THE EFFECTS OF SYNCHRONOUS AND ASYNCHRONOUS MATHEMATICS BASED ROBOTIC EDUCATION IN PRIMARY SCHOOLS: INVESTIGATING COMPUTATIONAL THINKING, INTEREST AND SELF-EFFICACY ACROSS GENDER

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UNIVERSITI SAINS MALAYSIA

2024

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by

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Thesis submitted in fulfilment of the requirements
For the degree of
Doctor of Philosophy

July 2024

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to my supervisor Dr. Siti Nazleen Abdul Rabu and my co-supervisor Dr. Jeya Amantha Kumar for their continuous support, motivation, interest, expertise and guidance in completing this thesis. Secondly, I would also like to thank all staffs and lecturers from Centre for Instructional Technology and Multimedia, USM that have directly or indirectly helped me in all matters regarding my research and growth as a PhD candidate.

I would also like to extend my gratitude to the Ministry of Education for my scholarship and also all teachers and students who participated in this research that have made this research successful. Lastly, I would like to thank my wife, my kids, my mother, friends and fellow colleagues for their support in every way that they have helped me in completing this thesis.

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LIST OF ABBREVIATIONS

ADDIE	Analyze, Design, Develop, Implement, and Evaluate
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AVRP	Asynchronous Virtual Learning Platform
CDC	Curriculum Development Division
CITM	Centre For Instructional Technology And Multimedia
CMU	Carnegie Mellon University
CoI	Community of Inquiry
COVID-19	Coronavirus Disease 2019
CS2N	CS-STEM Network
CT	Computational Thinking
DePAN	National e-Learning Policy
DLP	Dual Language Program
DV	Dependent Variable
e-Learning	Electronic Learning
ER	Educational Robotics
GUI	Graphical User Interface
ICT	Information and Communications Technology
ID	Instructional Design
IoT	Internet of Things
IT	Information Technology

IV	Independent Variable
KR20	Kuder-Richardson Formula 20
LEGO EV3	Lego Mindstorms Ev3
LMS	Learning Management System
LPM	Malaysian Examination Board
MOE	Ministry of Education
MOOC	Massive Open Online Course
MV	Moderator Variable
ODOO	Odoo Virtual Learning Platform
PPPM	Malaysian Educational Blueprint
QAMLM	Quality Assurance In Multimedia Learning Materials
S.D.	Standard Deviation
S.E.	Standard Error
SPSS	Statistical Package For The Social Sciences
STEM	Science, Technology, Engineering And Mathematics
SVRP	Synchronous Virtual Learning Platform
VIF	Variance Inflation Factor
VLP	Virtual Learning Platform
WRO	World Robot Olympiad

LIST OF SYMBOLS

D	Standardized difference between two means (Cohen's d)
O	Observation
X	Treatments
n	Number of test items
P	Proportion of those who answered items correctly
Q	Proportion of those who answered items incorrectly
p	Statistically significant effect
r	Correlations between variables
$\eta^2 p$	Partial eta square
η^2	Eta square
µ	Mean
SD^2	Square of the standard deviation

KESAN PENDIDIKAN ROBOTIK BERASASKAN MATEMATIK SEGERAK DAN TIDAK SEGERAK DI SEKOLAH RENDAH: MENYIASAT PEMIKIRAN KOMPUTASIONAL, MINAT DAN EFIKASI KENDIRI MERENTAS JANTINA

ABSTRAK

Kajian ini bertujuan untuk menyiasat kesan pendidikan robotik maya segerak dan tidak segerak terhadap minat, efikasi kendiri, kemahiran pemikiran komputasi (CT) dan pencapaian pemikiran komputasi (CT) pelajar sekolah rendah sambil mempertimbangkan peranan jantina. Memandangkan teknologi terus berkembang, masih terdapat jurang dalam memahami cara pengajaran melalui segerak dan tidak segerak dan bagaimana ia mempengaruhi minat, efikasi kendiri, kemahiran pemikiran komputasi (CT) dan pencapaian pemikiran komputasi (CT) merentas jantina dalam kalangan pelajar sekolah rendah. Penggunaan robotik sebagai kaedah unik pengajaran asas dalam mata pelajaran STEM bukan sahaja membawa faedah tambahan dalam pendidikan tetapi juga membolehkan pelajar terlibat lebih kerap dengan robot maya, membawa kepada peningkatan interaksi dan kebolehcapaian dari mana-mana dan pada bila-bila masa, akhirnya membantu mengurangkan jurang jantina dengan melibatkan dan memotivasikan pelajar perempuan untuk meneruskan profesion masa depan dalam bidang berkaitan STEM. Oleh itu, reka bentuk faktorial 2x2 telah digunakan secara kuantitatif menggunakan reka bentuk kuasi, dengan pembolehubah bebas (IV) terdiri daripada dua tahap mewakili pembelajaran segerak (SVRP) dan pembelajaran tidak segerak (AVRP), dan jantina berfungsi sebagai pembolehubah moderator. Seramai 138 pelajar sekolah rendah mengambil bahagian dalam

kajian ini, dan persepsi mereka terhadap hasil pembelajaran ini dinilai menggunakan Ujian Pra dan Ujian Pasca untuk menilai pencapaian pembelajaran CT dan tinjauan Pra dan Pasca untuk menentukan minat, efikasi kendiri dan kemahiran pemikiran komputasi (CT) pelajar. Untuk menganalisis pembolehubah dan menguji hipotesis kajian, kedua-dua statistik deskriptif dan inferensi digunakan. Analisis kovarian dua hala (ANCOVA) telah dijalankan untuk menilai kesan utama dan interaksi pembolehubah tidak bersandar (IV) dan pembolehubah penyederhana (MV) ke atas pembolehubah bersandar (DV). Dapatan menunjukkan bahawa hanya jenis reka bentuk (SVRP) sahaja yang mempengaruhi skor penilaian CT dengan saiz kesan d=.588 namun jantina dan interaksi antara IV dan jantina tidak memberi kesan yang signifikan terhadap skor penilaian CT. Kesan interaksi antara IV (segerak dan tidak segerak) dengan MV (jantina) tidak memberi kesan ketara kepada persepsi minat, persepsi keberkesanan kendiri dan persepsi kemahiran CT pelajar sekolah rendah dalam Pendidikan Robotik (ER). Secara keseluruhannya, hasil kajian ini mengesyorkan bahawa reka bentuk dan pembangunan kurikulum STEM untuk pendidikan robotik (ER) khususnya untuk robotik maya harus mengintegrasikan kedua-dua pembelajaran segerak dan tidak segerak bagi kedua-dua jantina untuk mencapai hasil pembelajaran yang positif.

THE EFFECTS OF SYNCHRONOUS AND ASYNCHRONOUS MATHEMATICS BASED ROBOTIC EDUCATION IN PRIMARY SCHOOLS: INVESTIGATING COMPUTATIONAL THINKING, INTEREST AND SELF-EFFICACY ACROSS GENDER

ABSTRACT

This study aimed to investigate the effects of synchronous and asynchronous virtual robotic education on primary school students' perceived interest, self-efficacy, computational thinking (CT) skills and computational thinking (CT) achievement, while considering the moderating role of gender. As technology continues to advance, there remains a knowledge gap in understanding how synchronous and asynchronous modes of instruction influence computational thinking, interest, and self-efficacy across gender in primary school students. As for the significance, the unique use of educational robotics as a fundamental teaching method in STEM subjects not only brings additional educational benefits but also allows students to engage more with virtual ER, leading to increased interaction and accessibility from anywhere and anytime, ultimately helping to reduce the gender gap by involving and motivating girls to pursue future professions in STEM-related fields. Therefore, a 2x2 factorial design was employed quantitatively using quasi experimental design, with the independent variable (IV) consisting of two levels representing synchronous learning (SVRP) and asynchronous learning (AVRP), and gender serving as the moderator variable. A total of 138 primary school students participated in the study, and their perceptions of these learning outcomes were assessed using Pre-test and Post-test to assess CT learning achievement and Pre and Post survey to determine students' perceived interest, perceived self-efficacy and perceived computational thinking (CT) skills. To analyze variables and test research hypotheses, both descriptive and inferential statistics are used. A two-way analysis of covariance (ANCOVA) was conducted to assess the main effect and interaction of the independent variable (IV) and moderating variable (MV) on the dependent variable (DV). The findings indicated that only the design type (SVRP) significantly influenced CT assessment scores with effect size d=.588 however gender and the interaction between IVs and gender did not have a significant impact on CT assessment scores. The main and interaction effects of the IV (synchronous and asynchronous) and MV (gender) did not significantly affect the perceived interest, perceived self-efficacy, and perceived CT skills of primary school students in Educational Robotics (ER). Overall, the results of this study recommended that the design and development of STEM curriculum for educational robotics (ER) especially for virtual robotics should integrate both synchronous and asynchronous learning for both gender to achieve positive learning outcomes.

CHAPTER 1

INTRODUCTION

1.1 Overview

This study investigates the effectiveness of synchronous and asynchronous virtual robotic education in affecting learning outcomes for science, technology, engineering, and mathematics (STEM) education among primary school students in Malaysia. The crisis situations like war and onset of the pandemic necessitated a shift from physical-based robotic curriculum to online modes, prompting an examination of two different online educational approaches: synchronous and asynchronous learning which aim to evaluate perceived interest, perceived self-efficacy, and computational thinking toward robotic education within these contexts. Additionally, gender serves as a moderating variable to determine the impact on these learning outcomes, with computational thinking (CT) evaluated based on competency and perception. Therefore, this chapter will begin with a background review of educational robotic and also focusing on the difference on gender and learning outcomes. Then, the problem statement, research objective, research questions, and hypotheses are identified and followed by a graphical representation and discussion of this study's theoretical and conceptual framework. Next, the significance, limitations, and definition of terms used in this study are discussed. Finally, this chapter ends with an overall summary.

1.2 Background of the Study

The Malaysian Ministry of Education, through the Malaysian Educational Blueprint (PPPM) 2013-2025 (Chong et al., 2020), prioritizes improving the education system to equip students with skills essential for future jobs, including innovation, creativity, problem-solving, and computational skills (Edy Hafizan et al., 2017; Ibrahim et al., 2014). In response to the rapid development of the Internet of Things (IoT), emphasis on STEM education, particularly at an early age, has become increasingly vital (B. Y. Lee et al., 2020). Early exposure to STEM has been advocated by various scholars, as it encourages career exploration and fosters interest in STEM fields among students (Dufranc et al., 2020; Mustafa et al., 2022).

Educational robotics (ER) plays a pivotal role in nurturing interest in STEM subjects (Barnes et al., 2020). ER encompasses activities that utilize robots to facilitate learning, promoting hands-on experience and application of theoretical concepts (Mustafa et al., 2022). ER has been shown to positively impact students' interest in STEM and enhance their understanding of abstract principles through tangible experiences (Hudson et al., 2020; Jawaid et al., 2020). Additionally, ER fosters knowledge scaffolding, problem-solving skills, and the development of computational thinking (Eguchi, 2015; Uzumcu & Bay, 2020), which are crucial components of STEM education (Talib et al., 2020).

Synchronous approaches to ER, such as remote robotics laboratories, facilitate interactive learning experiences and provide immediate feedback to learners (Evripidou et al., 2020a). Asynchronous approaches utilize recorded lectures and digital resources, offering flexibility in learning pace (Schwarz et al., 2022). Virtual robotics simulations have emerged as viable alternatives, supporting ER in primary school education (Kurniawan et al., 2020).

Furthermore, the usage of virtual robotics, either synchronously or asynchronously has also provided more opportunities to students despite their gender and acts as a catalyst for narrowing this gap (Alsoliman, 2022). At the same time, there has been a focus on encouraging girls in primary and secondary schools to pursue scientific and technological careers (Ayuso et al., 2021). Robotics has the potential to help narrow the gender gap in STEM by increasing girls' interest in STEM careers and their perceptions of their abilities (Pedersen et al., 2021). Nevertheless, both genders must have the same opportunities in STEM education without exclusion due to prejudices or stereotypes (Tselegkaridis, 2022).

Incorporating keywords such as perceived interest, perceived self-efficacy, computational thinking, synchronous learning, asynchronous learning, and educational robots, this study aims to elucidate the impact of virtual robotic education on primary school students' learning outcomes across gender. By investigating these factors, we seek to contribute to the growing body of knowledge on STEM education and inform educational practices in the digital age. Therefore, this study will focus on the application of synchronous and asynchronous approaches through virtual robotic education and its effect on computational thinking, interest and self-efficacy across gender in primary school.

1.3 Problem Statement

Robotic education was developed based on constructionism, which highlights the need to manipulate objects actively as part of the learning process, which helps children develop a mental representation of their environment (Castro et al., 2018). Nevertheless, with the onset of the pandemic, physical manipulation of robots for teaching and learning has been hindered by distance and thus the concept of constructionism could not be applied effectively (Mehrotra et al., 2021). The pandemic, as a whole, altered how ER could not only be taught in the classroom but forced educators to look at ER implemented based on distance learning by using virtual learning strategies (Gomes et al., 2020). First, according to Pozzi et al. (2021), the aspect of virtual learning for ER is still under-explored. Next, the implementation of remote robotic labs via virtual learning were sought after as a reference for teaching and learning strategies; it was limited to applications focusing either in higher education or secondary schools and not primary education as it will adjustments that adapt to age-appropriate activities (Giang & Negrini, 2022). For example, according to Dong et al. (2020), online teaching activities must be engaging and meaningful during the pandemic to cater to children's limited online attention span. Therefore, Alamo et al. (2021) added that with the recent pandemic issues, it is warranted to investigate if robotic education can be implemented virtually and without face to face interaction especially for primary school and how it could be implemented meaningfully.

However, Atmatzidou & Demetriadis (2017) claims that even in traditional robotic education, teachers often question the level of guidance required to enable students to acquire the necessary learning outcomes. Nevertheless, during the pandemic, such issues also occur as, most often, there is a lack of suitable materials that guide students and parents to follow classes at home (Younis et al., 2021), and concurrently, the presence of teachers is essential in such scenario (Havenga, 2020). Besides that, much time is needed for robotics and programming in physical robotics as its content and pedagogy are the toughest (Angeli & Giannakos, 2020), which implies that students may not feel they have sufficient time to complete the coursework. Thus, synchronous and asynchronous learning approaches were the alternative options available to provide guidance to the students in such a scenario (Alsoliman, 2022). Synchronous (lecture streaming) and asynchronous (recorded videos) have been proposed in this context for retaining contact, motivation, and interactions as a proposed remote teaching method (Alimisis et al., 2021), yet such intervention has not been validated (Gomes et al., 2020). Alsoliman (2022) found synchronous video integration favoured by primary school students; however, such intervention has not been carried out in Malaysia (Lee et al., 2021).

By so, one of the main facets of synchronous and asynchronous virtual robotic simulation applications for ER is guidance (Alimisi et al., 2021), where learners, especially children in makers movement, require additional support and assistance before they can begin a robotic activity (Blikstein & Worsley, 2016). According to Sapounidis & Alimisis (2021), the challenges of robotic simulation application often lies in the difference of curricula offered by different developers which does not include icebreaking activities, learning guidance and multilingual support in executing the ER tasks, which Alimisi et al. (2021) explained that there should be also differentiated based on level of education (primary, secondary and higher learning). Moreover, this is often challenged when children are concerned as there is a need to correlate such curricula with the primary curriculum of a specific country (Escarcina et al., 2021).

Nevertheless, implementing robotics in early childhood is a new challenge with numerous possibilities to innovate the 21st-century classroom (Todorovska & Bogdanova, 2020). According to Jiea et al. (2019), Malaysia's future human capital may be facing a huge deficiency in the STEM field and calls for the integration of STEM-based subjects to promote interest in this area in the school and university level. Additionally, Zaharin et al. (2020) added that students' interest and attitude toward STEM subjects and career paths are in regression, and if there is no intervention in cultivating interest and attitude, there will be a gap in catering to STEM-based industry in the future. However, while numerous studies have been conducted at the secondary and college levels (Barker & Ansorge, 2007), very limited interventions are conducted at the primary or elementary level (Dufranc et al., 2020).

In Malaysia, Zaharin et al. (2020) reported similar findings indicating ignorance at the primary school level yet, a significant number of programs for the secondary level, such as the Minimalist Robotic Education Programme. Empirical findings in primary education also have indicated a need to investigate interest (Matere et al., 2021; Tengler & Kastner-hauler, 2021; Todorovska & Bogdanova, 2020) and self-efficacy (Girshin et al., 2020; Namli & Aybek, 2022; Ma et al., 2021) and computational thinking skills (Matere et al., 2021; Jiang & Li, 2021; Skaraki et al., 2022). Nevertheless, there is a lack of studies comparing which strategies will be effective for primary school students, especially in the Malaysian context. This was further supported by Jung and Won (2018) identifying a lack of studies reflecting outcomes concerning the affective domain. Similarly, Alsoliman (2022) added that it is important to highlight the lack of empirical studies exploring and testing the outcomes of virtual robotics in STEM or its impacts on students' future interests, satisfaction, and career paths.

Despite the growing recognition of the importance of STEM education, especially at the primary level, empirical studies on virtual robotics' impact in the Malaysian context are limited (Zaharin et al., 2020). Furthermore, the gender gap in STEM and educational robotics persists, with girls often underrepresented and facing barriers to participation (Puertas et al., 2022). Empirical evidence suggests that girls are less likely to show interest or enroll in STEM classes (A. Jackson et al., 2021), and gender inequalities in STEM and educational robotics emerge as early as the primary school level (Tosato & Banzato, 2017). Robot phobia, particularly prevalent among elementary school girls, further exacerbates this issue (Cheng et al., 2017). According to Ali et al. (2019), young girls frequently encounter robots through science fiction media, where robots are portrayed as dangerous or threatening, generating a sense of discomfort and nervousness. In addition, another study on comparing robo fear found that girls shows higher level of fear to interact with robot compare to boys (Liang & Lee, 2017). Meanwhile, according to Widder (2022), boys believe that robots are fundamentally male gender which replicate human, and therefore boys interact with robots more frequently than women without any fear.

Understanding the origins and consequences of gender disparities in STEM and educational robotics is crucial for fostering inclusivity and addressing societal biases. Therefore, this study aims to investigate the effectiveness of synchronous and asynchronous virtual robotic education in promoting computational thinking, interest, and self-efficacy across gender lines in Malaysian primary schools. By examining the differential impacts of virtual robotics on male and female students, this study seeks to provide insights into effective strategies for narrowing the gender gap in STEM education. Through a quasi-experimental approach, this research aims to contribute to the existing body of knowledge by shedding light on the nuanced dynamics of virtual robotic education in diverse educational contexts. Such method has been deemed necessary by Hakami (2021) as studies between groups or within groups in ER research that compare the impact of using virtual robotics are limited.

1.4 Research Objective

The objectives of this research are:

i. To design and develop a synchronous virtual robotic platform (SVRP) and asynchronous virtual robotic platform (AVRP) for facilitating teaching and learning educational robotics for primary school students.

ii. To investigate the difference and interaction effects of synchronous virtual robotic platform (SVRP) and asynchronous virtual robotic platform (AVRP) with gender towards perceived interest using virtual robotic platform for primary school students.

iii. To investigate the difference and interaction effects of synchronous virtual robotic platform (SVRP) and asynchronous virtual robotic platform (AVRP) with gender towards perceived self-efficacy using virtual robotic platform for primary school students.

iv. To investigate the difference and interaction effects of synchronous virtual robotic platform (SVRP) and asynchronous virtual robotic platform (AVRP) with gender towards perceived computational thinking skills for primary school students.

v. To investigate the difference and interaction effects of synchronous virtual robotic platform (SVRP) and asynchronous virtual robotic platform (AVRP) with gender towards computational thinking assessment using virtual robotic platform for primary school students.

1.5 Research Questions

The following are research questions according to respective research objective which will be used to guide the study:

RO (i)

i. Is there a significant difference in perceived interest between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies?

ii. Is there a significant difference in perceived interest in virtual robotic platform for primary school students based on gender?

iii. Is there a significant interaction effect difference in perceived interest between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender?

RO (ii)

iv. Is there a significant difference in perceived self-efficacy between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies?

v. Is there a significant difference in perceived self-efficacy in virtual robotic platform for primary school students based on gender?

vi. Is there a significant interaction effect difference in perceived self-efficacy between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender?

RO (iii)

vii. Is there a significant difference in perceived computational thinking skills between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies?

viii. Is there a significant difference in perceived computational thinking skills in virtual robotic platform for primary school students based on gender?

ix. Is there a significant interaction effect difference in perceived computational thinking skills between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender?

RO (iv)

x. Is there a significant difference in computational thinking assessment between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies?

xi. Is there a significant difference in computational thinking assessment using virtual robotic platform for primary school students based on gender?

xii. Is there a significant interaction effect difference in computational thinking assessment between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender?

1.6 Research Hypotheses

Null hypothesis (H_0) is applied in this study as there is no empirical evidence on the tested relationships (Dongen & Grootel, 2021). Based on the researcher questions, the following were hypothesized:

H_{01}

$H0_{1.1}$: There is no significant difference in perceived interest between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies.

$H0_{1.2:}$ There is no significant difference in perceived interest in virtual robotic platform for primary school students based on gender.

$H0_{1.3:}$ There is no significant interaction effect in perceived interest between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender.

H_{02}

$H0_{2.1}$: There is no significant difference in perceived self-efficacy between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies.

$H0_{2.2:}$ There is no significant difference in perceived self-efficacy in virtual robotic platform for primary school students based on gender.

$H0_{2.3}$: There is no significant interaction effect in perceived self-efficacy between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender.

H_{03}

$H0_{3.1}$: There is no significant difference in perceived computational thinking skills between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies.

$H0_{3.2}$: There is no significant difference in perceived computational thinking skills in virtual robotic platform for primary school students based on gender.

$H0_{3.3}$: There is no significant interaction effect in perceived computational thinking skills between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender.

H_{04}

$H0_{4.1}$: There is no significant difference in computational thinking assessment between primary school students who used the synchronous virtual robotic platform (SVRP) and those who used the asynchronous virtual robotic platform (AVRP) learning strategies.

$H0_{4.2}$: There is no significant difference in computational thinking assessment using virtual robotic platform for primary school students based on gender.

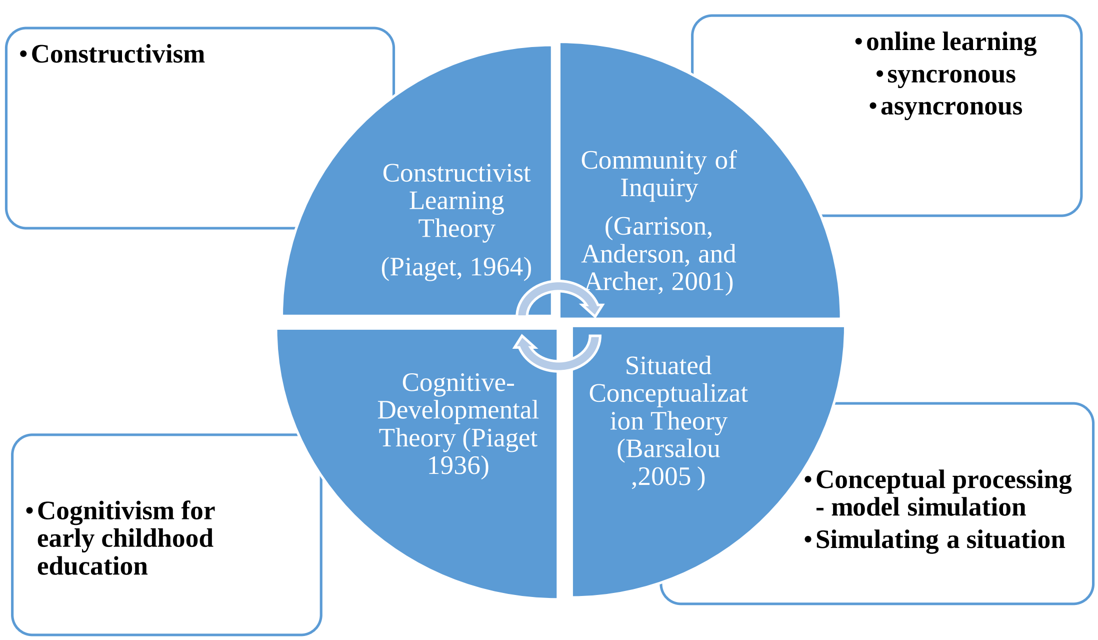
H0$_{4.3}$: There is no significant interaction effect in computational thinking assessment between primary school students who used the SVRP and those who used the AVRP learning strategies based on gender.

1.7 Theoretical framework

The theoretical framework for this study are based on the constructivist learning theory (Piaget, 1964), cognitive-developmental theory (Piaget, 1936), community of inquiry learning theory (Garrison et al., 2001) and situated conceptualization theory (Barsalou, 2005). The Figure 1.1 shows the integration of the four theories.

Figure 1. 1

Integration of the four theories



By integrating these four theories, the study aims to provide a comprehensive framework for understanding how Educational Robotics supports STEM learning outcomes. The constructivist approach highlights students' active role in constructing knowledge, while cognitive-developmental theory considers their cognitive growth. The community of inquiry learning theory emphasizes inquiry learning within an educational robotics community, while the situated conceptualization theory underscores the contextualized, experiential learning afforded by robotics activities. Together, these theories offer a multifaceted lens to examine the impact of Educational Robotics on students' learning experiences and outcomes.

1.7.1 Constructivist learning theory

Constructivism was developed by Jean Piaget (Piaget, 1964) and is based on the meta-cognitive thinking process and desired behaviours (Spector & Lin., 2017). It is applied in this study as robotics in STEM education facilitates thinking based on sequential logic of events, classification of objects in series, planning the design and implementation of a project. In constructivism, students must learn actively to build skills and knowledge (Huitt, 2015). For example, when learning through robotics, students will ponder, explore, and test alternative solutions to problems and will build their own understandings as a stepping-stone to producing their own knowledge (Hoyles et al., 2002). In this study, students using the concept of engineering related to robotics movement in a constructivist environment which integrated to fully interactive virtual robotic software and handled through a mouse that promotes curiosity, interactivity and imagination.

1.7.2 Cognitive-developmental theory

The cognitivist developmental theory was developed by Jean Piaget (Piaget, 1936) and recommended that every child's progress through the stages of development known as sensorimotor, preoperational, concrete operations, and formal operations (Hasan et al., 2019). As children's cognitive abilities change significantly as they progress from one stage to the next (Pakpahan et al., 2022), Piaget explained that the process of cognitive development is ongoing and follows the same pattern for all children, regardless of their environments or the diversity of their cultures (Maurya & Khan, 2021). In order to fulfil the development stages, educational robotics has leveraged Piaget's ideas of schema to great effect (Kirtay et al., 2021). This is especially true for describing how perceptual learning may occur in virtual learning environments, anywhere, according to students' own pace. In this study, students who will be in the concrete operational stages (7 to 11 years old) are described by Piaget as being able to recognise numbers, mass, classify objects and think logically (Pakpahan et al., 2022), hence capable of performing the task in for virtual robotics in stages.

1.7.3 Community of inquiry learning theory

The Community of Inquiry (CoI) introduced by Garrison and Anderson (Garrison et al., 2010) is helpful for understanding the online learning process (Castellanos & Reyes, 2020; Cifuentes, 2021). According to the CoI model, there are three primary components in controlling and maintaining the efficiency of online learning in an educational setting: teaching presence, social presence, and cognitive presence (Akyol & Garrison, 2008). The

CoI framework's three core components are the dynamics of the online learning experience, which are critical for improving and managing the quality of online learning (Garrison et al., 2010). Apart from that, CoI also reflects the need for synchronous and asynchronous online learning to predict students' experiences in online environments and their degrees of satisfaction (Aslan, 2021).

In this study, CoI is applied through virtual robotics, where students learn and complete tasks on their own by following the instruction given through online meetings (synchronous) or watching recorded videos (asynchronous) without the presence of a teacher physically. The principles of CoI can be utilised entirely in a virtual learning environment through virtual robotics (Archambault et al., 2022). In STEM and ER education, the immediate response through CoI model can provide feedback and support to students to help them become effective learners by completing problems or tasks given to them (Padayachee & Campbell, 2022). According to Evripidou et al. (2020a) and Monterubbianesi et al. (2022), in synchronous and asynchronous online learning, virtual robots can provide students with instant visualised and sensory input that would even increase the attractiveness toward the lesson and help build a blended robot-based and real life learning situation.

1.7.4 Situated conceptualization theory

Situated conceptualization theory is a process of establishing an experience from a situation in long-term memory or a record of conceptual processing in a given situation across all relevant components, each distributed across the brain (Krivosik et al., 2007). This theory reflects upon two themes (i) modal simulations underlie conceptual processing; (ii) conceptual representations are situated (Barsalou, 2005b). Robotic tasks stress that students should be placed within the context of the situation and not outside it (Krivosik et al., 2007). A person will learn only when he or she is immersed in a situational context because all knowledge is rooted in a situational context (Papies et al., 2022). Therefore, the learner should undergo real application and participation in order to take advantage of the knowledge (Chen, 2008).

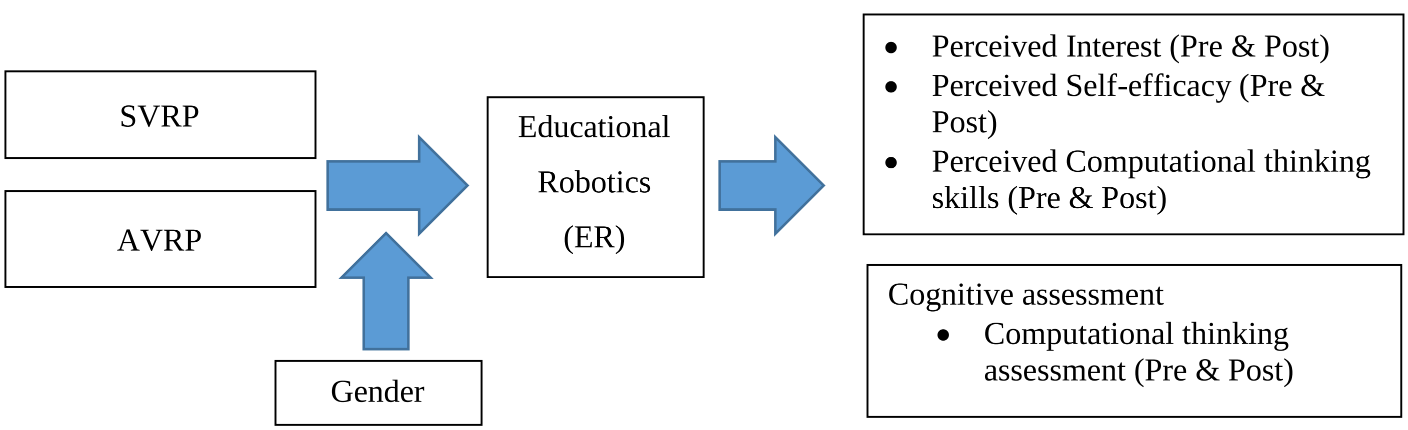
In this study, participants with experience in handling physical robots will be immersed in a virtual robotic platform as a safety measure for reducing the spread of the COVID-19 virus. Therefore, all the participants will be guided remotely by online meetings or recorded video lessons. Thus, the concept of situated conceptualization theory will be applied here, where participants have to apply their experience from handling a physical robot to do and accomplish tasks in a robotic simulator. Thus, in this study, constructivist learning theory, cognitive-developmental theory, community of inquiry theory and situated conceptualization theory will be applied to facilitate knowledge construction through the discovery and exploration of real word challenging problems in Virtual Robotics (Tselegkaridis, 2022) through synchronous and asynchronous learning approach.

1.8 Conceptual framework

A conceptual framework serves as a centre of an empirical study. The conceptual framework guides and supports a research (Ravitch & Riggan, 2016). A conceptual framework provides evidence for why a study is significant and how the design of this study such as data collection and analysis methods will answer the research questions (Varpio et al., 2020a). Furthermore, a conceptual framework places a study in multiple contexts by connecting the content, theory and the structure of the study in relation to all of these contextualising and mediating influences (Ravitch & Carl, 2020). A conceptual framework, when viewed holistically, serves as the connective tissue of a research. The graphical representation of the conceptual framework for this study is illustrated in figure 1.2.

Figure 1. 2

Graphical representation of the conceptual framework



The conceptual framework for this study encompasses the integration of several key variables to elucidate the relationship between synchronous and asynchronous virtual robotic education (SVRP and AVRP, respectively) and various learning outcomes. SVRP and

AVRP serve as the independent variables, representing the different modes of virtual robotic education utilized in the study. These modes are examined to ascertain their impact on dependent variables, including perceived interest, perceived self-efficacy, perceived computational thinking, and computational thinking assessment.

The choice of these dependent variables is grounded in their significance within the context of STEM education and the objectives of the study. Perceived interest reflects students' engagement and enthusiasm towards robotics and STEM-related subjects. Perceived self-efficacy pertains to students' beliefs in their ability to succeed in tasks related to robotics and computational thinking. Perceived computational thinking captures students' perceptions of their problem-solving and analytical skills in the context of robotics education. Computational thinking assessment involves objective measures to evaluate students' proficiency in computational thinking skills.

Moreover, gender is introduced as a moderating variable within the conceptual framework to examine how it influences the relationships between the independent and dependent variables. Gender serves as a crucial factor given the existing gender disparities in STEM education and the potential impact it may have on students' experiences and outcomes in virtual robotic education. By considering gender as a moderating variable, the study aims to explore whether and how gender differences affect the relationships between virtual robotic education modes and learning outcomes.

Overall, the conceptual framework provides a structured approach to understanding the interplay between different variables in the study. It guides the research design and analysis, allowing for a comprehensive exploration of the factors influencing students' experiences and achievements in virtual robotic education, while also shedding light on the role of gender as a potential moderator in this context.

1.9 Research framework

This study is divided into two parts: the first part is the design and development of the virtual robotic platform; and the second is to study the effect of the independent variables on the dependent variables.

Design and Development of the Virtual Robotic Platform (Treatment Condition)

In the initial phase of the study, emphasis was placed on designing and developing a virtual robotic platform tailored to the specific needs and objectives of the research. This involved conceptualizing the platform's features, functionalities, and user interface to facilitate effective virtual robotic education based on ADDIE instructional design model. The design process incorporated principles of instructional design based on Gagne's Nine Events ID theory, user experience (UX) design, and robotics lesson development methodologies to ensure the platform met the requirements for delivering synchronous and asynchronous virtual robotic education. The design and development of the virtual robotic platform are described in Chapter 3.

Research framework

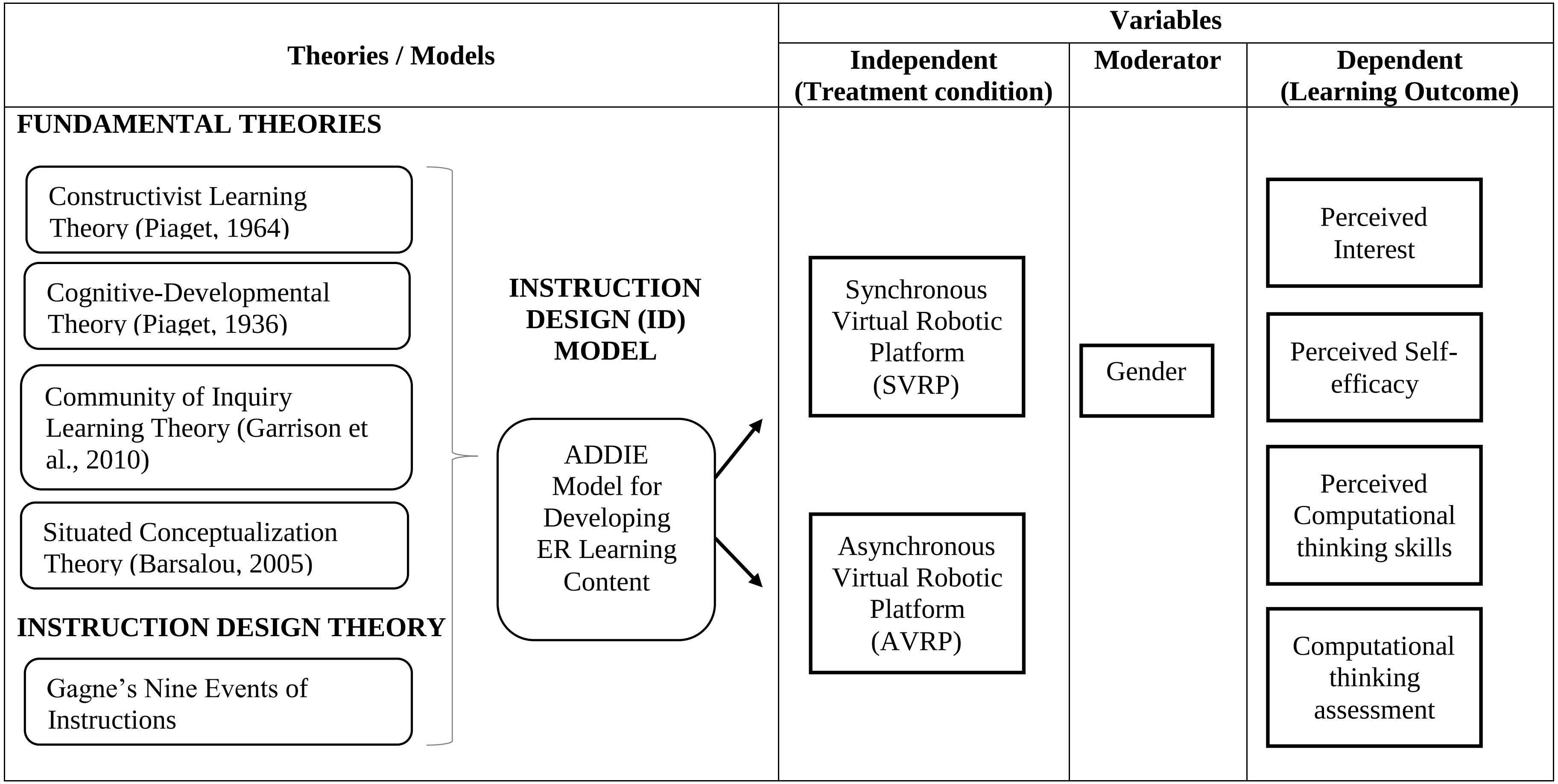


Figure 1.3 Graphical representation of the research framework of the study

Based on these variables and theories, Figure 1.3 illustrates the research framework of this study. The framework represents the relationship between the fundamental theories as described in Topic 1.7, insruction theory (ID) theory (Gagne's Nine Events of Instruction), ID model (ADDIE) and the variables involved.

Effect on the Learning Outcomes

Once the virtual robotic platform was developed, the study transitioned to the second phase, where the focus shifted to examining the effects of independent variables on dependent variables. Independent variables, such as synchronous and asynchronous virtual robotic education modes (SVRP and AVRP), were manipulated to assess their influence on various learning outcomes. Dependent variables, including perceived interest, perceived self-efficacy, perceived computational thinking, and computational thinking assessment, were measured to evaluate students' experiences and achievements in Educational Robotics.

Through rigorous experimentation and data analysis, the study aimed to uncover insights into how different modes of virtual educational robotics impacted students' interest, learning perceptions, and computational thinking skills. By systematically examining the relationships between independent and dependent variables, the research contributed valuable knowledge to the field of STEM education and informed the development of effective virtual learning environments for educational robotics.

1.10 Significance of the study

This study will contribute to Malaysian education in several ways. Firstly, there is no clear picture of how educational robotics should be integrated into Malaysian primary schools, but due to national agenda such as National Educational Blueprint 2013-2025 (Ibrahim et al., 2014), Malaysian primary schools have been amended to integrate technology-based content effective from 2013. Furthermore, schools in Malaysia face the question of how to boost students' interest and participation in STEM careers. In addition ER is unique in this context and has enormous potential to be the next big thing in teaching and learning (Lee et al., 2020). ER technology enables teachers to create a STEM-specific curriculum around technology. The uniqueness of using educational robotics as a fundamental teaching method in STEM subject offering a dynamic and hands-on approach during learning which bring additional educational benefits where through Educational Robotics, students actively engage with technology by designing, constructing, programming, and operating robots, fostering deeper understanding and retention of STEM concepts (Goh & Bilal, 2014).

Additionally, the crisis situations such as war and pandemic creates a more pressing need for students to engage in new normal learning experiences without physically entering classes, there has long been a desire for virtual education (Adedoyin & Soykan, 2020). Furthermore, according to Stein & Ledeczi (2021), the first and most noticeable problem is the cost of purchasing robots in physical ER classes. Robots will also need to be maintained in order to be re-used, and educators may need to be taught to repair the robots if they are damaged in the classroom. Students' activities may also consume fees for setting up, and thus using