DEVELOPMENT OF SCRATCH-BASED MATHEMATICS MODULE USING INQUIRY-BASED LEARNING TO ENHANCE COMPUTATIONAL THINKING AND MOTIVATION

MASYITHOH BINTI MD ZUBER

UNIVERSITI SAINS MALAYSIA

2025

DEVELOPMENT OF SCRATCH-BASED MATHEMATICS MODULE USING INQUIRY-BASED LEARNING TO ENHANCE COMPUTATIONAL THINKING AND MOTIVATION

by

MASYITHOH BINTI MD ZUBER

**Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy**

September 2025

ACKNOWLEDGEMENT

I would like to express my gratitude to Allah SWT for giving me opportunity and guidance endlessly in finishing my thesis PhD. First, I would like to express my deepest gratitude to the Ministry of Education Malaysia through the Education Sponsorship Division which has fully sponsored my studies. Next, my humble gratitude and thanks to my outstanding supervisor, Associate Professor Dr. Mohd. Asyraf bin Mansor, who has always supported and guided me since the application session for the HLP KPM scholarship until I completed this thesis. Besides that, thanks to my co-supervisor Associate Professor Dr. Chew Ching Ming who helped me a lot with the educational research. Without them, I may not have been able to complete this thesis. My deepest gratitude also to the 55 experts involved, 18 excellent teachers, EPRD, JPN, KPM, the schools involved, school administrators, teachers, and students who have helped throughout this study. I also thank the dean, deputy dean, lecturers, and all staff at the School of Distance Education for all their hard work. I also take this opportunity to thank SDE and IPS which have funded my presentation in conferences at RECSAM, Penang and ICRES, Türkiye. Not forgetting my beloved family, my parents, Md Zuber bin Omar and Che Yam binti Abdullah, my parents-in-law, my children, Khairul Muadz, Khaira Haura’, Khaira Yusra, and Khairul Fahim, thank for all your understanding and sacrifice, my siblings, and my friends. Special thanks to my husband, Mr. Khairul Syafiq bin Osman, who has been an incredible source of encouragement and ideas throughout this learning journey. Last but not least, my fellow post-graduate friends who have been a supporting pillar to encourage one another and always have my back. This thesis would not have been possible without the efforts of numerous people, and all of them deserve my deepest appreciation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF SYMBOLS

κ	Cohen’s Kappa
$\bar{x}$	Sample median
s^2	Sample variance
s	Sample standard deviation
r_s	The Spearman rho correlation coefficient
δ	Threshold values
$\bar{A}$	Aggregate calculation
r	Correlation coefficient
r_{SB}	Spearman-Brown formula
$r_{y_1 y_2}$	Pearson correlation
$I - CVI$	Item-level content validity index
CVR	Content validity ratio
$S - CVI$	Average content validity index

LIST OF ABBREVIATIONS

4D	Define, Design, Develop and Disseminate
4IR	Fourth Industrial Revolution Policy
5E	Engagement, Exploration, Explanation, Elaboration, Evaluation
ABC-Thinking	A Bebras Computational Thinking
AI	Artificial Intelligent
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ARCS	Attention, Relevance, Confidence and Satisfaction
BPK	Curriculum Development Division
CAS	Computing at School
CS	Computer Science
CT	Computational Thinking
CTEPI	Computational Thinking Education Policy Interactives
CTPF	Computational Thinking Pedagogy Framework
CTtLP	Computational Thinking Test for Lower Primary
DDR	Design and Development Research
DM	Digital Making
DSKP	Standard Document of Teaching Content
DSTIN	National Science, Technology and Innovation Policy
EDP	Engineering Design Process
EI	Emotional Intelligent
ELT	The Experiential Learning Theory
EPRD	Education Planning and Policy Research Division
FNCC	Finnish National Core Curriculum
FNCC	Finnish National Core Curriculum
HOTS	High Order Thinking Skills
IBL	Inquiry Based Learning
IBME	Inquiry Based Mathematic Education
IBSE	Inquiry Based Science Education
ICT	Information and Communication Technologies
IMMS	Instructional Materials Motivation Survey

IPG	Teacher Education Institute
IR	Industrial Revolution
JPN	State Education Department
KBSR	Integrated Curriculum Primary School
KBSR	New Curriculum Primary School
KLS	Old Primary School Curriculum
KLSM	Old Secondary School Curriculum
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MOE	Ministry of Education
MOSTI	Ministry of Science, Technology and Innovation
NCF	National Science Foundation
NCTM	National Council of Teaching of Mathematics
OECD	Organisation for Economic Co-operation Development
PDF	Portable Document Format
PISA	Programme for International Student Assessment
SBM	Programming in Mathematics via Scratch
PPD	District Education Office
PPPM	Malaysian Educational Development Plan
PT3	Form Three Assessment
QR	Quick Response
RBT	Design & Technology
SDG	Sustainable Development Goal
SEA-PLM	Southeast Asian Primary Learning Metrics
SISC+	School Improvement Specialist Coach
SPSS	Statistical Package for Social Science
STEM	Science, Technology, Engineering, and Mathematics
TIMSS	Trends in International Mathematics & Science Study
TMK	Information Technology and Communication
UK	United Kingdom
UNESCO	United National Educational, Scientific & Cultural Organisation
UTAUT2	United Theory of Acceptance and Use of Technology 2
W2020	Wawasan 2020

LIST OF APPENDICES

PEMBANGUNAN MODUL MATEMATIK BERASASKAN SCRATCH MENGGUNAKAN PEMBELAJARAN BERASASKAN INKUIRI UNTUK MENINGKATKAN PEMIKIRAN KOMPUTASIONAL DAN MOTIVASI

ABSTRAK

TIMSS 2023 menunjukkan murid di Malaysia masih bergelut dalam kemahiran berfikir secara logik dan sistematik dalam penyelesaian masalah, sama ada pada aspek penerangan, justifikasi, dan juga generalisasi hubungan matematik. Situasi ini menggambarkan bahawa murid-murid ini masih kurang berkemahiran menaakul dan berfikiran komputasional. Oleh itu, pengintegrasian pengaturcaraan dalam pembelajaran matematik dilihat sebagai satu peluang dalam mengillustrasikan konsep-konsep matematik ini secara visual, menarik dan melatih murid berfikir secara komputasional. Kajian ini bertujuan untuk membangunkan dan menilai keberkesanan modul matematik berasaskan *Scratch* (SBM) bagi meningkatkan kemahiran pemikiran komputasional (CT) dan motivasi murid tahun lima di sekolah rendah. Penyelidikan ini merupakan sebuah kajian pembangunan menggunakan pendekatan kajian penyelidikan reka bentuk dan pembangunan (DDR) yang telah dimodifikasi. Oleh itu, kajian ini mempunyai tiga fasa utama. Fasa pertama adalah fasa analisis keperluan yang menggabungkan instrumen temubual separa berstruktur bersama lapan pendidik dari beberapa institusi pendidikan dan soal selidik UTAUT2 bersama 101 orang guru matematik sekolah rendah. Dapatan fasa pertama menunjukkan guru-guru cenderung untuk dipengaruhi oleh faktor jangkaan pretasi dan motivasi hedonik dalam pengintegrasian pengaturcaraan dalam instruksional matematik sekolah rendah. Seterusnya, fasa kedua melibatkan temu bual separa berstruktur bersama empat orang pakar dan soal selidik bersama lima belas orang pakar-pakar bidang. Dapatan fasa ini menunjukkan terdapat keperluan pembinaan modul matematik yang mengintegrasikan pengaturcaraan dan modul SBM telah dibina berdasarkan elemen-elemen yang telah disepakati oleh pakar-pakar bidang. Fasa akhir melibatkan penilaian keberkesanan melalui kajian kuasi-eksperimen yang disertai oleh 82 orang murid tahun 5 sekolah rendah. Hasil analisis ujian ANCOVA terhadap pra dan pasca ujian CT (CTt) yang dijalankan menunjukkan terdapat perbezaan yang signifikan terhadap perkembangan kemahiran CT murid yang menggunakan modul SBM dalam pembelajaran ($F = 6.36$, $\rho - value = 0.003$). Manakala ujian ANOVA terhadap *Instructional Material Motivation Surveys* (IMMS) menunjukkan terdapat perbezaan skor yang signifikan terhadap motivasi murid dan ujian Tukey HSD mengesahkan purata skor bagi modul SBM adalah signifikan lebih tinggi bagi domain relevan (58.77) dan keyakinan (59.48) berbanding dua kumpulan kawalan lain. Tuntasnya, dapatan kajian menunjukkan modul SBM dapat meningkatkan kemahiran CT murid dan tahap motivasi murid tahun 5. Modul ini bukan sahaja mengangkat hasrat Kementerian Pendidikan dalam memperkasakan penggunaan digital, malah menyediakan satu bantuan instruksional kepada guru dalam pengajaran dan pembelajaran di bilik darjah.

DEVELOPMENT OF SCRATCH-BASED MATHEMATICS MODULE USING INQUIRY-BASED LEARNING TO ENHANCE COMPUTATIONAL THINKING AND MOTIVATION

ABSTRACT

TIMSS 2023 illustrated that Malaysian students were struggling with the logical and systematic thinking needed to solve problems through explanation, justification, and generalisation of mathematical relationships. It portrayed that Malaysian students were lacking in mathematical reasoning and CT. Hence, integrating programming into mathematics learning is an opportunity to illustrate these abstract concepts visually and train students to think computationally. This study aims to develop and evaluate the effectiveness of a Scratch-based mathematics (SBM) module to improve the computational thinking (CT) skills and motivation of year five students in primary school. This study is a developmental study that employs a modified design and development research (DDR) approach and consists of three main phases. Therefore, it has three main phases. The first phase involved a needs analysis, which included a semi-structured interview with eight educators from different institutions and the UTAUT2 questionnaire involving 101 primary school mathematics teachers. The first phase findings reveal that teachers tend to be influenced by performance expectations and hedonic motivation when integrating programming into primary school mathematics instruction. Next, the second phase involved semi-structured interviews with four experts and questionnaires with fifteen field experts. The findings of the second phase indicate that there is a need for a module that integrates programming into mathematics learning, and the SBM module was developed based on elements that had received expert consensus. The final phase involved evaluating the effectiveness through a quasi-experimental study with 82 year five students in the primary school. Based on the ANCOVA analysis of pre- and post-test scores, CT tests (CTt) show that there is a significant difference in the CT development using the SBM module in learning. Meanwhile, the ANOVA test on the Instructional Material Motivation Surveys (IMMS) found a significant difference between groups in student motivation, and Tukey HSD analysis indicates that the mean score of the SBM module is significantly higher in the relevance (58.77) and confidence (59.48) domains compared to other control groups. Overall, the findings show that the SBM module has an impact on the development of computational thinking and the level of motivation of students. This module not only upholds the enforcement of the digital usage aspiration of the Ministry of Education but also provides instructional materials for helping teachers in their instruction.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Mathematics is one of the fundamental skills that need to be mastered by students all over the world. From the simplest things as counting one, two, three, to the complex part of logical reasoning and abstraction in mathematics needs proper understanding. Besides, the parietal lobe of the brain responsible for processing all the inputs gained from the senses and can be activated by tasks involving number operations (Hamid et al., 2011). When doing creative mathematical reasoning, the brain will construct the mental processes and synthesise all the contextual information (Wirebring et al., 2022). Numeracy skills are the basis for mastery the Science, Technology, Engineering, and Mathematics (STEM) discipline at all educational level and needed in preparing technical competent for most industries in the future (Academy of Science Malaysia, 2018). Therefore, mathematical skills are a better indicator of university student performance who achieves first-class honours degree in university, especially in STEM courses (Delaney & Devereux, 2019). However, the Organisation for Economic Co-operation Development (OECD) survey of adults' skills revealed that 20 percent of respondents exhibited low performance across all disciplines and encountered difficulties with solving fundamental arithmetic and numeracy problems (Schleicher & Scarpetta, 2024). Many real-life problems cannot be resolved without mathematical skills since it is a part of analytical thinking. Analytical thinking enhanced cognitive control, working memory and focused attention without access to long-term memory (Williams et al., 2020). That skill develops the ability to think, manage how things work and develop wisdom. Hence, the student becomes smarter and provides an opportunity to get to the world.

Education is essential to the development of innovation as well as solutions to problems in the future. The relationship between mathematics education and programming is symbiotic and reliant. Mathematics is a fundamental skill for designing a coding language to facilitate the process for computers to handle commands, while programming can illustrated the mathematical concepts visually. Furthermore, programming skills are one of the future skills that need to introduce to the younger generation in speedy technological of today environment. Engaging in programming activities helps develop problem-solving skills through assessing problems, arranging a series of instructions, logical arguments, and abstract thinking. These skills are essential in empowering the thinking process and reasoning. Therefore, most employers consider these problem-solving skills as the indicator of employee selection. Since, 21.1 percent of coding inventors began experimenting with programming between 11 and 15 years old (HackerRank, 2018). The critical thinking abilities and future employment prospects will benefit from an early introduction to programming and mathematics in primary school level.

The fields of mathematics, programming, and computational thinking (CT) are all interconnected. While analytical thinking necessitates mathematical skills and CT to solve an issue in an ordered manner. Although CT can be interpreted in a wide range of domains, CT skills involve processes of problem decomposition, pattern recognition, abstraction, and algorithms (Yadav et al., 2022), and all these skills are closely related to mathematical skills. CT in mathematics education is a mental process involving the generation of problems in systematic computer-based solutions (Li et al., 2022). In practice, CT provides a framework for developing essential problem-solving abilities by fostering the formation of tangible and abstract knowledge through experience, investigation, and reflection (Kong & Wang, 2024). Therefore, some pioneers in CT highlight the significance of exposing children to these skills as early as feasible, as it can aid in their cognitive growth (Papert, 1980; Wing, 2008). Nonetheless, all the new policies were made to improve student performance, especially in mathematics and increase future skills for employability of the students in the future. Thus, the amalgamation of programming skills, CT and mathematical knowledge will be essential skill sets that fit into a future-ready career based on the industrial revolution (IR) 4.0.

Education is sophisticated and demanding in today’s world. To ensure the holistic development of children, the cognitive, emotional, and social aspects of learning must be simultaneously fostered. Without the ongoing support of the motivational part, the intellectual, psychological, and social development of the students will be hindered as every desire and need to be fulfilled requires continuous action. In a nutshell, people need inspiration to get up and keep working towards their goals. Interest, curiosity, and eagerness of the young learners to do assigned tasks are all sparked when they are motivated to do so (Boström et al., 2023). This excitement makes the classroom learning experience engaging and enjoyable. Therefore, this study aims to develop a mathematics learning module that helps students discover primary school mathematics concepts while expanding their CT skills and supporting intrinsic motivational needs.

1.2 Background of Study

When it comes to narrow the social inequality between children from different socioeconomic backgrounds and producing a competitive next generation, there is no better tool than education. Hence, both developed and developing nations recognise the importance of educational parity and focus on making sure everyone gets the opportunity to receive a quality education. To guarantee that all children in this world have access to quality education on equal terms, United National Educational, Scientific and Cultural Organisation (UNESCO) has established Sustainable Development Goal (SDG) 4 to improve world education strategies. SDG 4 reinforces the need of quality education. This quality education aims to achieve five primary goals: universal access to quality basic education, enhancement of higher and technical education, promotion of lifelong learning competencies, elimination of educational gaps, and advancement of skills required for the future economy. Whilst, in Malaysia, the Malaysian Education Development Plan (PPPM), Access to Education, and Equality in Education are all goals set by the Malaysian Ministry of Education (MOE) for the year 2025 to be achieved. From this core, all synergies are mobilised to achieve an optimal education for all students from pre-kindergarten through graduate school.

As educational policy keeps changing and expanding, students in some countries have been introduced to mathematics in preschool as early as three years old (Skolverkat, 2019). Meanwhile, primary school ages vary widely, 4 in Northern Ireland, 5 in England, 6 in Japan and Singapore, and 7 in Malaysia, Finland, Denmark, and Sweden (Department for Education, 2013b; MEXT, 2008b; The Northern Ireland Curriculum Primary, 2007;MOE, 2023; Ministry of Education and Culture, 2014). The approaches and characteristics of teaching mathematics differ from one to another based on their resources, culture, education philosophies and demographics. Some countries aim for the mastery of primary mathematical concepts, while others focus on nurturing an interest in mathematics, increasing confidence in mathematics, fluency in mathematical reasoning, or the ability to solve mathematical problems. While in the Malaysian context, mathematics education seeks to enhance students' comprehension of mathematical concepts, skills, and principles by efficiently utilising mathematical knowledge and abilities in daily life. Conclusively, most of the mathematics curriculum insists on developing potential of the students to use mathematical knowledge and skills in countering their daily situations. Those skills are essential not only to develop mathematical understanding but also to nurture creative thinking, analytical thinking, manipulating acquired skills in problem-solving and building self-confidence.

Recently, most nations were beginning to implement new strategies to strengthen their respective educational programmes. With advanced tools and good infrastructure facilities, it is believed that the outstanding education can be provided (Timotheou et al., 2023). Introducing CT and programming was considered a bridge to curriculum and life skills (Latifah et al., 2024). Hence, it is not an exaggeration that Nordic countries put CT skills and programming on par with numerical and literacy (Bocconi et al., 2018). Alongside literacy and numeracy, which provide students with fundamental skills of reading, writing, and counting, CT improves analytical thinking of the students (Wing, 2006). It is enabling them to think critically to solve everyday problems. The potential of CT and programming in education is undoubted, but how to exploit it in instructional is still recently debated. Thus, eleven European countries have just finished new educational programmes that involved CT and its relevant topics, with seven more countries on the way (Berge, 2017). In fact, Mathematics appeared to be the most frequent subject that links in terms of coverage and learning outcomes with the rationale that it fosters problem-solving, logical thinking skills, and motivates students to learn mathematics (Bocconi et al., 2018; Skolverket, 2018). As programming and CT teaches students that there are many possible solutions, explanations and techniques to a given problem that can fit any given situation (Taylor et al., 2020). Therefore, the incorporation of programming into mathematics lessons is viewed as an ideal opportunity to enhance mathematical skills, as well as to cultivate CT and motivate students.

Among all kinds of programming, unplugged and visual-based programming represent appropriate options for incorporating into mathematics education. Without requiring sophisticated programming language, both are easier and simpler for novices. Hence, it provides students more room to explore mathematical concepts and experiment with numerous algorithmic routes to completing a task. Currently, a few programming software can aid in mathematics instructional. Scratch has become one of the worldwide most common software programs. In conjunction with supporting educational materials and providing a platform for community interaction, it is free and available to all students. Recently, this software has been incorporated into the Design and Technology (RBT) curriculum in Malaysia. Hence, students in years 4, 5, and 6 of primary education are now familiar with Scratch.

Both students with different performance must be motivated to retain their learning journey and avoid math anxiety. Math anxiety has a significant reciprocal relation with lower performance in mathematics (Gunderson et al., 2018; Mutlu, 2019) and is typically caused by unpleasant sentiments from the emotional, cognitive, and behavioural aspects that lead to students avoiding mathematics and all mathematics-related events (Krinzinger et al., 2010). Even, Shanghai students have had the highest Programme for International Student Assessment (PISA) scores for two years in a row, their confidence in mathematics remains low in terms of self-perception and classroom engagement (Yao et al., 2018). Hence, both situation leads to stress and disturbs the focus to learn mathematics. But it can be alleviated by satisfying the intrinsic or extrinsic psychological requirements of the students. Motivation of the students rises when their emotional requirements are addressed. There is no denying the power of motivation to maximise academic performance. Motivation transforms into a spark that can inspire students to be engaged in class and eager to learn. Consequently, there is a critical need to improve mathematics instruction by highlighting student motivation (Xia et al., 2022).

Students can acquire a thorough comprehension of skills and knowledge if the learning material is well-designed, well-organised, and effective. Ultimately, an effective learning transition process can scaffold students' exploration and develop their potential. Inquiry-based learning (IBL) is one of the most natural ways to make students engage actively in their learning (Erickson et al., 2017). Through IBL, students take a sense of ownership of their education and have a reduced necessity of close teacher monitoring. Besides, they also engage in higher-order thinking skills such as observation, communication, classification, prediction, questioning, hypothesis testing, and interpretation (Warner & Sower, 2005). With such engagement in learning, students can pique curiosity and motivation in more active ways.

1.3 Problem Statement

Developing mathematical knowledge and skills of the children alongside the most current soft skills foundations, such as digital literacy, high-level thinking, and CT, has become a necessity. A general worry about dealing with mathematics anxiety and lower analytical skills among students exists across the world. The most reason for negative attitudes towards mathematics was students do not feel attracted to it and find mathematics to be a subject that requires 'too much work' (Aguilar, 2021). Further, those students will demonstrate difficulties with a variety of foundational mathematical skills, including the capacity to solve problems using simple arithmetic, select the proper computation, and compare magnitudes (Nelson & Powell, 2018).

Even Shanghai primary school students with the highest PISA scores demonstrate poor skills in solving problems, analytical abilities, and intercultural interaction (Cai et al., 2017).

In Malaysia context, Year 5 primary school students performed well on the Southeast Asian Primary Learning Metrics (SEA-PLM) 2019, with 64 percent obtaining band 6 or higher (EPRD, 2022). Students at this level demonstrated Mathematics skills that correspond to the expected achievement at their end of primary school. Almost two-thirds of Malaysian students have mastered foundational mathematics skills. These students were defined as being prepared to meet the challenges of a 21st century skills-based curriculum when they entered secondary school. However, in international assessment for secondary school illustrated different findings. Contrarily, the Trends in International Mathematics and Science Study (TIMSS) 2023 highlighted that Malaysian students in grade eight average score are 405, which is at the basic level of mathematical knowledge, while 48 percent failed to achieve the basic level of mathematical knowledge (EPRD, 2024). Meanwhile, in the cognitive thinking domain, these Malaysian students received an average score of 405. This result indicated that these students were still struggling with the logical and systematic thinking needed to solve problems through explanation, justification, and generalisation of mathematical relationships. It portrayed that Malaysian students were lacking in mathematical reasoning and CT. The same nuance was found in the PISA 2022 Malaysia report. In comparison to other domains, the reasoning domain exhibited the lowest percentage of mathematical literacy achievement, with a mere 38.5 percent (EPRD, 2023). This result was significantly far lower than the global average of 69.1 percent and demonstrated the weakening of Malaysian students in reasoning skills.

When comparing these three international assessments, SEA-PLM shown relatively strong results, as it does not include a reasoning domain and focused solely on the basic knowledge that primary school students were expected to acquire. Those three assessments also revealed that students have problems in reasoning and solving problems due to lack of logical and systematic thinking skills. Students exposed to traditional teaching methods demonstrated no significant improvement in problem comprehension and strategic thinking (Alashwal & Barham, 2025). Therefore, despite exhibiting good basic mathematical proficiency at the primary level, there remained a critical need to strengthen reasoning abilities of the students to support their learning progression in secondary school.

There is a significant correlation between anxiety and confidence in mathematics performance towards learning mathematics (Norwaheda & Siti Mistima, 2022). Thus, high confidence and a low level of anxiety lead to better performance in mathematics. However, the outcomes of the TIMSS 2023 international study reveal a concerning reality. Seventy percent of students lack confidence in mathematics (EPRD, 2024). This finding suggests a substantial disparity between psychological characteristics of the pupils and their proficiency in mathematics. Lacking confidence may result in increased anxiety, impairing concentration, comprehension, and academic achievement in mathematics.

Further, the TIMSS 2019 report states that more than two-thirds of teachers need professional development in integrating technology into their mathematics teaching and improving their thinking process and problem-solving skill of the students. But only 35 per cent of the teachers integrate mathematics instructions and assessments into technology. Even though most educators acknowledge that technology has a place in instruction and there is room for growth in teachers' ability to leverage it for benefit of the students, only a minority use technology in their classrooms (DeCoito & Richardson, 2018; Perienen, 2020). Even most mathematics teachers in Malaysia concur that they do not know mathematics software (Chee & Rosli, 2020). Besides, mathematics teachers are less likely to employ technology in their classrooms than science teachers (Li et al., 2018). It shows that even though there are benefits and considerations to using technology in the instructional, most educators were unable to use this tool effectively. Over the last five years, there has been an increase in research on computing in education, with several literature reviews (Dagienė et al., 2019; Holmes, 2019; Rich et al., 2020; Uppal, 2020; Waite et al., 2019). These mainly address pedagogy, curriculum, assessment, and experiences of primary school students. Surprisingly, a module to assist teachers in preparing and experiencing integrating programming in mathematics education, particularly in K-12, is missing from these studies.

This study intends to address the primary issue of poor computational thinking skills and little motivation among students in mathematics education. Both issues must be addressed, as they impact students' performance and engagement in mathematics. Consequently, a mathematics learning module that prioritises the cultivation of computational thinking and motivation must be designed.

1.4 Research Objectives

Examining the practicality of incorporating programming into mathematics classrooms with the goal of fostering CT and student motivation is the focus of this research. In this context, Scratch-based Mathematics (SBM) module designed and developed to empower the CT and motivation of the students. This module was designed for fifth-grade pupils, as they were introduced to the Scratch application in fourth grade. Consequently, year five pupils are best suited to use this module to apply their Scratch abilities to the Coordinates learning subject. This study used the Design and Development Research (DDR) approach founded by Richey and Klein (Richey & Klein, 2014). The objectives of the study as follows:

i. To determine the factor that influence teachers' acceptance of using the programming in the classroom and mastery of programming skills among primary school mathematics teachers.

ii. To evaluate the need to develop of Scratch-based Mathematics (SBM) module to enhance CT and motivation among primary school students.

iii. To design the SBM module to improve CT and motivation based on Inquiry-based Learning (IBL) model for primary school students by identifying the learning objectives, components, learning strategies, technology tools, and suitable media in SBM module based on consensus of the experts.

iv. Evaluate the effectiveness of SBM module in developing CT skills and enhancing motivation level of the year five primary school students in mathematics.

1.5 Research Questions

The research questions are conducted to answer the research objectives based on the three phases. Therefore, the study will answer the following research questions.

i. What factors are expected to influence primary school mathematics teachers to incorporate programming into their instruction and mastery level of programming skills among mathematics teachers?

ii. Why is there a need to develop Scratch-based Mathematics (SBM) module to enhance CT and motivation among primary school students?

iii. How to design SBM module to improve CT based on Inquiry-based Learning (IBL) model for primary school students by identifying the learning objectives, components, learning strategies, technology tools, and suitable media in SBM module based on consensus of the experts.

iv. Is there any significant impact of SBM module in developing CT skills and enhancing motivation level of the year five primary school students in mathematics?

1.6 Research Hypotheses

This study aimed to identify the following relationship.

Hypothesis for independent variable one (IV1).

H_o: By controlling for covariate variables (pre-test scores), there is no significant impact on CT skill of the students when using the SBM module.

H_1: By controlling for covariate variables (pre-test scores), there is a significant impact on CT skill of the students when using the SBM module.

Hypothesis for independent variable two (IV2).

H_o: There is no significant impact on interest of the students in learning mathematics when using the SBM module.

H_2: There is a significant impact on interest of the students in learning mathematics when using the SBM module.

1.7 Significance of Study

Based on the problem statement, there is a need to develop mathematics teaching modules that integrate the use of technology, especially programming. Various applications of technology can be used in teaching and learning sessions. However, programming offers several advantages and needs to be incorporated into the mathematics learning environment. The existence of this module is seen to uphold the Malaysian Ministry of Education (MOE) efforts in integrating mathematics and science in technology and engineering. The introduction of a programming topic in the RBT syllabus by 2020 is an opportunity to intertwine mathematics and RBT subjects. In addition, teachers nowadays have at least basic skills in using simple software and technology such as mobile phones. The finding of Chew & Mohamed (2021) shows that preschool teachers in Kuala Selangor District possess high skills in using ICT, such as Microsoft Word and Microsoft PowerPoint. However, exposure and empirical evidence on using programming software specifically in teaching mathematics in primary school are rarely explored by teachers, especially in Malaysia’s context. Therefore, a programming module in mathematics teaching is a good opportunity as an effort to share ideas and develop the skills of the teachers to improve the quality of the learning environment. There are several factors and importance to develop a mathematical programming module for the primary school purposes of the students. Among the factors are:

(i) Numerous empirical evidence has been done and shown that technology is a useful tool to increase interest and reduce mathematical anxiety of the students in learning. Although this study is high significance with mathematical skills, SBM Module is designed by the researcher to promote interest in mathematics and build up CT of the students. Even students with early visual-spatial skills predicted later higher mathematical achievement, but students' working memory indicated gains in mathematical achievement depended on assessment time differences (Kahl et al., 2021). This module can be one of the alternative and interesting approaches to enrich the learning session as a supportive and positive learning environment.

(ii) Despite learning mathematics and RBT, outcomes of this study fortified students with the 21st century skill which is programming. Programming is a vital skill that enable students to invent and develop critical thinking in designing their own ideas. Students will be an inventor of the product and no longer just a consumer, which is a crucial skill needed in the future.

(iii) This module can be used by mathematics teacher. There is various module in teaching mathematics but rarely there is a module that use programming especially in primary school level. This study offered significant contribution to the available literature by strengthening the existing teaching mathematics approaches. In this SBM module is considered as leading module to support the teachers and schools to scaffold students learning mathematics thru programming. It does not only allowed students to explore mathematics idea but also enhance students understanding in RBT and develop critical thinking.

(iv) This module will be a new paradigm in mathematics education system in Malaysia as other developed countries have started to implement programming and coding in their primary school curricula.

(v) SBM modules covering mathematical skills, programming and CT can be a benchmark for integrating other programming skills in mathematics. Many more programming skills and software can be explored in the future.

(vi) This study also offered some suggestions to potential researchers and educators to explore more on programming and educational robotics in other topics, other subjects, and other learning theories.

1.8 Rationales of the Study

This study was conducted on several considerations. Malaysia's current policies encourage the integration of mathematics and science education into technology and engineering. Besides, the development of the SDGs could be one of the foundations of programming education in schools. The SDGs are part of a 15-year action plan adopted in 2015 by all United Nations member states as part of the 2030 Agenda for Sustainable Development, which aims to increase prosperity, promote peace, and eradicate global poverty by 2030. It aims to make human rights a reality for all through 17 SDGs and 169 targets (Department of Economic and Social Affairs, 2015). This research is particularly relevant to Goal 4, quality education. The goal of this educational experience is to provide students with strategies for problem solving and communicating ideas using a computer and the cooperation of a programming language applied to mathematics. This quality learning experience enhances the level of mathematical skills of students presently while concurrently strengthening their soft skills for future endeavours.

In conjunction with those policies, Malaysia primary school curriculum newly introduces programming in the RBT syllabus. Therefore, the researcher takes these chances to integrate the programming in RBT syllabus with mathematics primary school curriculum. As programming used widely been explored as an extra-curricular activity in Malaysia either in primary or secondary school. However, the integration of programming in mathematics curricula are rarely explored in classroom setting. Besides, chairman of the National STEM Movement, Prof Datuk Dr. Noraini Idris, in her speech at *Hari Cahaya Malaysia* which was posted lived on *Apadilangit*'s official Facebook account on 28th May 2020, said the STEM Education approach was important to increase the number of students pursuing STEM as based on statistics, only 19 percent of approximately 447000 candidates who sat for the Form Three Assessment (PT3) entered the science stream when setting foot into form four (Apadilangit, 2020). Ideally, a drastic step should be taken immediately to address this problem. In conclusion, this study is important to be implemented to deepen the learning of mathematical programming-oriented design activities in the context of primary schools in Malaysia. Programming has a huge potential to increase interest of students through activities that are practical in nature but also CT skills can also be strengthened. Therefore, the study is expected to help fellow teachers, schools, District Education Office (PPD), State Education Department (JPN) and MOE on the contributions of the study to enhance national education.

1.9 Scope of the Study

This study will focus to develop and evaluate the effectiveness of the SBM module in the primary schools setting. In terms of methodology, this study focuses on developing and evaluating the SBM module to foster CT and motivation for primary school students. Therefore, the module focuses on integrating programming into mathematics subjects. Due to the complexity and precision needed to construct modules, daily lesson plans, and activities based on cognitive and theoretical preparation, this module will only adapt two mathematics topics. The module only covers coordinate and space. Whilst online questionnaires and online interviews via email will be administered throughout the study to address issues of accessibility and time restrictions.

Apart from that, the purposive sampling will be used to examine the effectiveness of the module. Hence, the samples are limited to students and teachers in Penang only. Penang was selected due to the partnership between the state government and non-governmental organisations in establishing the Penang Science Cluster to improve potential of the students in the field of digital technology. Expert technical support, training, and technological resources can be obtained more easily to ensure the accomplishment of this project. Therefore, the study does not represent the entire population of Malaysian students. The findings of this research should not be generalised beyond the scopes of chosen samples as different students have different background and the exposure to the ICT learning environment.

Next are the participants in the research. It will involve year five students in national primary schools as RBT will only be taught to students in level two primary schools. Since year four is an introduction to programming, year 5 is the most appropriate for the study to be conducted as the students already have a foundation in programming. In terms of software, this study focuses on Scratch as a pedagogical medium for students to explore mathematical concepts to review the development level of CT and increase the level of mot. Therefore, this study does not focus on programming skills or other programming software. Only activities in the form of unplugged and visual-based programming will use throughout this study.

Meanwhile, the participants for the evaluation of the effectiveness of the SBM module prototype involved students who were in schools that had stable internet network system, computer labs and computers equipped with ‘Scratch’ software. On the other hands, the structure and results of the study may vary based on the cognitive development of the students, the environment, teachers’ strategies, and other programming software.

1.10 Operational Definitions of Terms

There are several terms used in this study that need to be defined according to the context of their use.

1.10.1 Development

Seels & Richey (1994) stated development research is the systematics study of designing, developing, and evaluating instructional programs, process and products need internal consistency and effectiveness. Therefore, in this study context development and evaluation is the process of the module must go through. Starts with the need analysis on the purpose of developing the module, then proceed to design and develop the module with the expert consensus, the flow of the research follows the systematics scheme of work. In the end, the module that had been constructed and designed will have to undergo the evaluation process to test its effectiveness.

1.10.2 Scratch-based Mathematics (SBM)

Scratch is defining as a simple visual interface that allows children to create digital stories, games, and animations by using the coding language (Scratch Foundation, 2022). It is a block-based programming tool that integrates a simple programming language. The software employs a friendly visual interface and ‘drag and drop’ features to produce digital narratives, games, and animations. Within the context of this study, Scratch is utilised in mathematics learning to clarify and implement mathematical concepts while simultaneously promoting computational thinking and problem-solving abilities in a creative way.

1.10.3 Module

Module is defined as a teaching and learning unit that discusses a particular topic in a sequence and systematic way to make it easy for students to master the learning topic (Sidek & Jamaludin, 2005a). In other words, module is an instructional package dealing with a single conceptual unit that enables each student's select and master that unit of content individually (Russell & Lube, 1974). The modules can be used individually or combine as modular approach. Hence, in this study context module is an instructional package of learning a particular topic to master that topic in easy and systematic way.

1.10.4 Inquiry-based Learning

Learning through inquiry is a method of actively constructing developing self-understanding (Greenwood & Kelly, 2020). One must first engage in a process of inquiry, which includes questioning, learning discussion, peer collaboration, information selection, collection, interpretation, and analysis to draw conclusions to address the tasks or questions presented. Hence, in this study context IBL is a learning activity throughout this module that engaging students in the inquiry process to develop their own understanding and knowledge.

1.10.5 Computational Thinking

CT is defined as a process to enhance cognitive skills and support the teaching and learning process (Cansu & Cansu, 2019). While Piatti et al., (2022) defines CT as a cognitive activity or taught process that consists of the problem setting can be solved, a particular algorithm can be represented and implemented by an agent to solve the problem and assessing the quality of the solution. Thus, in this study context CT is a process of thinking to solve the problem using an algorithm that can enhance the cognitive skills and support teaching and learning process.

1.10.6 Motivation

Motivation is the force that propels a person not only to initiate a task, but also to maintain a desire to completion (Bostrom et al, 2023). Intrinsic and extrinsic motivation both influence an individual either to keep on going or surrender. In the context of this study, intrinsic motivation encourages students to keep engaging in all learning activities throughout the implementation of this intervention.

1.11 Summary of Chapter 1

This chapter describes in detail the background of the study that will be conducted. Further, this chapter also presents the issues and problems encountered in teaching and learning mathematics. Therefore, the objective and questions of the research developed based on the problem statement. Next, the limitations of the study have been stated to clarify the boundaries so that the study is more focused. Finally, this chapter explains the operational definition so that the terms found in this study can be well understood by the reader. The next chapter explains the literature highlights and the theories used to ensure that the study conducted is empirical in nature.

CHAPTER 2

LITERATURE REVIEW

2.1 Learning Theories

Educators agree that an ideal, holistic, and vigilant learning environment is best measured by instructional quality, student growth, and curriculum design and implementation (Chen et al., 2022). Hence, there is a need for realistic models and a good environment perceive students to enhance the process of learning mathematics and achieve mathematics education goals better (Ardiansah et al., 2019). Children in several countries, including Malaysia, begin school with no or very limited knowledge of coding. Because of these circumstances, researchers need to investigate the effects of this specific learning activity on cognitive skills, CT, and motivation of the primary school students. Even though programming is covered in the RBT curriculum in Malaysia, unfortunately, there is no specific strategy for assist teachers in their classroom and they must explore programming on their own.

2.1.1 Constructivism Theory

Learners are viewed as actively engaged in the learning practice and construct their meaningful knowledge in constructivism (Amineh & Asl, 2015). Hence, this theory emphasises students as contributing thinkers to form their understanding through activities such as observing, gathering information, setting up and assessing hypotheses, collaborating, and incorporating knowledge across the curriculum. These activities can be integrated instructionally and enhance motivation to improve the learning setting. Therefore, constructivists believe that the distinctive nature of an individual's cognitive capabilities reflects gained experiences, social interaction, and prior knowledge (Schunk & DiBenedetto, 2020). Even in the same class with the same teacher, students will have vastly different rates of absorption and intellectual growth. Since the newly acquired interaction that they heard, observed, and comprehended information will be blended with existing knowledge to form a new understanding.

Besides, exogenous (knowledge obtained through the external environment, such as experience, exposure, and teaching), endogenous (knowledge obtained through cognitive abstraction and predictable sequence), and dialectical (knowledge obtained through interaction between humans and the environment) are the three perspectives involved in constructivism (Schunk & DiBenedetto, 2020). These three approaches are considered appropriate for learning mathematics in different contexts and for different purposes. As developing a solid foundation in mathematics calls for a variety of approaches, including an exogenous focus during exploration, an endogenous focus during the application of more abstract concepts, and a dialectical perspective facilitated by social interaction among peers. Nevertheless, dialectical constructivism fits perfectly with numerous modern theories.

The theories of Piaget and Vygotsky have greatly influenced constructivist learning. Piaget believed that cognitive development is shaped by four main factors: biological maturation, physical experiences, social experiences, and a process called equilibration (maintaining mental balance). Among these, equilibration plays a key role because it helps learners process and adjust to new information. These four factors together form what Piaget called a schema. A schema is a mental framework that stores knowledge in long-term memory and helps individuals make sense of the world. Based on this, Piaget emphasised that teaching should support the cognitive development of students through active learning, social interaction, and experiences that challenge their current understanding (Piaget & Cook, 1952). Learning happens through three main processes, which are assimilation, accommodation and equilibration.

Assimilation is a state when new information fits into existing schemas and is easily accepted. At the same time, accommodation is a state when new information doesn't fit and requires changes to existing schemas. Meanwhile, equilibration is the process of restoring mental balance when there is conflict between new and old information. Equilibrium can happen in three ways: when thinking feels correct, when a contradiction causes mental strife, and when that conflict is resolved by changing the way we think. If equilibrium is not achieved, the new information cannot be properly understood or stored, which is why some students struggle to grasp certain lessons.

Unlike Piaget, Vygotsky emphasised the importance of social interaction in learning. He believed that a person's thinking skills develop through social experiences and responses to challenges in their environment. These interactions can happen naturally, through structured teaching, or from everyday experiences (Hedges, 2021). Learning does not just happen in classrooms, but it also comes from the people around the student who influence how the student sees the world and the educational tools they use (Pritchard & Woollard, 2010). Because of this, social constructivist teaching focuses on strategies like scaffolding, shared learning, guided instruction, and mentoring to help students build skills. In this approach, the teacher acts as a scaffold, supporting the student's learning through social interaction and guidance. This support may include giving encouragement, simplifying tasks, asking questions, or giving feedback. To enhance learning in early childhood, Vygotsky also stressed the importance of verbal guidance from more knowledgeable individuals, teaching that matches the child's thinking level, and guided pretend play (Smolucha & Smolucha, 2021). These social interactions support not only learning but also brain development and emotional growth.

Mathematical learning can be acquired as factual knowledge, procedural knowledge, or conceptual knowledge (Kacmaz & Dubé, 2022). However, teachers frequently employ factual and procedural knowledge when teaching mathematics in the classroom (Voon & Amran, 2021). However, this method only emphasises memorisation of the solution or working method, which requires little comprehension of the significance of each operation performed. Compared to conceptual knowledge, students are more active in constructivism learning and have more opportunities for curiosity, deep learning, and generalisation of the entire learning concept. Therefore, Pritchard & Woollard (2010) outline eight constructivist-based learning strategies. The strategies involve stimulating existing knowledge, technology for collaboration, pair work, educators learning about teaching, collaborating on learning, cross-curriculum collaboration, paired game creation, and reaching a consensus for the conclusion. With an effective teaching method, student learning is more systematic, creative, and engaging. Not only can the learning objectives be met, but students are also motivated and eager to continue discovering learning on their own. Therefore, it is believed that the constructivist approach provides more meaningful learning.

Constructivism has been applied to the teaching of mathematics in primary schools in several learning studies (Bunyodom et al., 2023; Jumaida et al., 2024; Ng, 2023; Kilag et al., 2024). However, these studies do not address the implementation of constructivism in mathematics learning that involves coding, programming, or computational thinking. Table 2.1 shows a summary of several past studies on constructivism.