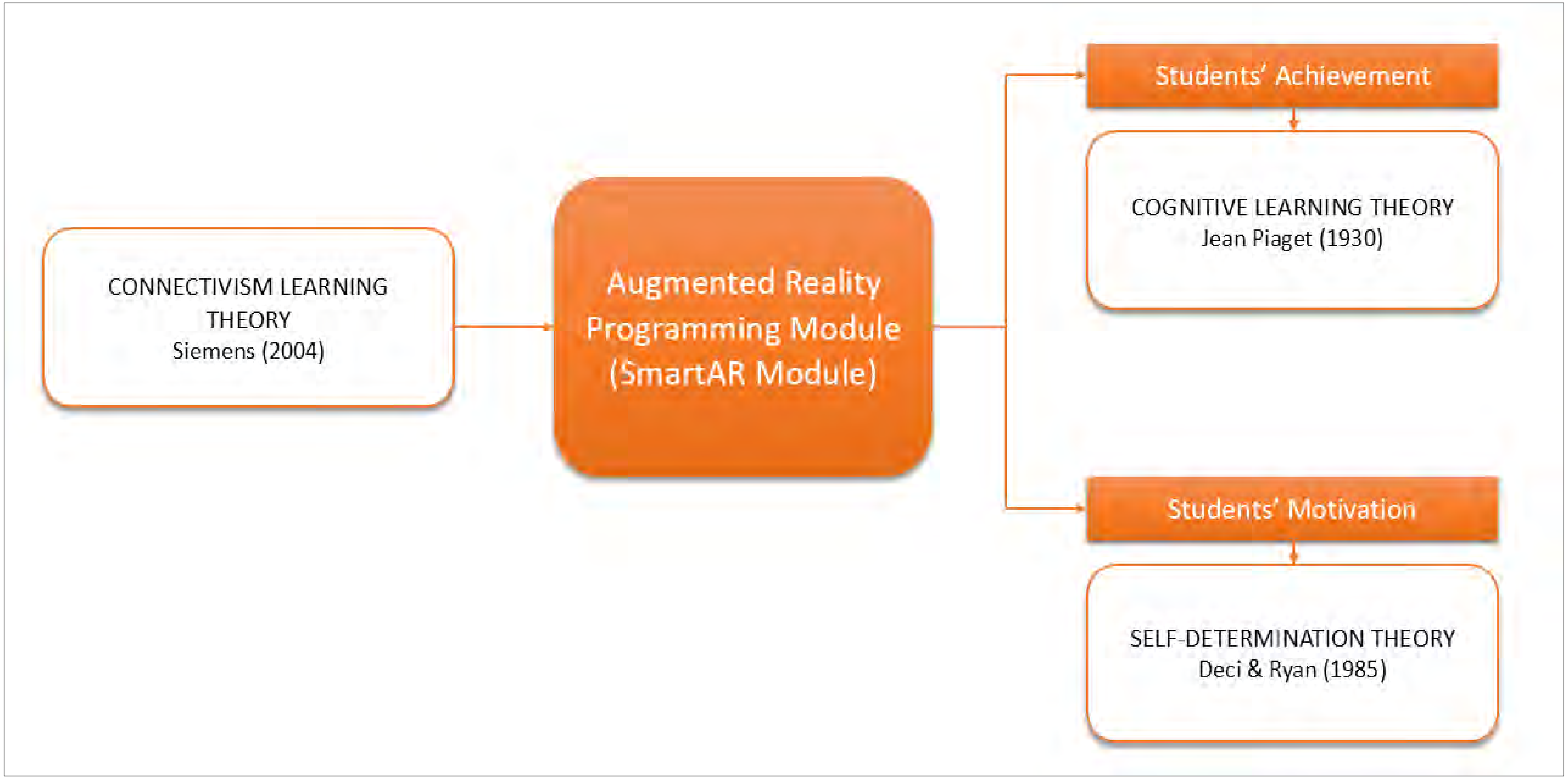
> Ho1: There is no significant difference between the pre-test mean scores and post-test mean scores in students' achievement in learning programming before and after using the SmartAR Module.

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.

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 teachercentered 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 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 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 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 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.

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 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 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

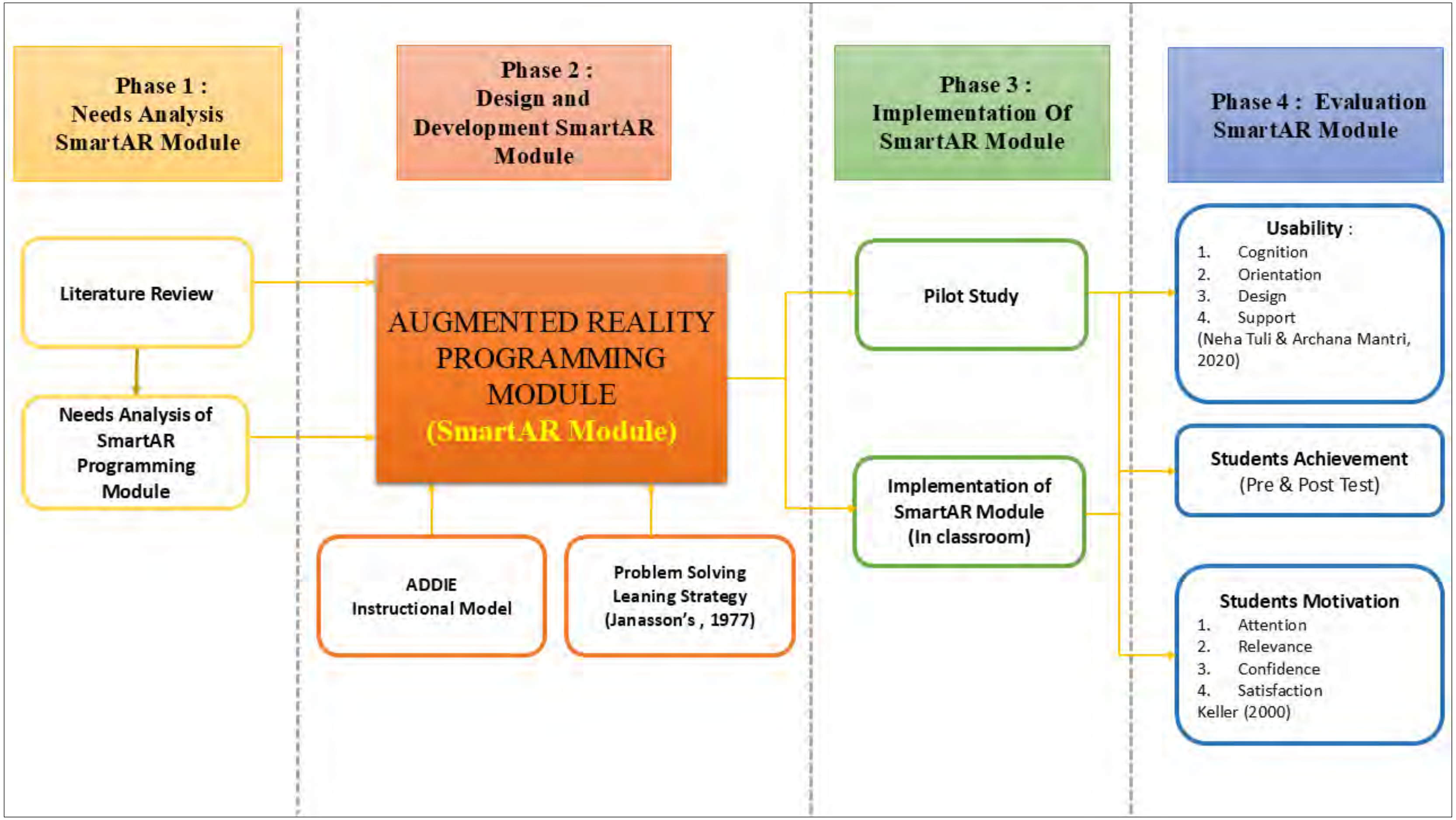
The second dependent variable of the study was students' motivation, measured after using the SmartAR Module. This study utilized the Instructional Materials Motivation Survey (IMMS; Keller, 2010) questionnaire, and to interpret the motivation levels, a scale similar to that used by Zainuddin, Chu, Shujahat, 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 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.

Figure 1.2

Conceptual Framework of the study



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.

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).

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 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.

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.

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 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.

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.

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

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 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.

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.

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' 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.

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 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.