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"Reigniting the Passion for Innovative Teaching of Science and Mathematics in the VUCA World"

30 October – 2 November 2023
SEAMEO RECSAM, Penang, Malaysia

PROCEEDINGS

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2023

10TH International Conference on Science and Mathematics Education

‘Reigniting the Passion for Innovative Teaching of Science and Mathematics in the VUCA World’

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Proceedings

Hosted by:

SEAMEO Regional Centre for Education in Science and Mathematics

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Theme

Reigniting the Passion for Innovative Teaching of Science and Mathematics in the VUCA World

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Preface

The International Conference on Science and Mathematics Education (CoSMED) 2023 marks the milestone tenth edition of this esteemed series, which has served as a cornerstone event since its inception in 2005. CoSMED stands as a pivotal platform initiated by the Regional Centre in Education for Science and Mathematics (RESCAM), aimed at fostering collaborative discourse among educators to address critical issues in science and mathematics education.

Under the resonant theme, "Embracing the Essence: Fostering the Flame of Progressive Science and Mathematics Education in the VUCA World," this year's conference emerges as a beacon of innovation and collaboration. This theme burgeoned from the conviction that convening scholars, educators, and budding teachers from diverse regions facilitates a profound exchange of insights, heralding emerging trends and pioneering pedagogical methodologies in science and mathematics education. Our earnest aspiration is that the discussion fostered within this conference will inspire educators to equip students with the aptitude to navigate the intricacies and seize the opportunities inherent in today's dynamic world. Indeed, it is imperative that educational paradigms evolve to authentically reflect the realities of the VUCA World.

The papers published in this Proceedings were selected through a blind peer-review process. The reviewers' recommendations were then conveyed to the authors for further improvement. During the final editing, the editors endeavoured to maintain the character and focus of the paper as intended by the authors) with only minor corrections and formatting.

On behalf of the organisers, we would like to extend our sincere appreciation to the Panel of Reviewers, all authors and everyone whose contributions have made the publication of this Proceedings possible.

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Educators' Perception of Programming Module on Mathematics Instruction for Primary School

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Abstract

This paper aimed to assess the educators' perceptions on the implementation of implementing of programming modules in mathematics instruction at primary schools to enhance pupil's computational thinking skills and motivation. The study employed a qualitative approach. Specifically, the instrument is composed of semi-structured interviews via a purposive sampling method. A total of eight respondents among mathematics educators from different institutions were involved. This study reveals that most respondents have a favourable view of programming modules integrated into mathematics education in primary school. In fact, most of the respondents concur that such a module can boost student learning motivation. However, they have limited or no programming application skills. Hence, the findings suggest that the mathematics curriculum for primary school needs a structured module in programming. Consequently, this study recommends the development of a module that integrates programming in mathematical learning with the intention to assist primary school mathematics educators in enhancing pupils' computational thinking and boosting their learning motivation in mathematics.

Keywords: Mathematics, programming, computational thinking, motivation, instructional module.

Introduction

The performance of Malaysian pupils in mathematics on national and international assessments is alarming. 29% of pupils in national examinations, such as the *Sijil Pelajaran Malaysia* (SPM) 2022, are only able to acquire basic math skills, and another 24.3% failed (Lembaga Peperiksaan, 2023). In worldwide comparison, 59% of Malaysian pupils are only at level 2 of mathematical literacy on the Programme for International Student Assessment (PISA) 2018 (Kementerian Pendidikan Malaysia, 2018), indicating that they can only solve and evaluate simple problems. The Trends in International Mathematics and Science Study (TIMSS) 2019 results were consistent with this finding; on average, Malaysian pupils performed poorly in mathematics compared to international peers. Based on these assessments, it can be concluded that by learning mathematics for six years in primary school and five years in secondary school does not guarantee the pupils will develop a strong foundation of mathematical knowledge. Even these pupils' reasoning skills are still at lower-order thinking skills (LOTs) and have yet to reach the level of higher-order thinking skills (HOTS). Therefore, computational thinking (CT) and motivation towards mathematics need to be fostered to improve pupils' thinking skills at an early age. The study of computational thinking in Malaysia's learning context is mostly directed toward the study of CT surveys and integration in mathematics learning in secondary schools. Therefore, there is a need for the construction of a complete module to guide primary school teachers in classroom instruction.

Programming and Mathematics Education

Programming in learning is viewed as bringing a new perspective to mathematics instructional learning in primary schools. Programming has become an essential skill for today’s generation. Countries like Norway and Finland consider programming knowledge on par with literacy and numeracy (Bocconi et al., 2018). Innovations in technology have become practically unavoidable in today's world. New technologies are being developed every day, and research into artificial intelligence is making strides. Pupils who acquire these abilities not only benefit as end users but also have the potential to contribute to the technology’s development.

Programming is the capability of performing a particular task by instructing a computer to operate. The set of commands is organised as code to facilitate human-computer interaction. Therefore, the application of mathematical skills in assembling programming language algorithms and the growth of pupils' cognitive processes in completing the assigned activities are two instances where programming's incorporation into mathematics instruction is regarded to have a mutual relationship. For the formation of this code, pupils require cognitive pattern recognition skills, which can be obtained through mathematics pattern recognition skills. To recognise patterns, pupils need skills in prototype-matching, feature-matching, and sequence-matching (Ling & Loh, 2020). On the same bargain, pupils must demonstrate deep, logical, and organised thought to construct the code. Starting with analysing the problem, assembling a suitable programming language algorithm, testing, and implementing various strategies are all essential steps in code creation. All these logical disciplines are the core elements of mathematics and are essential to cognitive skills. Thus, programming in mathematics education in primary school is viewed as an excellent opportunity to encourage pupils to reason problems while boosting their mathematical skills actively (Husain et al., 2017). In addition to applying acquired mathematical abilities, developing in-depth mathematical concepts through programming is possible.

Three types of programming can be integrated into mathematical learning, but unplugged and block-based programming is frequently used in primary schools (Fatih et al., 2021; Huang et al., 2021; Namli & Aybek, 2022). Unplugged-based programming can be defined as any learning or activity that prepares pupils to function, create new ideas, and resolve problems utilising the principles of algorithms and data structures without involving any electronic devices (Huang et al., 2021). Therefore, unplugged learning activities can use materials such as paper and pen, board games, movement, and jigsaw puzzle. It has been shown that children as young as five can increase their CT capacity through engaging in various unplugged activities (Hynes et al., 2019). While block-based programming is software that employs a visual interface or blocks to be assembled like a puzzle to form an algorithm of commands. As a first exposure to programming, this medium is more user-friendly and more accessible for novices or young learners to employ than earlier programming languages that were more complex and difficult with programming syntax (Resnick et al., 2009). Through these two mediums, various programming-integrated mathematical learning activities can be executed and supported to accommodate the diverse learning preferences of pupils in primary school without being impacted by complex technical issues. Even with fascinating features, pupils are eager to engage and discover further for food their curiosity. This type of learning environment allows them to engage in more meaningful, adaptable, and social activities.

Module for Mathematical Programming in Malaysia

There are different ways to teach programming, either as an independent subject, as a cross-disciplinary skill, or as part of a current school subject (Holo et al., 2022). Some European countries, like Sweden, Norway, and Finland, decided to teach programming as part of the mathematics course (Bocconi et al., 2018; Skolverket, n.d.; Utdanningsforskning.no, 2021). In Malaysia, however, programming is taught as part of an established subject called Design and Technology (RBT) in primary schools and as a separate subject called Basic Computer Science (ASK) in secondary schools. The RBT curriculum content standard mandates pupils require knowledge of the basics of programming, the generation of instruction code, the basics of programming design, the formation of algorithms in microcontrollers, and an introduction to the basics of robotics systems (Putrajaya: Bahagian Pembangunan Kurikulum, 2018).

The ultimate objective of this topic is to enable the application of basic technological skills to develop pupils to be competitive, critical, creative, and innovative. Thus, RBT teachers have a better programming teaching experience in primary school compared to mathematics teachers. The results of the teaching of these RBT teachers revealed that students as young as seven can follow programming learning with the full assistance of facilitators, and more than half of ten-year-olds can follow programming learning by effectively implementing self-tutorial instructions (Ismail et al., 2016). This finding suggests that these students have a strong interest in and capacity for independent programming exploration. However, these RBT teachers acknowledge a need for additional support materials, such as additional programming modules, to accomplish teaching and learning activities (Yusof et al., 2023). On the same bargain, teaching and learning programming is difficult. Therefore, teachers require a module with examples of organised practical activities (Sahaat & Nasri, 2020). As a curriculum-cross element, the programming skills acquired in this RBT subject have the potential to be integrated into mathematics. Some initiatives have been implemented in Malaysia to incorporate programming and mathematics education (Awang et al., 2016), but these are not yet widespread. This effort keeps emphasising both secondary and higher education. There is still opportunity and potential for expanding the integration of mathematics and programming at the primary school level because the implications can bring positive changes in the growth and potential of children.

Need Analysis

The needs analysis is performed before module development is planned (McKillip, 2011). This process identifies the need to highlight issues and assess the need to develop a module that impacts professional practice (Siraj et al., 2021l). In this study, a need analysis was conducted to investigate the perception of utilising technology in the classroom and educators' perceptions regarding the development of programming modules for primary mathematics instruction. This needs analysis applies the qualitative methodology via semi-structured interviews with primary school educators.

The objective of the study aimed to justify the need to develop a programming module for primary school mathematics instruction in the Malaysian context. Given that the existing programming module for teaching mathematics in primary school is less practical for our

Malaysian cultural and educational context, the research objective can be broken down into three parts:

1) Discovering how pupils perceive their mathematics learning environments.
2) Assessing educators' views on technology to improve the mathematics learning environment.
3) Determining the need for a programming module for mathematical learning in primary school.

This study addresses three research questions, specifically:
1) How do pupils perceive the mathematics learning environments?
2) What is educators' view on the use of technology to enhance mathematics learning environments?
3) Why is it necessary to develop a module on mathematical programming for primary school pupils?

Research Methodology

Study Design and Sampling Method

This study utilised semi-structured interview methods with eight educators from three different institutions. Five mathematics primary school teachers from the Ministry of Education, two educators from a private mathematics education centre, and a lecturer from the Malaysian Institute of Teacher Education (IPGM). The respondents were chosen using purposive sampling from heterogeneous groups as it could provide diverse information. They must meet several requirements before being considered, including having a bachelor's degree or higher and at least five years of experience teaching mathematics at the primary school level, where they inevitably face a wide range of challenges from pupils of varying intelligence. This inclusion criterion allows respondents to reflect on their strengths, failures, and limitations in delivering the primary mathematics curriculum. Thus, they have an expanded viewpoint and may apply their comprehensive knowledge to issues (Bolger & Wright, 2017). The educators were excluded if they had taught mathematics for less than five years.

Data Collection

An interview protocol was prepared to collect data through open-ended semi-structured. This study requires direct experience sharing from primary school practitioners to understand their perceptions of the issues better and ensure that essential details can be extracted from respondents (Merriam, 2009). This study has received ethical authorization from the Malaysian

Ministry of Education (KPM) via the Educational Planning and Research Division (EPRD) because the respondents are professionals in government educational institutions. This interview protocol originated to address the research questions and was finalized by author 2 and three other experts in qualitative research for review and improvement. The questions addressed in the interview protocol are listed in Table 1.

Table 1

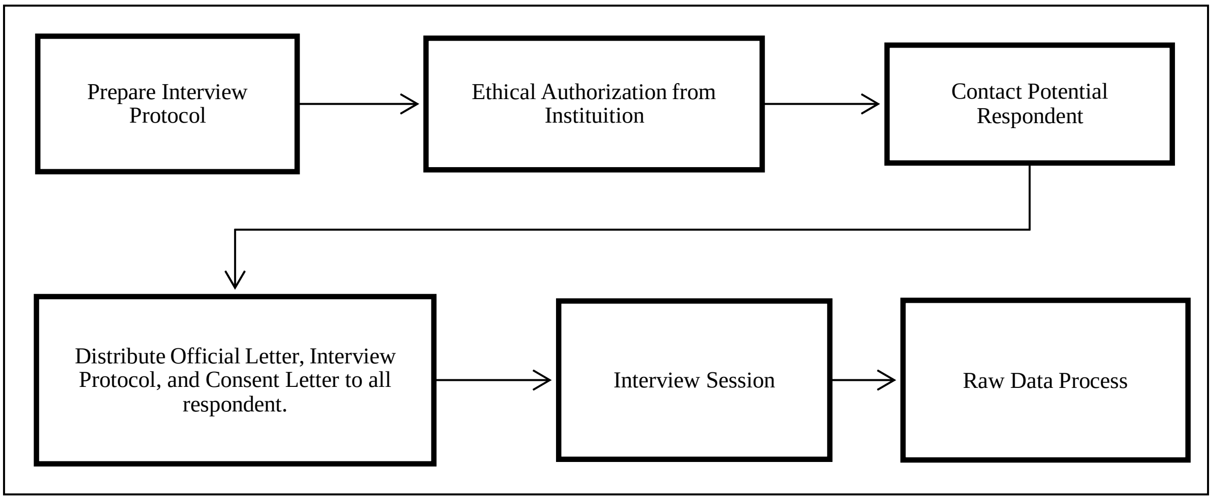
Questions in Interview Protocol

Question
1. How does the student's perception of mathematical instruction in the classroom?
2. Describe the strategies you employ to assist pupils who are mathematically weak and disinterested?
3. Elaborate your ideas on the usage of technology to enhance the mathematics learning environment?
4. State the typical barriers in applying technology into mathematics instruction?
5. Elaborate your thoughts on the incorporation of programming into the elementary mathematics curriculum?
6. How programming might assist in enhancing pupils' mathematical computational thinking and motivation?
7. Describe your perspective on the necessity of integrating programming into a mathematics learning module.
8. Can you describe about your knowledge in programming?
9. Explain further about your skill in programming?

After obtaining ethical approval, all respondents who had been identified were contacted via telephone and invited to participate in the study. Email is used to distribute the official invitation letter, interview protocol, and consent form to all participants. Consent forms were collected before conducting interviews with respondents (refer to Appendix A). All interview sessions were conducted via Google Meet and lasted between 20 and 30 minutes. To ensure the respondents' convenience, the study was conducted in an environment free of distractions and their native language, either English or Malay. The interview protocol underwent a pilot interview session to review and revise the sentence structure of the interview questions so that they are simple to understand, not repetitive, and express the research question. However, the findings from this session were not considered in this study. Interviews were conducted until data saturation was achieved based on the stopping criterion. Therefore, when no new codes are identified, or a code frequency in the data repeats three to five times, the stopping criterion for this study has been met (Hennink & Kaiser, 2022). The interview concluded with the eighth participant. All interviews are audio recorded, and the researcher is responsible for assuring the confidentiality and security of the data collected. Figure 1 summarizes the flow of the research data collection.

Figure 1

The Flow of Data Collection



Data Analysis

The audio recordings were transcribed verbatim. The respondents reviewed their transcript to refine and clarify the overview of the presented information. After completing the member-checking procedure, each transcription is labelled R1 through R8 for confidentiality. Each response was compiled into a transcription table based on the research questions to begin the coding process.

The researcher and peer reviewer manually analysed data to ensure the accuracy of interpreting interview transcripts. Each interview transcript is pre-read, the data are recorded and coded, and the findings are reported. Unprocessed data was used to create a coding structure using an inductive strategy. Each generated code will be broken down into phrases and categorised based on the meaning shared by each code group. Some of the generated codes create a subtheme and then a theme. It is determined that the codes, subthemes, and themes produced will address the research questions. After completing this, the second author verifies the coding process, subthemes, and themes in the table's transcription. Finally, this theme is examined to address all research questions.

Results

The result will presented in the form of demographics, perception of the mathematical instruction in the classroom, strategy assisting pupils who are mathematically weak and disinterested, technology usage to enhance the mathematics learning environment, barriers in applying technology into mathematics instructional, the incorporation of programming into the primary mathematics curriculum, programming assist in enhancing pupils' mathematical computation thinking and motivation, the necessity of integrating programming into a mathematical learning module, finally educators skills and knowledge in programming.

Demographic

Eight respondents agreed and declared the consent form for involvement in this study. The demographic information of the study respondents is presented in Table 2. All respondents fell into one of three professional categories: primary school mathematics teachers (n=5), private educators (n=2), and an IPGM lecturer (n=1).

Table 2:

Demographic information

Respondent Code	Gender	Age (years old)	Qualification	Experience in teaching mathematics (years)	Field of work
R1	Male	36 - 45	Master's degree	11 - 20	Private educator
R2	Female	36 - 45	Master's degree	11 – 20	IPG Lecturer
R3	Male	31 – 35	Degree	11 – 20	Primary school teacher
R4	Female	36 – 45	Master's degree	11 – 20	Primary school teacher
R5	Female	31 – 35	Master's degree	11 – 20	Primary school teacher
R6	Male	Above 45	PhD	More than 20	Private educator
R7	Female	31 – 35	Master's degree	5 – 10	Primary school teacher
R8	Male	36 – 45	Degree	11 – 20	Primary school teacher

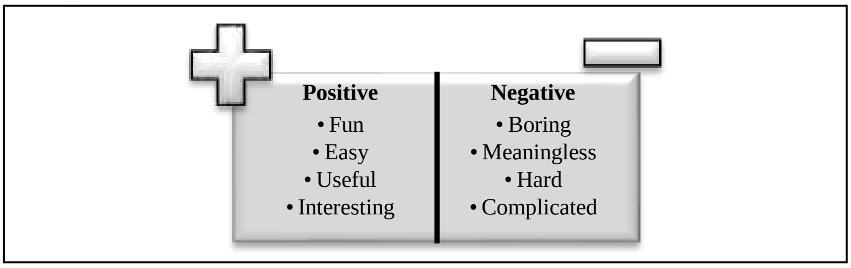
Four males and four women contributed to the study. Three of the eight respondents were between the ages of 31 and 35; four were between 36 and 45, and just one respondent older than 45. Most respondents (n=5) hold master's degrees, while only two hold bachelor's degrees, and only one holds a doctorate. All respondents have worked in mathematics education for more than five years.

Perception of Mathematical Instruction in the Classroom

There are two major themes regarding pupils' perceptions of mathematical instruction in class: positive and negative. Figure 2 depicts the pupils' perspectives on mathematics instruction in the classroom.

Figure 2

The Pupils' Perspectives on Mathematics Instruction in the Classroom



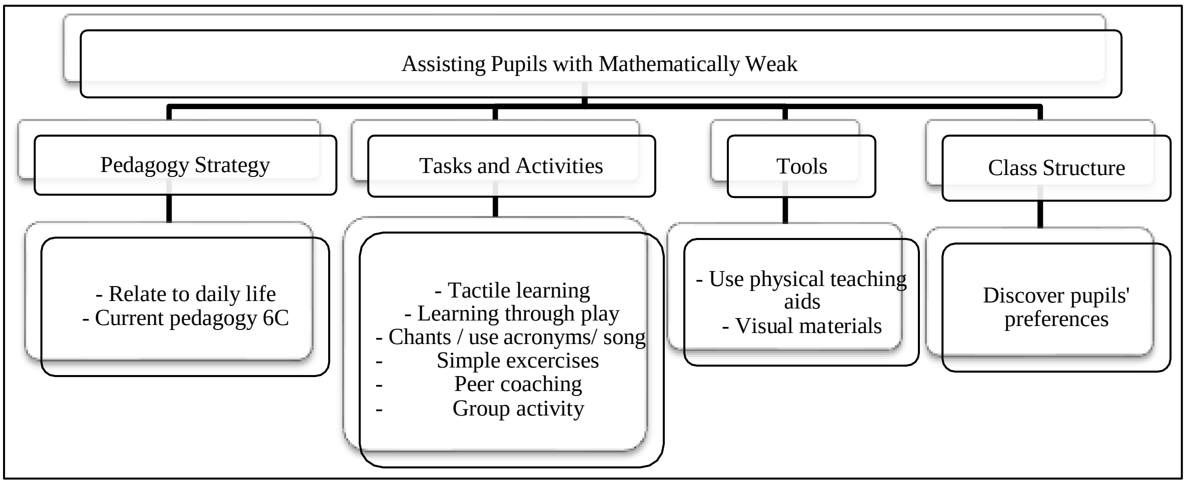
For positive themes, four subthemes are listed: fun, easy, helpful, and interesting, while for negative themes, four subthemes are listed: difficult, meaningless, boring, and complicated. A teacher, R3, remarked, "They (the pupils) find it difficult," and another teacher, R4, concurred, "Mathematics is a difficult, complicated, and boring subject". Besides, the finding also suggests that educators play a crucial role in shaping the learning environment within the classroom—a student's perception of mathematics results from the teacher's classroom instruction. A private educator, R1, stated, "It depends on the classroom mathematics instruction. If the learning content is engaging, it will be fun, useful, and easy. Otherwise, it will be boring, meaningless, and hard". R2, a lecturer at IPGM, agrees, stating, "Pupils' perceptions of mathematics instruction depend on how the educator conducts the teaching".

Strategies to Assist Pupils Who Are Mathematically Weak and Disinterested

Four primary themes are discussed when assisting pupils with mathematically weak: pedagogy strategies, tasks and activities, tools, and class structure. Figure 3 illustrates the theme.

Figure 3

Strategy Assisting Pupils with Mathematically Weak



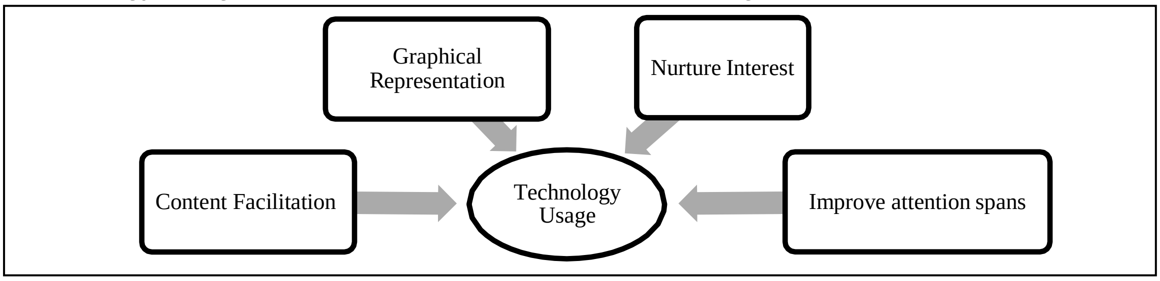
Each pupil is unique and has his or her preferences. Therefore, only a teacher can determine the most effective strategy for assisting pupils who are deficient in mathematics and less interested in the subject. Some of these respondents were concerned with enhancing pedagogical strategy, diversifying tasks and activities, employing an assortment of tools, and enhancing class structure. R1 and R3 choose to relate learning content to analogies or real-life situations. R1 stated, "Link the topics to daily life scenarios". R3 implements 21st-century learning, which emphasises teaching the 6Cs (critical learning, collaboration, communication, creativity, culture, and connectivity). Additionally, these characteristics of learning in the twenty-first century are also emphasised in the 2017 KSSR Revision curriculum (Putrajaya: Bahagian Pembangunan Kurikulum, 2018). Conversely, other respondents highlighted an array of tasks and activities in the classroom as their strategies. Tasks and learning activities include tactile learning, learning through play, the use of chants, acronyms, and songs, simple exercises emphasising basic mathematical skills, peer mentoring, and group activities. For R2, learning through play is one of the strategies that can assist weak pupils. Mathematical concepts will be easier for pupils to comprehend if they value and enjoy learning. This interest can be stimulated when the learning progression corresponds to the student's level, from simple to moderate to difficult. R7 stated that "explanation with simple exercises will aid pupils in mastering the fundamental skills". While R8 concurs with this viewpoint and emphasises the "try to make mathematics easy". The distinction between these strategies depends on the lesson objectives. In certain circumstances, pupils are required to memorise standard units, formulas, and multiplication facts. Therefore, for R3, "I also used specific chants and acronyms to memorise formulas". In addition, R5 believed that feeble pupils benefit greatly from peer mentoring and group activities through collaboration with their peers. Moreover, the use of tools and a well-structured class that aids these weak pupils should not be overlooked. Some of the weak pupils have difficulty visualising abstract concepts. Consequently, they require physical tools and visual aids. R2 indicated that "weak pupils have a low capacity for visualisation. They are unable to visualise the taught mathematical concepts. Therefore, educators must use concrete or even visual materials to ensure that pupils comprehend the concept accurately". R5 stated, "Video explanations could also attract the pupils' attention". In addition, R6 emphasises the need for teachers to know their pupils' preferences before the commencement of class: "adapt lessons based on pupils' preferred learning style". In the end, teachers need to be more aware of the needs of their pupils and focus on these four themes when making plans for learning support that will help weak pupils.

Technology Usage to Enhance the Mathematics Learning Environment

Four themes emerged from the use of technology to enhance mathematics learning in the classroom: content facilitation, graphical representation, nurture interest, and improved attention spans. The theme is illustrated in Figure 4.

Figure 4

Technology Usage to Enhance the Mathematical Learning Environment



All respondents acknowledged that the use of technology in mathematics education is extremely beneficial. R5 remarked, "Extremely helpful”. Therefore, the use of technology in the classroom is viewed as an essential resource for facilitating learning and instruction. The utilisation of Microsoft PowerPoint slides, the installation of songs or chants via the audio system, and the dissemination of assignments via Google Form are examples of the use of technology that facilitates learning sessions and saves teachers time when delivering educational content. "The use of technology, such as online activities and songs that can be installed and related to the mathematics, can facilitate pupils' comprehension of mathematics easily and enliven the classroom environment," according to R7. Nonetheless, two respondents emphasised that the use of technology must be tailored to the learning needs at an appropriate time. As indicated by R8's response, "helpful if used on the right time". Although technology is very accessible to today's generation, there is also a need for time allocation for other activities. Since R1 stated that, "however, in the learning stage, hands-on approaches are valid and appropriate. Drilling exercises are still necessary".

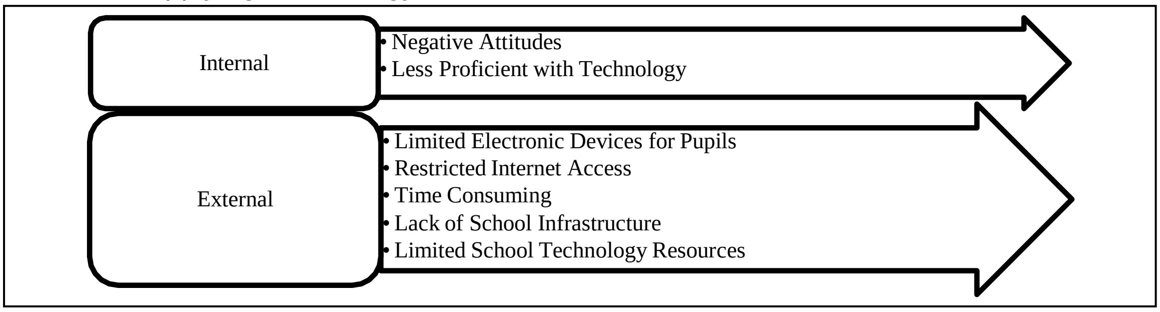
As a versatile learning resource, technology clarifies a mathematical concept. "There are numerous technological methods for visualising abstract concepts", according to R2. Visualisation enables the explanation of a mathematical concept because it is supported by images and explicit visual displays and can be explored extensively (Mukhtar & Rosli, 2022). This method is essential for discussing a complex and abstract concept. Hence, pupils can comprehend mathematical concepts with a deeper understanding. Even R3 believes that "the presence of programming gives more illustrations than our whiteboard and marker". As an instance of the application of augmented reality (AR), it can be used to see three-dimensional structures in more detail, and the Geometry Sketchpad software may display the object's translation and reflection. Regardless of advancements in artificial intelligence (AI) technology, a virtual practical example is possible and unlimited in learning (K. Zhang & Aslan, 2021). The concentration and passion for learning mathematics could be bolstered by a firm understanding and foundation. R2 believes that "technology's BBM can create a more positive learning environment and pique pupils' interest". While R5 mentioned that "technology enhances classroom focus". Focus during lessons and a desire to learn have a significant impact on student learning motivation (Herpratiwi & Tohir, 2022). The ability to succeed in mathematics is correlated favourably with passion for the subject (D. Zhang & Wang, 2020). In this regard, the usage of technology can indirectly increase pupils' engagement, focus, and drive to succeed in mathematics classes.

Barriers in Applying Technology into Mathematics Instructional

Typical barriers to the incorporation of technology in mathematics education can be categorised into two groups: internal and external constraints. Figure 5 illustrates the topic.

Figure 5

Barriers in Applying Technology into Mathematics Instructional



The Curriculum Development Division (BPK) has supplanted the current curriculum with the Revised Integrated Primary School Curriculum (KSSR) since 2017. Among the introduced reforms are the enhancement of constructivist learning and the incorporation of Science, Technology, Engineering, and Mathematics (STEM) in the Revised KSSR Mathematics for primary schools. Despite nearly six years of STEM integration, particularly technology in mathematics education, primary school mathematics teachers continue to confront a variety of external constraints. Restricted internet connection, financial constraints affecting the provision of electrical devices to all pupils, the lack of well-maintained facilities in computer labs and classrooms in primary schools, and the absence of other resource support, such as professional courses for teachers and technicians who can assist teachers. Internet connectivity remains a main issue for four of the respondents at school, they claimed. R5 reported that "the school's internet is still slow". Therefore, the process of producing educational resources with the aid of technology becomes challenging and cumbersome for teachers, resulting in a decline in their motivation to use technology in the classroom. R8 concurred with this statement and added, "limited school technology resources or restricted internet access". R7 also mentioned that "not all classrooms have adequate facilities and infrastructure". To make matters worse, these teachers are overburdened with limited time and additional teaching chores. R4 added "time constraints in the classroom".

Apart from external obstacles, respondents also list internal issues. Negative thinking is the primary obstacle for teachers. Even with external limitations, teachers remain able to embark on other initiatives if they have a strong desire and determination to overcome them. R2 considers "the negative attitude of educators who are resistant to change and who continue to use conventional teaching methods. Teachers consider the implementation of this technology to be burdensome and time-consuming to implement in the classroom". This mindset makes the development of technology in classroom instruction more challenging. Inadequate skills and knowledge in integrating technology into instruction also contribute to this barrier. According to R3, "...few teachers are literate in technology". With the participation of the ministry, the State Education Department (JPN), the District Education Office (PPD), and the school administration, these obstacles can be minimised with adequate attention.

The Incorporation of Programming into the Primary Mathematics Curriculum

Six respondents believe programming can be implemented into primary mathematics education. This integration aligns with the growth of mathematics education worldwide. R3 believes "it is therefore appropriate for our country to follow those steps to prepare our pupils with this programming knowledge to compete on a global level." In addition, R7 felt that "with programming, pupils will be more welcoming to studying mathematics". Thereby, R4 suggests "appropriate for pupils beginning level 2". Nevertheless, two respondents disagreed. R8 argues that this integration is "still struggling to be implemented". Even R6 claims that "programming is not a part of daily life, so neither pupils nor their parents are interested". As a private educator, R6 claims that the programming has not yet been well received by parents and pupils due to facility limitations and teachers' lack of expertise in programming. Therefore, teachers confront the challenging task of convincing pupils and parents of the significance of this integration for the pupil's growth.

Programming Assist in Enhancing Pupils' Mathematical Computational Thinking and Motivation

Programming and computational thinking (CT) possess cognitive and pedagogical similarities that have a positive effect on the learning of primary school pupils (Bers et al., 2022). In addition to this finding, five respondents stated that programming activities improve pupils' critical, logical, creative, and reasoning thinking. R2 states, “train them to think critically. Clearly, this can enhance CT skills". R6 believed that "programming employs mathematics and logical thinking". These competencies encourage pupils to always pursue the intended outcome. According to R5, "programming requires pupils to plan to achieve the desired outcome". When these skills are effectively developed through programming activities, pupils can solve problems. R3 stated, "Programming can help pupils learn and adopt problem-solving skills". This gives pupils a positive impression of mathematics. R1 said, "Programming improved the teaching of mathematics, particularly during the topic's introduction, where pupils would have a strong mental image of it". Through programming, pupils are also free to explore and ultimately experience learning satisfaction. R3 believes that "help boost motivation given that they achieved their objective of using programming in studies".

The Necessity of Integrating Programming into a Mathematical Learning Module

The necessity for incorporating programming into the mathematics learning module has two themes: enhancing pupils' problem-solving skills in mathematics learning and facilitating teachers to deliver instruction. In Malaysia, modules that integrate programming and mathematics education at the primary school level have yet to be developed. This is due to the tie between programming and RBT subjects or only as extracurricular activities. However, all respondents to this study believed the development of such a module was necessary. R2 and R8 stated, "It is essential to develop a mathematics learning module that includes programming." This is because programming encourages pupils' imaginative problem-solving abilities. This ability is essential when dealing with mathematics. This finding suggests all respondents are conscious of the necessity and benefits of integrating programming into primary mathematics education. It not only provides pupils with early exposure to computer literacy but also fosters their critical thinking skills. On the contrary, such a module can provide teachers with guidance and scaffolding for systematic, directed, and comprehensive lesson planning. According to R5, "this module construction is good and assists a teacher in mathematical instruction with a combination of programming". Programming skills and knowledge are very extensive. Therefore, beginners will encounter difficulties if basic programming skills are lacking. The existence of a comprehensive module that integrates learning mathematics and programming has become a guide for teachers to implement classroom instruction, and this module has become the foundation for the future development of teachers' ideas.

Educators Skills and Knowledge in Programming

Unfortunately, most educators have limited or beginner-level programming knowledge and skills. Only R6 has in-depth knowledge and proficiency with any programming software. This finding suggests that although teachers are mindful of the significance of integration in mathematics education, most of them still have limited programming knowledge and skills.

Discussion

This study's primary objective is teachers' perceptions of the need for programming modules in primary mathematics instruction. As a relatively new approach to the mathematical learning environment in Malaysia, researchers must assess the nature of the current mathematics learning environment in Malaysian primary schools and the teachers' readiness for technology-based teaching and learning before implementation. Thus, the objective of the first research question is to evaluate students' perceptions of the current mathematics learning environment. Positive and negative student perceptions are portrayed in Figure 1's summary of results. Nevertheless, just a few had a favourable opinion of mathematics education. Conversely, nearly half of respondents expressed a negative opinion. This reveals that pupils have a negative impression of mathematics. Even in Rameli & Kosnin (2017)study, it was demonstrated that primary school pupils most frequently have negative perceptions of mathematics, including laziness to do mathematics exercises when difficult, lack of interest, inability to concentrate, and perception that mathematics is difficult. Instead, international assessments like TIMSS 2019 reveal that 41 eighth-graders dislike mathematics lessons (Mullis et al., 2020). These negative perceptions come from employed strategies that are inappropriate, less engaging, and the delivery of learning materials is inadequate. However, these negative perceptions will be changed if pupils have a more favourable teaching style, are exposed to engaging strategies, and utilise interesting instructional aides that correspond to their development level. This is because only effective teaching methods can impart a favourable impression on students (Shi & Baker, 2022). Whether the perception is positive or negative, it reflects the pupils' experiences. This is because teachers' practices in the classroom have a tremendous impact on pupils' cognitive development and complement the early exposure that pupils experience at home. Further worrying is the fact that not only is there a negative perception of mathematics, but pupils also struggle to master basic facts and essential mathematical concepts in primary school (Mamat & Abdul Wahab, 2022). The negative perception of mathematics among pupils in primary schools must be addressed promptly. If left untreated, this issue will lead to other issues like math anxiety, poor achievement (Gunderson et al., 2018; Mutlu, 2019), and avoiding all math-related events (Krinzinger et al., 2010). It is necessary to raise teachers' awareness of creating a learning environment that can diminish students' arithmetic fear (Hasala & Kelly, 2020; Kim et al., 2017; Liu et al., 2017). Thus, this finding also indicates that there is a critical need for teachers to enhance their classroom instruction. Since there is potential, the issue will become more prominent at the secondary school and higher education levels.

The second research question addresses instructors' perspectives on the incorporation of technology to improve the mathematics learning environment. Each respondent admits that technology can improve the mathematics learning environment. Figure 4 summarises how the respondents of this study often utilise technology for content facilitation, visual representation, nurturing pupils' interests, and stimulating students' focus on learning. Educational technology practice can increase pupil engagement in mathematics instruction and promote positive and engaging pedagogy (Attard & Holmes, 2020). Since those practices and educational materials can facilitate the lesson and portray abstract concepts. Even students who use technology such as GeoGebra also show more outstanding achievements compared to their friends who use traditional learning, providing sufficient facilities individually (Juandi et al., 2021). Moreover, introducing pupils to more captivating learning content in primary school can pique their curiosity in STEM fields (Kamsi et al., 2019). Nonetheless, several barriers must be considered when employing technology in education. Unavailability of internet access, lack of school technology resources, time constraints, and lack of technological expertise among educators are the obstacles that educators frequently face. This finding is consistent with the mathematics instructional trend research conducted by Ng & Maat (2022).

Eventually, internal factors have a greater impact on teachers' use of technology in mathematics education. Although there are various constraints in terms of equipment and expertise, teachers who are determined to use technology in the classroom will take many initiatives to accomplish their goals. The success of these pupils' learning processes depends on the scaffolding provided by carefully designed and controlled value-added construction of learning elements. Hence, the successful implementation of educational technology in early mathematics education depends on the teachers' support (Verbruggen et al., 2021). However, two respondents emphasised the necessity of using technology at the appropriate time and according to their learning needs. Educators must determine the necessity and adequacy of technology in a particular educational content of their choosing (Ravendran & Daud, 2019). Considering each mathematical concept necessitates a distinct medium. There are times when physical activities are required to enhance student comprehension, such as hands-on work and discussion, or when drills activities are necessary for math skills exercise.

The final research question addresses the need for programming modules in primary school mathematics education. Each respondent concurs that such a module is essential for learning mathematics in primary school. This module should be designed and developed to strengthen current mathematics instruction and learning. This is primarily attributed to the fact that programming in mathematics education has cognitive, social, and motivational benefits. Programming undoubtedly fosters a culture of critical and computational thinking, which is useful in the development of problem-solving skills in mathematics education. Indeed, it will encourage pupils to explore their mathematical knowledge and abilities more. Besides, it also serves as a resource for teachers who wish to integrate programming into mathematics education. However, most respondents must acknowledge that they lack programming knowledge and skills, along with the ability to incorporate programming into mathematics education. In the meantime, the study suggests that the quality of teaching and learning practices impact teachers' performance (Yang & Kaiser, 2022). Hence, employing modules as a guide improves and organises the quality of instruction. Teachers have high expectations for modules that provide explicit lesson plans, teaching and learning objectives, detailed steps, guides for teachers, suggested teaching time, suggested activities, and suggested teaching materials (Jamel et al., 2019). Consequently, the development of this module will assist in enhancing teaching practice and the overall quality of teachers' instruction.

Limitations of the Study

There are potential limitations to this needs analysis study. This study's intended results depend on the data collected and analysed using the instruments and methods employed here. The findings from this study could be affected by variables such as bias and ambiguity. Our estimates may be conservative and underestimate the full potential of mathematical programming module for primary school, such as (1) our baseline scenario assumed that this programming module helps in improving mastery of CT skills and student motivation; (2) we only evaluated this study using the need analysis approach; (3) we only used a qualitative approach that used a semi-structured interview instrument; (4) sampling methods that are limited to purposive samples; (5) sample size is quite small and not representative of the entire population; (6) research respondents who involve only the educators from different organisation without the involvement of students, parents, officers at the ministry, and experts at other public higher education institution. However, we did not include any other potentially beneficial effects in this study. Therefore, this finding cannot be generalised to reflect the entire population of primary school mathematics teachers in Malaysia. We are also aware of the potential risk of missing explicit information that needs more exploration of programming ability apart from improving CT skills and student motivation.

Future Research

Future work should consist of obtaining viewpoints on this combination from different kinds of groups, including pupils, parents, administrators, curriculum experts, and relevant ministry officials. To facilitate data triangulation, methodological improvements can be made by including instruments such as observations and checklists. As an outline, it would be advantageous to specify what elements are required and expected by teachers for a module, so that the developed module meets the actual requirements of teachers and supports teaching in the classroom holistically.

Conclusion

This study explores students' perceptions of current mathematics education and the need for programming to be integrated into mathematics education in primary institutions. Although teachers are aware of the importance and benefits of programming in enhancing CT skills and motivation in mathematics, the main hurdle they face is a lack of programming skills and the incompetence to integrate programming into mathematics instruction. Consequently, there is an imperative need to develop a mathematical programming module for pupils in primary schools to assist teachers in grasping these skills. This study is the first step in developing a comprehensive programming module for learning mathematics for Malaysian pupils in primary schools.

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APPENDIX A

Consent Form

Interview Consent Form

Research Project Title: The Design and Development of Programming Modules for Mathematics Instruction in Elementary Schools

Researcher: Masyithoh Md Zuber

Respondent: 1

The interview will take about 30 minutes. We do not anticipate any risks associated with the participation, but you have the right to stop the interview or withdraw from the research at any time.

Thank you for participation in this interview session. This consent is required to ensure that respondents apprehend the purpose of their participation and accepted to the terms of their involvement. Please review the attached information document and sign the form to indicate your approval of the following:

- The interview will be audio recorded and transcribed.
- The respondent will receive the transcript and could rectify any factual errors.
- The researcher will analyse transcripts for the purpose of the study.
- Access to interview transcripts is restricted to researchers, academic colleagues, and other researchers who collaborated on this study.
- Any summary of the content of the interview or quotes directly from this interview that are made available through academic publication or other academic outlets will be kept confidential, as will any personal information of the respondent or other information related to this interview.
- The actual recording will be kept until the submission of this thesis is complete, after which it will be destroyed.

Quotation Agreement

I also understand that my words may be quoted directly.

I wish to review the notes, transcripts, or other data collected during the research pertaining to my participation.
I agree to be quoted directly.
I agree to be quoted directly if my name is not published and anonymised.
I agree that the researchers may publish documents that contain quotations by me.

All or part of the content of your interview may be used.

- In academic papers, journal articles or policy papers.
- On our website and in other media that we may produce such as spoken presentations.
- On other feedback events
- In an archive of the project as noted above

By signing this form, I agree that.

a. I am voluntarily taking part in this project. I understand that I don't have to take part, and I can stop the interview at any time.
b. The transcribed interview or extracts from it may be used as described above.
c. I have read the Information sheet.
d. I don't expect to receive any benefit or payment for my participation.
e. I can request a copy of the transcript of my interview and may make edits I feel necessary to ensure the effectiveness of any agreement made about confidentiality.
f. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

____

Printed Name

____

Respondents Signature Date

Researcher’s Signature Date

Mnemonics Strategy in Enhancing Graph Sketching Skills

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Abstract

This paper aimed to present the impact of using the mnemonics strategy or known as acrostics to improve students' graph sketching skills and enhance students' confidence in sketching graphs. This research involved seven students who enrolled in the course Mathematics SM015 at Kolej Matrikulasi Pulau Pinang during the academic session 2022/23. The cognitive load theory serves as the theoretical framework adopted to achieve the aim of this study. The Kemmis and Mctaggart model is applied in this study. Pre-tests and post-tests were conducted to investigate students' performance after implementing the mnemonic strategy in graph sketching. The mnemonic strategy effectively improves students' graph sketching skills and enhances their confidence in graph sketching. From the paired-sample t-test, the p-value <0.5 implies a significant difference in the pre-test and post-test means. Furthermore, the higher mean of the post-test indicates that students improved significantly in sketching graphs after introducing the mnemonics strategy. The students are more confident when sketching graphs after implementing the mnemonic strategy.

Keywords: graph sketching, mnemonic strategy, cognitive load theory

Introduction

Mathematics utilises graphs to create meaningful representations and enrich the comprehension of scientific knowledge. According to Inan et al., (2014), graphing is an indispensable element of science and social studies, which is essential for students to represent information in graphs and interpret the graphs from an early age. However, students encounter various obstacles in sketching graphs and consequently lose interest in learning different types of graphs. Many researchers believe that more graphing skills are needed to comprehend the concepts of Mathematics and Sciences (Lapp & Cyprus, 2000). Therefore, the ability to use graphs to do scientific analysis of the behaviour of a phenomenon is crucial for students.

As a result, researchers need to have a strategy to guide students in sketching graphs. One of the strategies used is the mnemonics strategy, where it is appropriate to remember information. In this study, researchers implemented the mnemonics strategy (acrostics) to help students remember the five main steps to sketch graphs, which are (1) Type of graph, (2) Shape of the graph, (3) Special point or line, (4) Intercepts, (5) Graph sketching. The researchers transform the five steps into the mnemonics phase, 'The Simple Steps in Graphing,' to help students remember the steps in graph sketching. Belleza (1981) defined mnemonics as learning strategies that can improve the initial learning and later recall of information. Thus, researchers used the mnemonics phase of ‘The Simple Steps in Graphing’ to assist students in quickly recalling the procedures of graph sketching.

Problem Statement

In most tutorial classes, when the lecturer asks students to sketch the graph of a given function learned in their lecture, students tend to show frustration and depression when attempting to sketch the graph. Most of them needed help to sketch the graph correctly as they had no experience with graph sketching since secondary. The poor experience eventually caused students not to have a clear idea of how to begin sketching a graph. Students cannot digest the knowledge and techniques they learned during lecture hours and need more time to discuss with friends. In addition, peer discussion often only helps a little, as most of their friends need to improve graph sketching. They are also reluctant to ask their tutor as they can only tell their problem in graph sketching once their lecturers pose questions to them to identify their mistakes while sketching graphs. Furthermore, the students need more motivation to learn graph sketching due to their ignorance of the meaningfulness of graphs in mathematics and real-life applications.

Research Objectives

This research aims to investigate the impact of using the Mnemonic strategy in

(a) Improving students' graph sketching skills.

(b) Enhance their confidence in sketching graphs

Research Questions

(a) Does mnemonic strategy improve students' performance in graph sketching?

(b) Does mnemonic strategy enhance students' confidence in sketching graphs?

Significance of Study

The topic “Functions and Graphs” contributes a significant weightage of about 20% in the Mathematics SM015 final exam of the matriculation program. Graph sketching is one of the essential skills within the topic. Nevertheless, students often need help with graph sketching during every session. In the context of this research, an educator must be creative and adaptive to make changes whenever necessary to help students in their learning. Besides that, an educator should be able to predict the possible learning obstacles students encounter and facilitate their problem-solving skills. It is also essential for an educator to take the initiative to consistently improve pedagogical skills to create an excellent teaching and learning experience for students.

Scope and Limitations of Research

The focus of this study is to help students level up their graph sketching skills. As outlined in the syllabus of the course Mathematics SM015, students are expected to be capable of sketching graphs of 10 types of functions. However, this study will only focus on the graphs of 6 kinds of functions: Quadratic, Absolute, Root, Rational, Exponential, and Logarithmic functions. Researchers are constrained by time limitations when evaluating various functions because researchers need to complete certain topics within a specific timeframe. This ensures that students can adequately prepare for their summative tests as scheduled.

Theoretical Framework

The cognitive load theory was initially developed by psychologist John Sweller in 1988 and served as the framework adopted to achieve the aim of this study. This theory suggests that our working memory, or short-term memory, can only hold a small amount of information at one time and that instructional methods should avoid overloading it to maximise learning (Sweller, 1988). There are three types of cognitive load: intrinsic, extraneous, and germane load. However, this study is mainly focused on germane cognitive load, as according to De Jong, T. (201, 0), germane load refers to "process" (what goes on in learning). The germane cognitive load is imposed by the processes of interpreting, classifying, interring and organising in the the construction of schemes and subsequent automation as the primary goal of learning learning. (Mayer 2002). Therefore, researchers use mnemonic strategies to help organise the graph sketching steps to reduce the germane cognitive load.

In the context of this research, students enrolled in the course Mathematics SM015 are tasked with mastering the skill of sketching ten different types of function graphs within a limited time frame. These graphs exhibit varying shapes, intercepts, and asymptotes, making it a great challenge for students to remember them all. Consequently, students' working memory resources required for processing information exceed the available working memory capacity. This results in cognitive overload because the working memory's capacity is limited to about 20 seconds. (Peterson, L and Peterson, M, 1959). As a result, students need help to sketch any graphs, and sketching even a graph becomes time-consuming. Consequently, the entire learning process becomes less effective, and transferring knowledge from short-term to long-term memory becomes difficult.

To address this challenge, new methodologies should be developed to capture cognitive load in real-time and link to strategy use. (Baekaerts, M, 2017). To this end, researchers have employed cognitive load theory as a foundation to design a new approach to teaching graph sketching, utilising a mnemonic strategy. Initially, researchers break down the graphing process into steps into five distinct steps, thereby reducing the complexity of the task and lightening the cognitive load. Subsequently, a mnemonic strategy is applied to assist students in organising these steps, ultimately reducing the cognitive burden on working memory and enhancing the efficiency of the learning process.

In conclusion, the cognitive load theory that serves as this study's guiding framework helps create an instructional method to prevent overloading students' working memory. Thus, by adopting this new approach, students can enhance their learning experiences in graph sketching.

Literature Review

Graph sketching is one of the fundamental skills frequently employed by mathematics teachers to explain various topics in mathematics (Kong and Kwok, 1999). Graph sketching provides easy comparison analysis of data and a deeper understanding of data by visually depicting relationships between variables, enabling conclusions and aiding in communicating research findings (Cuemath, 2023). Proficiency in graph sketching enhances mathematical communication and reasoning skills, allowing for more straightforward explanations and interpretations of mathematical concepts (Kranak et al., 2019). Expert teachers can sketch graphs instantly using their knowledge of graphs (Komaromi, 1990, as cited in Kong & Kwok, 1999). However, it remains a challenge for many students to sketch graphs manually due to various factors.

Some students are even reluctant to acquire manual graph sketching skills, deeming them unnecessary due to the ease and convenience of utilising digital tools such as DESMOS, GeoGebra, and graphing calculators nowadays. While digital tools undeniably offer tremendous assistance in graph sketching and learning mathematical concepts, the manual approach has its enduring value that deserves mastery. According to Wees (2012), the convenience offered by digital tools in graph sketching can reduce students' analytical and problem-solving skills as their minds tend to put less effort into the task, making them less likely to learn. Furthermore, Wees (2012) suggests that digital tools disguise critical mathematical concepts in specific tasks, potentially reducing conceptual understanding of these mathematical concepts.

"Mnemonic" is a word, sentence, poem, etc., that helps you to remember something, according to the Oxford Advanced Learner's Dictionary 7th edition (2005). Mnemonic can take on various forms, often as sentences or phrases, to facilitate the memorisation of information. Table 1 from Putnam (2015) illustrates some of the popular mnemonics and their descriptions.

Table 1

Descriptions of Popular Mnemonic Techniques and Systems

Mnemonic	Description
Link method	Interactive visual imagery connects items in a list, making a chain. Item 1 is joined with item 2, and a separate image joins item 2 with

	item 3, and so on. Then, retrieving an item in the list cues the next item.
Method of loci	First, a memory palace—a mental map of a building or walk you know well, such as your house—is memorised. Then, imagery stores list items at different locations throughout the palace. Items are retrieved by "walking" through the palace.
Peg system	A "peg list," or a list of concrete objects in a specific order (e.g., one is a bun, two is a shoe, three is a flea), is learned. Then, visual imagery combines the to-be-remembered items with the peg items. Items can be retrieved by thinking of a number and the corresponding peg, which cues the target item.
Keyword method	First, a keyword that sounds like an unfamiliar word (e.g., "dentist" sounds like "la dent") is found. Then, imagery joins the keyword with the definition of the unfamiliar word (an image of a "dentist" holding a large "tooth"). Seeing "la dent" activates the dentist, which in turn should activate the tooth.
Phonetic system	Each number corresponds to a consonant sound (1 = t, 2 = n, 3 = m etc.). The numbers can be remembered as words, using vowels as necessary. For example, 321 can be remembered as "manatee." Words can be decoded back into numbers.
Acronyms	The first letters of a list of words are used to create a new word. For example, the colours of the rainbow (red, orange, yellow, green, blue, indigo, violet) can be remembered as ROYGBIV. Each letter serves as a retrieval cue for the target items.
Acrostics	The first letters in a list of words are the first in a new sentence or phrase. For example, the colours of the rainbow can be remembered as Richard Of York Gave Battle In Vain. The first letter in each acrostic word serves as a retrieval cue.
Songs, stories and rhymes	Words in a list are joined together by elements in a story or included in a song or rhyme. Songs and rhymes can also be written to remember specific information (e.g., i before e except after c).

Implementing a mnemonics strategy in the teaching and learning context is not a recent innovation. According to Putnam (2015), first-letter mnemonics (acronyms and acrostics) appear to be the most widely used mnemonics in education, followed by the others.

The first-letter mnemonics are also commonly used in learning mathematics. The acronym BODMAS is one of the most famous and widely used mnemonics for remembering the order of operations. In addition, there are other intervention acronyms such as LIPET to remember the part of integrand to set equal to "*u*" when performing integration by parts (Taylor, 2019) and DAIS to recall the steps in sketching the graph of exponential and logarithmic functions (Aw Yang and Fu, 2017). Furthermore, a list of mnemonics implemented in mathematics was compiled by Singh (2022) in his studies for additional examples besides acronyms.

Numerous studies have discovered positive outcomes concerning the integration of mnemonics. According to Bellezza (1996), mnemonic learning can enhance learning by facilitating a positive transfer from existing knowledge to acquiring new knowledge. Subsequently, further research by Laing (2010) has found that mnemonic devices can accelerate the rate at which new information is acquired and improve formal reasoning. The findings of both studies indicate that mnemonic strategies are suitable for implementation in teaching and learning contexts. Mnemonics provide a natural learning approach and can be integrated within the cognitive landscape to combine students' prior knowledge with new knowledge, resulting in a more accessible and organised format. Another research study by Greene (1999) concluded that mnemonic training enhances learning and that mnemonic instruction is retained over time, especially among students with learning disabilities. As students possess different learning abilities, it is undeniable that students require mnemonic strategies to assist them in retaining essential and complex information in their memory for a longer time.

Scruggs and Mastropieri (1991) have found the significant impact of mnemonic strategies in the classroom, whereby trained students could effectively generate and apply their techniques to novel content. This research, therefore, sets out to achieve the ultimate objective of exposing students to mnemonic strategies during graph sketching, with the belief that this will not only assist them in organising their thoughts when sketching graphs but also cultivate their interest in the subject and encourage them to create their mnemonics to facilitate mastery of Mathematics or any other topic in the future.

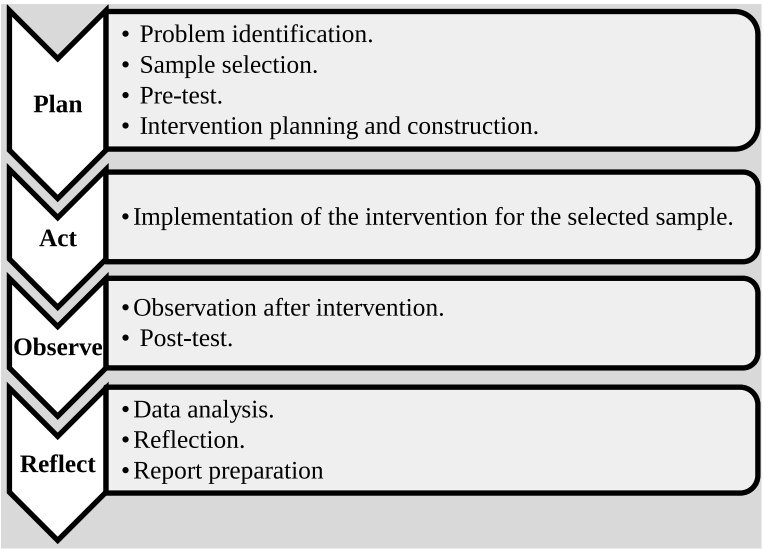
Research Methodology

Research Design

This research employed a quasi-experimental design, specifically the one-group pre–test–post–test design, embedded within the four processes outlined by Kemmis and Mctaggart (1988). This can be refer to Figure 1.

Figure 1

Kemmis and McTaggart's Model (1998)



Planning of action

The lecturer identified the target group based on students' academic backgrounds and observations in tutorial class after the students attended the mathematics lecture for the topic "Functions and Graphs", and the observation was recorded. Then, the lecturer carried out a pre-test on the target group.

(a) Students' academic background.

Every subject will be given a nickname, namely Student 1 until Student 7. Table 2 shows their SPM Modern Mathematics and Additional Mathematics results.

Table 2

Students' SPM Modern Mathematics and Additional Mathematics results.

Subject	Modern Mathematics	Additional Mathematics

Student 1	A	D
Student 2	A	D
Student 3	A	E
Student 4	A-	E
Student 5	B-	E
Student 6	A+	A+
Student 7	A+	B+

Reflection: Most students need a more robust concept of Mathematics as they did not achieve good grades in Additional Mathematics.

(b) Observation method

An observation regarding attitude when sketching graphs was done on these selected students. Table 3 shows the result after observing each student.

Table 3

Observation results as early data to the subject study

Subject	Attitude When Sketching Graphs
Student 1	She has no confidence in graph sketching.
Student 2	She needs help remembering what she has learned about graph sketching from the lecture.
Student 3	She is only good at sketching certain functions, such as quadratic functions.
Student 4	He has no idea how to sketch some of the graphs.
Student 5	It is time-consuming for her to sketch a graph.

Student 6	He cannot sketch a graph properly despite being a score student.
Student 7	He is only good at sketching graphs of certain functions and weak in exponential and logarithmic functions.

Reflection: From the observation, the subjects do not have clear guidelines for sketching a graph nor expose themselves to any method that can help them master graph sketching.

Implementation of Mnemonics Strategy

The lecturer explained to students the five main steps for sketching a complete graph as the following:

Step 1: Identify the 'Type of function'

For example, identify the function $f(x)=(x-1)^2+2$ as a quadratic function.

Step 2: Determine the given function's 'Shape of graph'.

This step requires students to know the basic shape of the given function. For example, the graph of a quadratic function has a parabolic curve that is either open upward or open downward.

Step 3: Find the graph's 'Special point or Special line'.

Each type of function has its unique point or line(s) and is named a particular point or special line(s) in this study. For example, the special point of the graph for the function $f(x)=(x-1)^2+2$ is the minimum point.

Step 4: Find the 'Intercept point(s)' on the x-axis and y-axis if they exist.

If the intercept points on the x-axis and y-axis, also known as the x-intercept and y-intercept, exist, they must be found. The x-intercept can be found by solving x when $y=0$, while the y-intercept can be found by solving y when $x=0$.

Step 5: Begin 'Graph sketching'

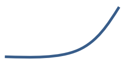
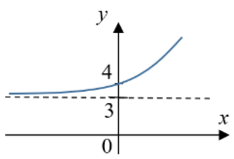
Gather all the information from Step 1 until Step 4 to sketch the graph. Subsequently, the lecturer combined the five steps in a mnemonic phase, as shown in Table 4.

Table 4

Graph sketching steps converted to mnemonic phase.

Steps	Mnemonic Phase
Type of function	**T**he
Shape of graph	**S**imple
Particular point or Special line(s)	**S**teps
Intercept on the *x*-axis and *y*-axis	**I**n
Graph sketching	**G**raphing

The lecturer demonstrated the application of the mnemonic phase to sketch the graph $f(x) = e^{3x} + 3$ to guide the students in graph sketching, and the result was stated as follows.

The:	**T**ype of function	→	Exponential function
Simple:	**S**hape of graph	→	
Steps:	**S**pecial line	→	$y = 3$ (Horizontal asymptote)
In:	**I**ntercept	→	*y*-intercept at $(0,4)$ where $f(0) = e^0 + 3 = 4$
Graphing:	**G**raph sketching	→	

The implementation of the mnemonic strategy (acrostic) in the graph sketching for all six functions can be further referred to in the Appendix. Next, the lecturer gave a post-test, and the corresponding results were recorded for further analysis. Meanwhile, the lecturer also made and recorded the observations during the post-test. After that, reflections regarding the post-test result and the observations were done. The research activities are summarised in Table 5.

Table 5

Activities of Research

Steps	Week	Evaluation	Activities

Early observation	9	Early observation	The observation was done during tutorial class.
Planning of action	10	Choosing subject	The subjects were chosen based on SPM Modern Mathematics and Additional Mathematics results and through pre-tests.
Implementation and Observation	10	Intervention session	Use mnemonics strategy (acrostics). (Mnemonics phase: **T**he **S**imple **S**teps **I**n **G**raphing.) (i) The five steps to complete a graph sketching were introduced. (ii) A post-test and observation were carried out during the post-test.
Reflection	11	Analyse result	Data analysis and reflection of the study were done. Then, the report was prepared.

Research Sample

The researchers chose seven students who enrolled in the course Mathematics SM015 at Kolej Matrikulasi Pulau Pinang during the academic session 2022/23. Five were selected based on their underperformance in SPM Modern Mathematics and Additional Mathematics. According to the researcher's observation during the tutorial lesson, two other students with distinction grades were selected due to their lack of confidence and limited understanding of graph sketching.

Instruments

A pre-test and a post-test were designed to assess students' graph sketching skills. The test, designed by the researchers, consisted of 12 questions. These questions involved six types of functions: Quadratic, Absolute, Root, Rational, Exponential, and Logarithmic functions. Students needed to sketch a graph to answer each question. In every question, students must be able to sketch the correct shape of the graph, intercepts, or asymptotes to obtain full marks.

Data Analysis

The scores from the pre-test and post-test will be analysed to calculate the mean, standard deviation, and p-value and to determine students' performance after applying the mnemonic strategy (acrostics). Seven students' observations during the pre-test and post-test are also recorded.

Research Finding and Discussion

A pre-test and a post-test (each with a total score of 12) were conducted before and after the students were exposed to the Mnemonic strategy (acrostics) in graph sketching, respectively. The means, standard deviations, and the *p*-value by the pair-sample t-test are summarised in Table 6.

Table 6

Mean, standard deviation and p-value were measured using a paired-sample t-test for the pre-test and post-test

Test	N	Mean	Standard Deviation	*p*-value
Pre-test	7	5	2.16025	0.0002
Post-test	7	10.4286	1.27242	

The mean score of the pre-test is five, which is 41.667% out of the full score, whereas the mean score of the post-test is 10.4286, which is 86.905% out of the total score. The results of the paired-sample *t*-test with $p < 0.05$ imply a significant difference between the means of pre-test and post-test. The significantly higher mean score in the post-test compared to the pre-test suggests that the students can perform much better in graph sketching after the mnemonic strategy (acrostics) was introduced to them. The students' attitudes in sketching graphs during the post-test were observed and recorded in Table 7.

Table 7

Observation results after learning the mnemonics phase

Subject	Attitude When Sketching Graphs
Student 1	She showed more comfort and confidence in sketching graphs.
Student 2	She could remember the steps in a short time and showed more eagerness to sketch various graphs.
Student 3	She has the confidence to sketch other graphs
Student 4	He knew how to start sketching graphs without having blurred expressions.

Student 5	She was able to sketch graphs quickly.
Student 6	He showed more organised steps during sketch graphs.
Student 7	He was able to sketch graphs of exponential and logarithmic functions.

Based on the observation, the mnemonic strategy (acrostics) enables students to be more confident in sketching graphs. Students were able to begin sketching graphs of a given function without much hesitation. The mnemonics phase helps students sketch graphs more organised and systematically.

Conclusion

The mnemonics strategy (acrostics) facilitates students' remembering of the steps in graph sketching as it provides more organised thinking to achieve a proper graph. As a result, students have a clear picture of how to start drawing the graph of a given function. Besides that, the mnemonics strategy (acrostics) improves students' confidence in sketching graphs, and further motivates them to sketch various graphs.

This study's strength is applying the mnemonics strategy (acrostics) to the researcher's students. This allows the researcher to monitor the students' improvement in graph sketching skills in detail. The researcher discovered that the mnemonics phase helps students recall the steps in graph sketching easily.

On the other hand, the weakness of this study is that students may not have a proper understanding of graph sketching. They only sketch graphs by memorising steps with the aid of the mnemonics phase. This apparently does not nurture students to appreciate the meaning of having graphs or the interpretation of information from them. Further research may be needed to identify the retention time of students in the graph sketching skills after exposure to the mnemonics phase and the effectiveness of the mnemonics phase in helping students to do graph interpretation.

Overall, the mnemonic strategy (acrostics) is still needed at this moment as a guideline for students to learn graph sketching. Thus, teachers can use this mnemonic phase to teach their students to sketch graphs in the classroom.

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APPENDIX

Mnemonic Strategy in Graph Sketching

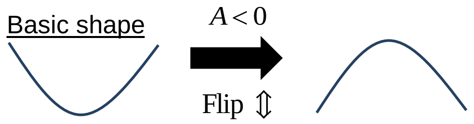
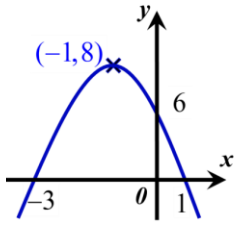
<table>
<tr><th>Mnemonic Phase</th><th>Procedures</th></tr>
<tr><td>The</td><td>Step 1: Type of function
▪ Identify the type of a given function in the following form accordingly.

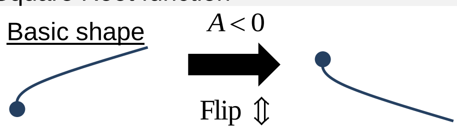
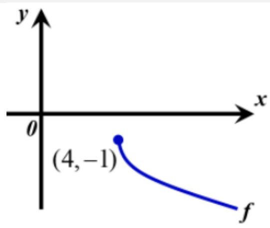
Quadratic Function: $f(x)=A(x+h)^2+k$
Square Root Function: $f(x)=A\sqrt{mx+c}+k$
Absolute Function: $f(x)=A\left|mx+c\right|+k$
Rational Function: $f(x)=\frac{A}{mx+c}+k$
Exponential Function: $f(x)=A\left(a^{mx+c}\right)+k$, $a>1$
Logarithmic Function: $f(x)=A\log_a(mx+c)+k$, $a>1$

Remarks:
▪ $A\neq 0$ and $m\neq 0$
▪ Conversion may be required on the given function to achieve the form above.</td></tr>
<tr><td>Simple</td><td>Step 2: Shape of graph
Determine the shape according to the sign of the constants A and m.
• Begin with the basic graph shape of the function.
• Followed by flipping the graph vertically $A<0$ and horizontally if $m<0$</td></tr>
<tr><td>Steps</td><td>Step 3: Special points or Lines

Quadratic Function: $(-h,k)\Rightarrow$ maximum / minimum point
Square Root Function: $\left(\frac{-c}{m},k\right)\Rightarrow$ vertex
Absolute Function: $\left(\frac{-c}{m},k\right)\Rightarrow$ corner point
Rational Function: $x=\frac{-c}{m}\Rightarrow$ vertical asymptote
$y=k\Rightarrow$ horizontal asymptote
Exponential Function: $y=k\Rightarrow$ horizontal asymptote
Logarithmic Function: $x=\frac{-c}{m}\Rightarrow$ vertical asymptote</td></tr>
<tr><td>In</td><td>Step 4: Intercept on the x-axis and y-axis
▪ y−intercept (if it exists): Calculate the y value based on $x=0$.
▪ X-intercept (if it exists): Calculate the x value based on $y=0$.</td></tr>
</table>

Graphing	**Step 5: Graph sketching** Sketch the graph in a Cartesian Plane.

Example 1: **Quadratic Function** $f(x)=-2x^2-4x+6$			
The:	**T**ype of function	→	By completing the square, $f(x)=-2(x+1)^2+8 \Rightarrow f(x)=A(x+h)^2+k$ Quadratic function
Simple:	**S**hape of graph	→	
Steps:	**S**pecial point	→	$(-1,8) \Rightarrow$ maximum point $(-h,k)$
In:	**I**ntercept	→	• *y*-intercept at $(0,6)$ [When $x=0$, $y=f(0)=6$] • *x*-intercept at $(-3,0),(1,0)$ [When $f(x)=0$, $x=-3$ or $x=1$]
Graphing:	**G**raph sketching	→	

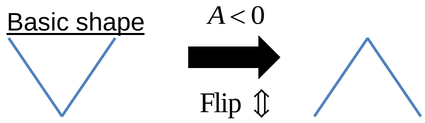
Example 2: **Square root function** $f(x)=-\sqrt{x-4}-1$			
The:	**T**ype of function	→	$f(x)=-\sqrt{x-4}-1 \Rightarrow f(x)=A\sqrt{mx+c}+k$ Square Root function
Simple:	**S**hape of graph	→	
Steps:	**S**pecial point	→	$(4,-1) \Rightarrow$ vertex $\left(\frac{-c}{m},k\right)$
In:	**I**ntercept	→	• *y*-intercept does not exist [No solution for *y* when $x=0$] • *x*-intercept does not exist [No solution for *x* when $f(x)=0$]
Graphing:	**G**raph sketching	→	

Example 3: **Absolute Function** $f(x) = -|2x+1| + 3$

The: **T**ype of function → $f(x) = -|2x+1| + 3 \Rightarrow f(x) = A|mx+c| + k$

Absolute function

Simple: **S**hape of graph → Basic shape



Steps: **S**pecial point → $\left(\frac{-1}{2}, 3\right) \Rightarrow$ corner point $\left(\frac{-c}{m}, k\right)$

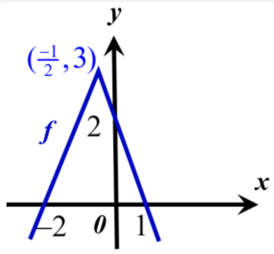
In: **I**ntercept →

- y-intercept at $(0, 2)$

  [When $x = 0$, $y = f(0) = 2$]
- x-intercept at $(-2, 0), (1, 0)$

  [When $f(x) = 0$, $x = -2$ or $x = 1$]

Graphing: **G**raph sketching →

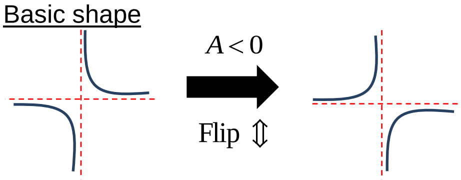


Example 4: **Rational function** $f(x) = \dfrac{-3}{2x+2} + 4$

The: **T**ype of function → $f(x) = \dfrac{-3}{2x+2} + 4 \Rightarrow f(x) = \dfrac{A}{mx+c} + k$

Rational function

Simple: **S**hape of graph → Basic shape



Steps: **S**pecial lines → $x = -1 \Rightarrow$ vertical asymptote $x = \dfrac{-c}{m}$

$y = 4 \Rightarrow$ horizontal asymptote $y = k$

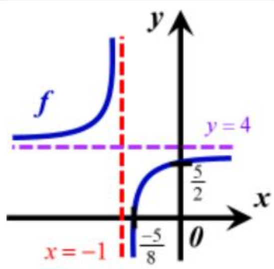
In: **I**ntercept →

- y-intercept at $(0, \frac{5}{2})$

  [When $x = 0$, $y = f(0) = \frac{5}{2}$]
- x-intercept at $(\frac{-5}{8}, 0)$

  [When $f(x) = 0$, $x = \frac{-5}{8}$]

Graphing: **G**raph sketching →

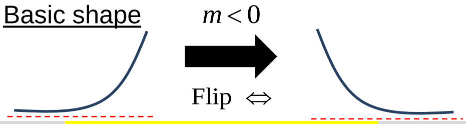


Example 5: **Exponential function** $f(x)=2e^{-x}-3$

The: **T**ype of function → $f(x)=2e^{-x}-3 \Rightarrow f(x)=A\left(a^{mx+c}\right)+k$

Exponential function

Simple: **S**hape of graph → Basic shape $m<0$

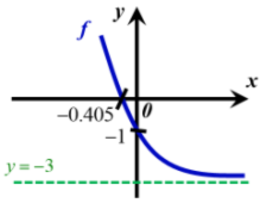


Steps: **S**pecial line → $y=-3 \Rightarrow$ horizontal asymptote $y=k$

In: **I**ntercept →

- y-intercept at $(0,-1)$
  [When $x=0$, $y=f(0)=-1$]
- x-intercept at $(-0.405,0)$
  [When $f(x)=0$, $x=-0.405$]

Graphing: **G**raph sketching →

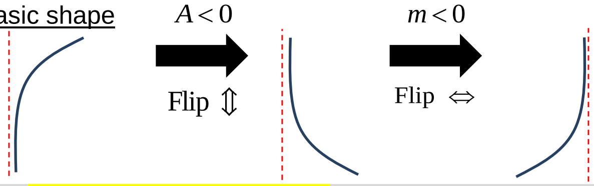


Example 6: **Logarithmic function** $f(x)=-\ln(2-x)+3$

The: **T**ype of function → $f(x)=-\ln(2-x)+3 \Rightarrow f(x)=A\log_a(mx+c)+k$

Logarithmic function

Simple: **S**hape of graph → Basic shape $A<0$ $m<0$

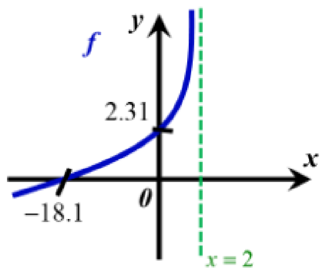


Steps: **S**pecial line → $x=-1 \Rightarrow$ vertical asymptote $x=\frac{-c}{m}$

In: **I**ntercept →

- y-intercept at $(0,2.31)$
  [When $x=0$, $y=f(0)=2.31$]
- x-intercept at $(-18.1,0)$
  [When $f(x)=0$, $x=-18.1$]

Graphing: **G**raph sketching →



Survey on Computational Thinking Skills with Internet of Things (IoT) Activities: Assessing Educators' Perspectives

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Abstract

In the age of rapid technology growth, computational thinking abilities are considered necessary. It is critical to grasp educators' viewpoints on the importance of computational thinking skills in Internet of Things (IoT) activities as IoT technology integration becomes more common in educational settings. In the context of IoT activities, this study intends to investigate educators' understanding, views, and practices linked to computational thinking skills. This study aimed to introduce the basics of electronics using Arduino microcontrollers and create circuits with the breadboard. The data collection method was mainly through a survey method and a Guttman scale questionnaire consisting of dichotomous and open-ended questions. Preliminary findings from the survey highlight the importance of educators' awareness and understanding of computational thinking skills in the context of IoT activities. The survey's findings will shed important light on how computational thinking skills are currently embedded into IoT activities and the assistance and materials educators need. This knowledge can help design curricular standards, policy suggestions, and targeted professional development programmes to improve educators' ability to encourage computational thinking skills through IoT activities. This poll adds to the more extensive discussion on the successful integration of IoT technology and computational thinking in educational contexts by understanding educators' perspectives.

Keywords: Computational thinking skills, Internet of Things, IoT, educators, survey, professional development, curriculum integration.

Introduction

Computational thinking (CT) skills involve problem-solving processes that include several characteristics, such as logically ordering and analysing data, creating solutions using a series of ordered steps (or algorithms), and disposition, such as the ability to deal with complexity and open-ended problems confidently. In education, CT skills are essential to developing computer applications, but these skills can also be used to support problem-solving across all disciplines, including mathematics, science, and the humanities. Students who learn CT skills across the curriculum can begin seeing a relationship between subjects and school and life outside the classroom. The Internet of Things (IoT), the new technological paradigm, is conquering the world by connecting various objects around us. In light of society's rising digitisation, the rapid rise of Big Data, IoT, and Artificial Intelligence applications has enhanced the demand for experienced individuals in STEM fields. The craze surrounding these applications has presented STEM educators with new difficulties and opportunities (Benita et al., 2021). IoT is a global network that connects things and materials to the Internet to enable them to interact or communicate with their surroundings (Abd-Ali et al., 2020). IoT was introduced in education, allowing Internet-based communications to be used in between physical things, sensors, and controls. Massive changes were made to educational institutions by embedding augmented reality and sensors in things and incorporating cloud computing (Bagheri & Movahed, 2016).

The essential purpose of this research paper is to assess educators' perspectives on computational thinking skills interrelated with IoT activities, the challenges they face, and potential solutions to overcome these challenges. With the advancement of education in the twenty-first century, teaching and learning are becoming more challenging. The necessities of the modern world require that education be in line with them in the information and technological age. To effectively solve problems in digital technology, CT skills are a vital talent that must be mastered from early education through higher education. Precisely, the research paper explores how educators in Southeast Asian nations perceive their perspectives.

This research paper aims to introduce the concept of CT skills and their importance in problem-solving and decision-making, as well as to develop the ability to identify patterns, analyse data, and create algorithms to solve problems in various fields. Besides that, this research exposes educators to the basics of electronics using an Arduino microcontroller and how to create basic circuits with the breadboard, acquire Arduino programming language and Integrated Development Environment (IDE), and how to troubleshoot and fix errors while developing basic Arduino circuits. Moreover, this research also assesses educators' current level of proficiency in CT skills in IoT activities. High-quality education is a core tenet of the 2030 Sustainable Development Agenda of the United Nations. It seeks to provide all educators and learners with inclusive, equitable, high-quality education. Digital technology has become crucial for achieving this objective (Haleem et al., 2022). Identifying and overcoming the barriers and challenges in this research aids educators in enhancing their technology skills.

Literature Review

Computational Thinking Skills

The competencies, knowledge, and abilities required for success in contemporary society have altered in the twenty-first century. CT was first discussed in terms of how computer scientists think. Still, in the modern era, it has become a fundamental skill for anyone who needs to navigate the technological world and solve problems successfully. According to Wing (2006), CT skills should be included in everyone's analytical skill set in addition to reading, writing, and mathematics (PALTS & PEDASTE, 2020).

Digital culture and technology are pervasive in the modern world. One of the skills needed to overcome problems in today's technologically sophisticated and complex world is CT (Subramaniam et al., 2022). Wing (2006) defines CT as "the mental operations involving framing problems including their solutions expressed in a way that an information-processing agent may successfully carry out." Numerous research studies were conducted to close the CT gap (Sun et al., 2021b). As a result, many scholars underline the importance of incorporating CT into the curriculum to promote 21st-century literacy at all levels of education, from kindergarten to university (Subramaniam et al., 2022).

According to Voogt et al. (2015), computational thinking is regarded as a fundamental skill needed in the twenty-first century. It is well known that CT skills enable students to build and improve their capacity for creative problem-solving and thinking, equipping them with the necessary CT skills to handle more challenging challenges successfully. According to Wing (2006), CT is a technique of thinking that solves problems rather than a particular field. As a result, having CT skills may help someone tackle a more challenging problem (Wing, 2006). The abilities required for computational thinking frequently include problem breakdown, pattern recognition, abstraction, and creating algorithms to solve problems (Shanmugam et al., 2021).

Internet of Things (IoT)

IoT has gained the attention of global researchers in computer science and other scientific and human domains because of its significance in many spheres of life, especially education, and because of the crucial services it offers to most educational institutions (Suaad et al., 2023). The Internet of Things is the next phase in the evolution of information and communication networks. It is a qualitatively new technology that enables the interaction of various specialised computing or control devices, both locally within specific buildings and structures and globally at the level of entire cities and even the entire world (Dallaev et al., 2023). The term "Internet of Things" refers to the idea that all the appliances and technology we use daily can be connected to the Internet and controlled via a computer, a smartphone app, or other online-connected control devices

(Suaad et al., 2023). The Internet of Things is a new paradigm that makes it possible for electrical gadgets and sensors to communicate with one another over the Internet to make our lives easier. The IoT uses smart gadgets and the Internet to offer creative answers to problems faced by the business, governmental, and public/private sectors worldwide (Kumar et al., 2019).

Due to its capacity to link theoretical ideas with practical applications, the Internet of Things (IoT) is heavily included in STEM (education to give students hands-on learning opportunities. IoT aids in enhancing the education sector by utilising innovative technology to its advantage, as this industry serves as the foundation for the knowledge economy, which will be the most visible front for significant economies in the years to come. Moreover, IoT applications have provided and will continue to provide numerous advantages and benefits to every teacher, student, and school. They also contribute to the concrete, practical clarification of the educational process in a way that raises the quality of education, and their outputs are what the nation needs in terms of qualified human resources (Suaad et al., 2023).

Methodology

This study assessed the educator's perspective on computational thinking skills with IoT activities. To accomplish this, the study adopted a quantitative research methodology—a sample of 42 Southeast Asian educators surveyed using Google Forms. The survey questionnaire consists of two sections, each addressing a different aspect of the topic. Respondents were asked to rate their agreement with statements on a Likert-type scale, where respondents were asked to express their level of agreement or disagreement. Moreover, some survey questions are based on dichotomous questions and open-ended items. Open-ended inquiries are flexible and valuable in a variety of research contexts. They are accommodating when you want to learn more in-depth about a subject or while researching a new subject where predetermined response options might not fully address all potential solutions. These inquiries support the gathering of simple and category data. The survey questions were carefully developed to ensure the validity and reliability of the results and were reviewed by experts in education. The collected data was analysed using descriptive statistics to determine educators' level of knowledge and skills. Informed consent, confidentiality, and other ethical standards were followed during the study's execution. The technique utilised in this study offered a thorough and systematic approach to gathering information on educators' digital capabilities in Southeast Asian nations, providing insightful data on the computational thinking skills with IoT activities.

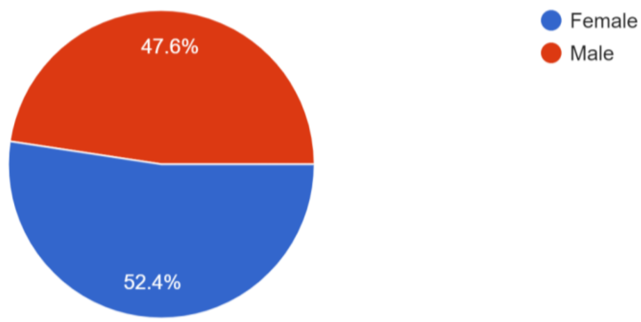
Findings

This research paper aims to gain insight into educators' perspectives on computational thinking abilities related to Internet of Things activities, their obstacles, and potential solutions to these challenges. The study investigates explicitly how instructors in Southeast Asian countries view their perspectives. The survey received 42 responses from Southeast Asian countries.

Section I

1. Gender distribution of the respondents

Figure 1:
Gender distribution

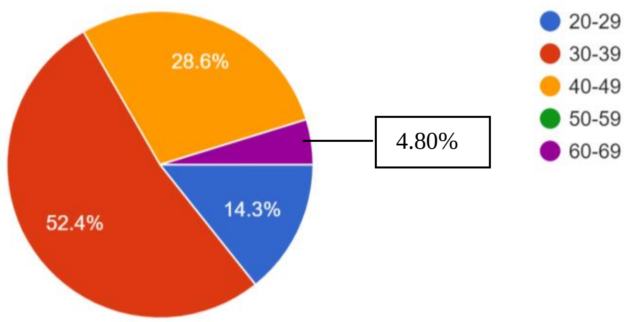


The pie chart in Figure 1 allows us to grasp the gender distribution at a glance quickly. It effectively showcases the significant difference between the percentage of females and males in the population, highlighting the female majority. Women have significantly increased their involvement in the teaching profession over time. It's important to remember that instructors of both genders are crucial in influencing the educational landscape and fostering an all-inclusive learning environment.

2. Age composition of respondents.

Figure 2:

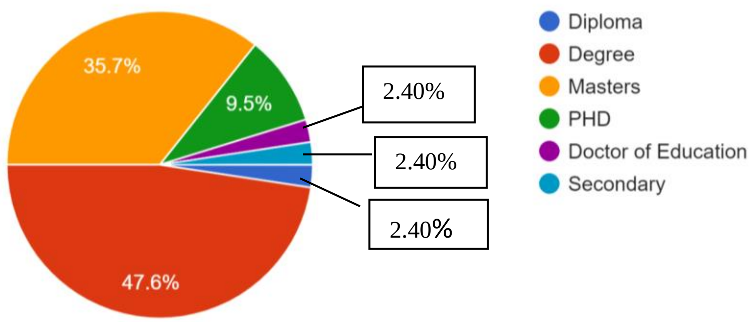
Age composition



The pie chart above visually represents the distribution of respondents across different age groups. Notably, it reveals that the age group 40-49 constitutes a substantial 28.6% of the sample, indicating a significant presence within this demographic. Surprisingly, there are no respondents from the age group 50-59, a notable absence in the data. Additionally, the age group 20-29 comprises 14.3% of the sample, representing a younger demographic. This pie chart serves as a valuable tool for quickly summarizing the age distribution of the participants. It is worth highlighting that the sample demonstrates a well-balanced distribution across various age groups. The most prominent group among the respondents falls within the 30-39 age bracket, making up 52.4% of the sample. This age group often encompasses millennial, who are known for their early adoption of new technologies and a preference for experiential aspects over material ones. On the other end of the spectrum, individuals aged 60-69 comprise the smallest segment, accounting for a modest 4.80% of the sample. The diverse representation across age groups within the study's participants is noteworthy. This diversity enhances the comprehensiveness of the insights gathered regarding Southeast Asian educators' technology adoption trends, reflecting various perspectives and experiences.

3. Education level of respondents.

Figure 3:
Education level

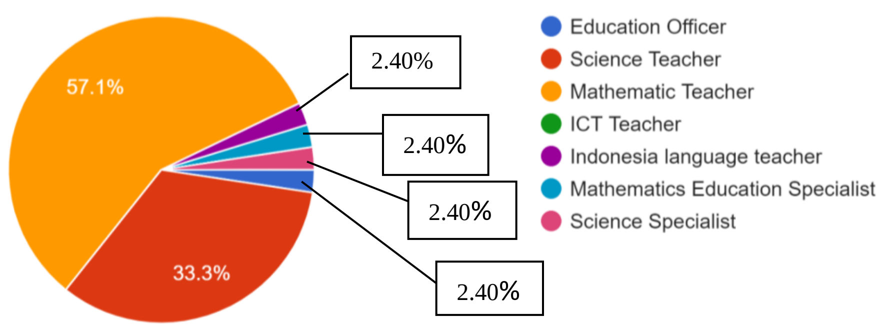


The pie chart in Figure 3 offers an immediate visual overview of the education levels of the respondents. The largest segment of respondents, representing 47.6% of the sample, holds a bachelor's degree. This group likely includes individuals who have completed four years of undergraduate education. Moreover, within this dataset, it is noteworthy that 35.7% of the respondents hold a master's degree, demonstrating a substantial representation of individuals with postgraduate qualifications. Additionally, 9.5% of the respondents have attained a Ph.D., reflecting a notable presence of individuals pursuing advanced research and academic achievements. Individuals with a Doctor of Education, diploma, and others comprise the smallest segment of respondents, accounting for 2.40%. Individuals in this group may have undertaken advanced research or specific professional certifications. The distribution of educational backgrounds among the response pool is successfully shown using this pie chart, highlighting the wide range of qualifications respondents hold.

4. Designation of respondents.

Figure 4:

Designation of respondents

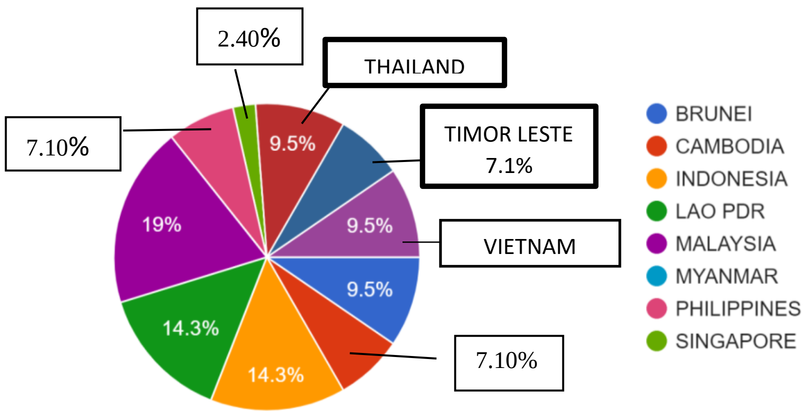


The pie chart in Figure 4 offers a quick and informative overview of designation in the education sector for Southeast Asian respondents, such as mathematics, science, language, information and communication technology teachers, education officers, and education specialists. The largest segment of respondents, 57.1% and 33.3% of the sample, comprises mathematics and science teachers. Furthermore, it is worth highlighting that 2.40% of the respondents each occupy roles as Indonesian language teachers, education officers, science specialists, and mathematics education specialists. These specialist positions highlight the variety of viewpoints and areas of expertise covered in the survey and add to the diverse nature of Southeast Asia's educational community.

5. Respondent's Country.

Figure 5:

Respondent's country



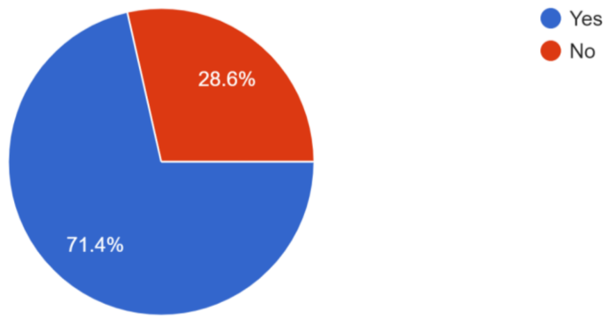
The pie chart analysis of respondents' countries of residence in Figure 5 provides valuable insights into the geographic distribution of the surveyed individuals. Malaysia (19.0%), Indonesia (14.3%), and Lao PDR (14.3%) are the top three contributors, showcasing their significant presence in the survey. Together, Thailand, Vietnam, and Brunei account for 9.30% of the respondents, while Timor Leste, the Philippines, and Cambodia collectively represent 7.10% of the participants. Singapore constitutes 2.40% of the total respondents. This wide range of countries highlights the survey's worldwide reach and emphasizes the need to consider multiple perspectives in computational thinking with IoT activities.

Section II

1. Understanding the Internet of Things (IoT).

Figure 6:

Understanding of IoT



This questionnaire aims to assess respondents' awareness and knowledge of IoT. IoT refers to the network of interconnected devices and objects that can communicate and exchange data without human intervention. 71.4% of the sample responded that they were aware of IoT, while 28.6% of educators were unaware. This questionnaire informs educators that they understand the need for emerging technology in education. The questionnaire also reveals the gaps in educators' mastery of IoT. In the context of IoT, it aids in identifying potential for growth and innovation as well by educators.

2. Level of understanding of IoT

Figure 7:

Level of understanding of IoT.

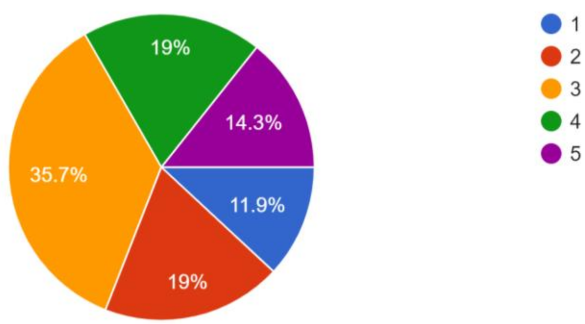
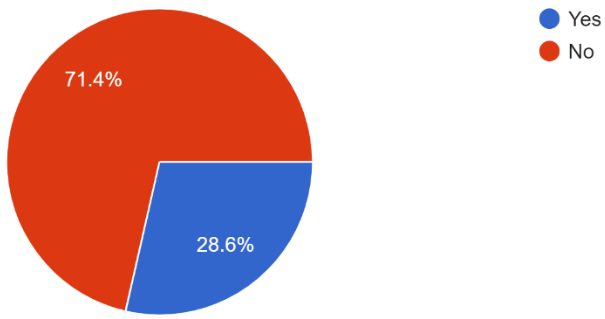


Figure 7 displays the level of understanding in IoT. Based on the results obtained, most of the educators (69.0%) have a high level of understanding from level 3 and above. This is followed by a relatively low percentage (31.0%) of educators needing a higher understanding of IoT. Assessing the level of understanding of IoT is vital to determine how educators recognise and grasp the effect of IoT in the education system. Besides that, educators can adapt their teaching strategies and materials by being aware of technology integration in teaching and learning.

3. Involvement in any training or professional development related to teaching IoT.

Figure 8:

Involvement in any training or professional development related to teaching IoT



The pie chart in Figure 8 displays the participation of educators in training or professional development related to teaching IoT. Markedly, a significant majority, 71.4% of educators, have not attended any such training. In contrast, 28.6% of educators have proactively sought and attended training sessions or professional development opportunities in this field. There are several reasons why this distribution is justified. First, it can indicate how few IoT-related training programs are inaccessible in educational institutions. In addition, the information given raises concerns regarding the potential advantages of expanding instructor access to IoT-related training. More possibilities for educators to acquire IoT training could result in more creative and successful teaching strategies, ultimately benefiting students and better preparing them for a world driven by technology.

4. Understanding about Arduino microcontrollers.

Figure 9:

Understanding of Arduino microcontrollers

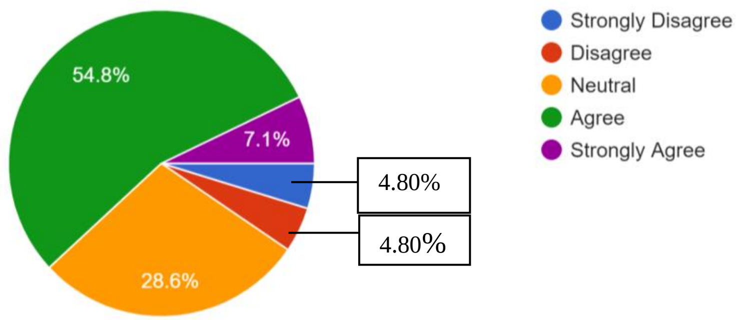
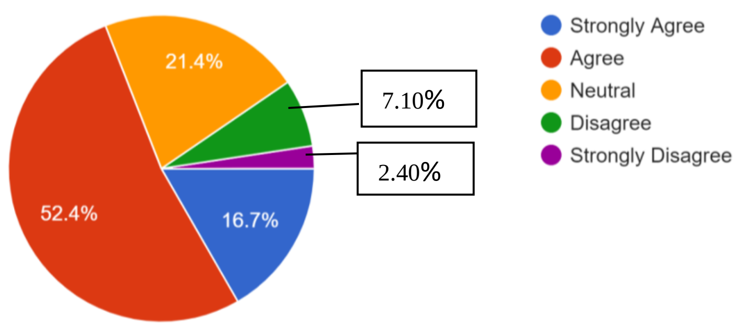


Figure 9 presents a comprehensive overview of educators' perceptions and understanding of the Arduino microcontroller. A small but notable percentage of educators (7.10%) fall into the 'Strongly Agree' category, indicating a deep and confident understanding of the Arduino microcontroller. This is followed by the largest portion of educators, at 54.8%, 'Agree' that they have gained a better understanding of the Arduino microcontroller. This data highlights the positive impact of the workshop, with a sizable majority of educators feeling more empowered and confident in their knowledge. Nearly one-third of educators (28.6%) remain in the 'Neutral' category, whereas a small percentage, 4.80%, ' Disagree' and 'Strongly Disagree' with their understanding of the Arduino microcontroller. This information suggests that educators may require additional training or resources to advance their knowledge and abilities in the basics of electronics using Arduino.

5. Understanding the basics of electronics using Arduino.

Figure 10:
Understanding the basics of electronics using Arduino.



The pie chart above illustrates the understanding of the basics of electronics using Arduino by educators. 16.7% of educators strongly agree and 52.4% agree that they understand the basics of electronics using Arduino. 21.4% of educators are neutral whereas only 7.10% disagree and 2.40% strongly disagree. From the data received, educators can grasp the basics of Arduino and explore it in depth. Besides that, understanding the basics of electronics using Arduino indirectly gives a great way to get started with hands-on activities with electronic projects and programming. Furthermore, it's a useful and effective tool for anyone curious about electronics.

6. Ability to acquire Arduino programming language.

Figure 11:

Acquiring Arduino programming language.

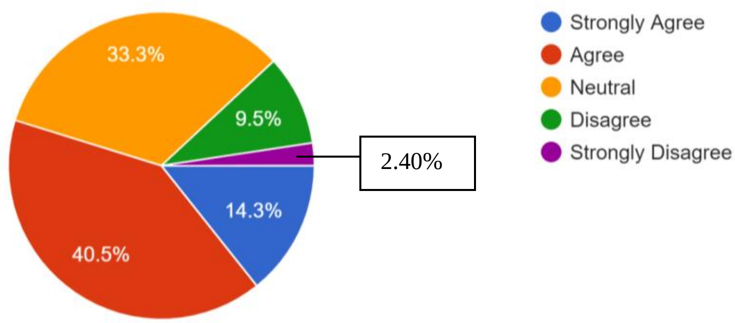
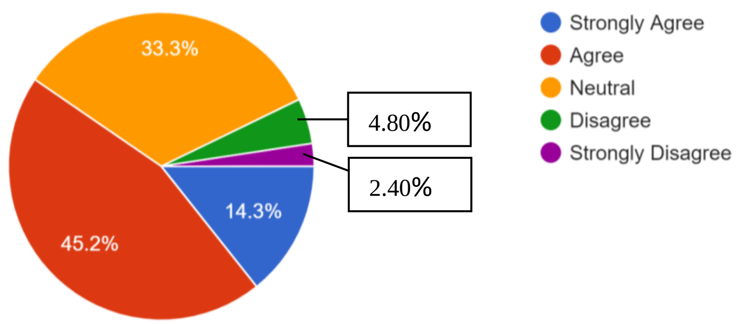


Figure 11 illustrates the diverse methods educators employ to acquire proficiency in the Arduino programming language. Each segment represents a distinct avenue to cultivate an understanding and expertise in this programming language. Most educators (40.5%) agree and 14.3% strongly agree, indicating they think the figure successfully depicts the variety of approaches to mastering the Arduino programming language. In addition, 33.3% of educators are neutral whereas 9.50% disagree and 2.40% strongly disagree. A potential factor that could be the reason for the difficulties faced by educators in acquiring Arduino programming language is the complexity of concepts. In addition, Arduino programming combines ideas from the software and hardware worlds. Educators who don't have a background in electronics may find it difficult to comprehend how the physical parts interact with the programming code. Educators need to acquire structured or collaborative learning Arduino programming. In addition, project-based teaching will be helpful for educators to create lessons that incorporate Arduino for practical coding and problem-solving.

6. Ability to create basic circuits with the breadboard.

Figure 12:
Ability to create basic circuits with the breadboard.



The pie chart in Figure 12 offers an insightful visualisation of constructing fundamental electronic circuits using a breadboard. The chart succinctly illustrates that 45.2% of educators agree and 14.3% strongly agree that they can create basic circuits with the breadboard. Moreover, 33.3% of educators were neutral. Uncertainty and moderate skill level to breadboard may be why 33.3% of educators were neutral. They might choose "neutral" rather than "agree" or "strongly agree" to avoid overstating their expertise. The results show that educators need more training and activities on IoT kits for efficient and interesting learning experiences. Conversely, a smaller percentage, 4.80%, "disagrees" and 2.40%, "strongly disagrees," showing educators have difficulties creating basic circuits with the breadboard.

7. Ability to gain knowledge in an Integrated Development Environment (IDE).

Figure 13:
Ability to gain knowledge in an Integrated Development Environment (IDE).

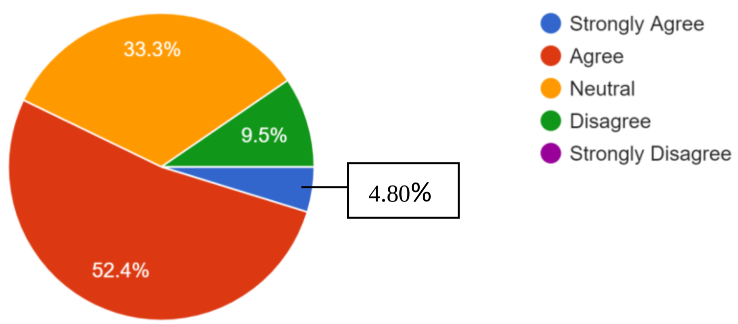


Figure 13 displays the knowledge gained through a software programme known as an Integrated Development Environment (IDE). Based on the results obtained, 52.4% of educators agree and 4.8% strongly agree indicating a high degree of self-assurance in their competence. However, a significant portion, 33.3% of educators remain "neutral" on the subject, signifying a substantial degree of uncertainty or perhaps a lack of exposure to IDE. A smaller group, 9.50%, "disagrees" with their ability to gain knowledge in IDE. This means that the least number of educators are not fully proficient in using these software programmes. Training and courses in the future can aid educators' proficiency in using IDE for effective teaching programming and software development to students.

8. Potential to develop basic Arduino circuits.

Figure 14:
Potential to develop basic Arduino circuits.

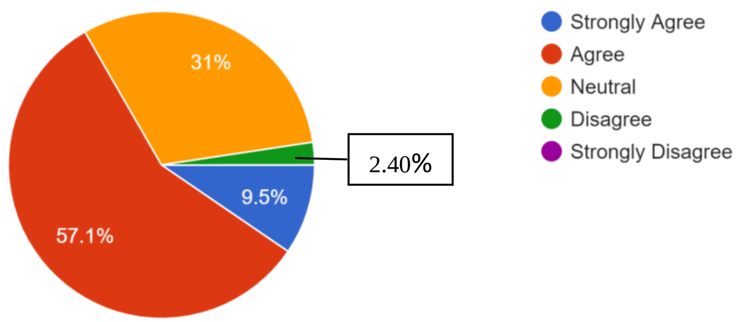
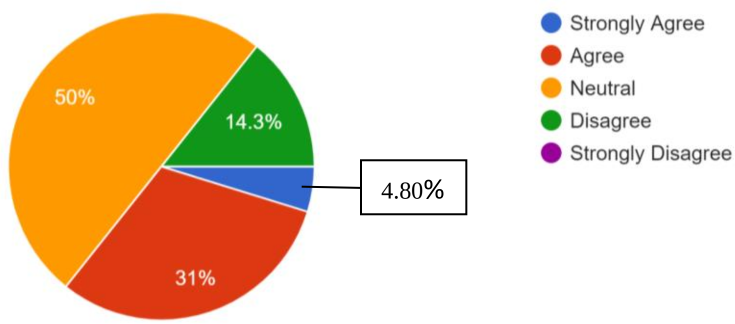


Figure 14 displays educators' proficiency in developing basic Arduino circuits. Based on the results obtained, most educators can develop basic Arduino effectively. Specifically, 57.1% of educators agree and 9.5% strongly agree that they can develop basic Arduino. This combination of nearly two-thirds of educators agreeing or strongly agreed shows a high level of competence and confidence in this area. A sizeable percentage of 31.0% of educators remain neutral whereas only a small fraction, 2.4%, disagrees with their ability. Developing basic Arduino effectively by educators in their lessons can offer students various advantages in their hands-on activities, customised learning, cross-disciplinary integration, and fostering innovation.

9. Mastery of troubleshooting and fixing errors while developing basic Arduino circuits.

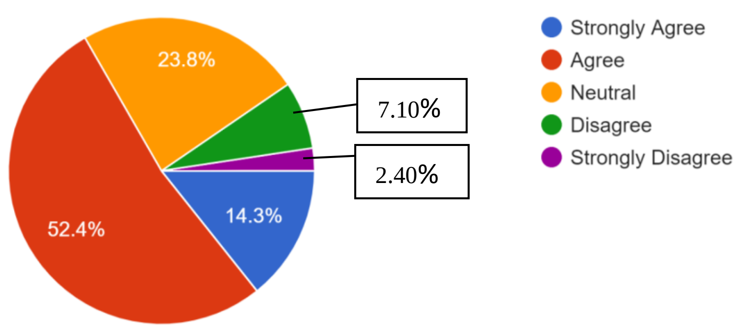
Figure 15:
Troubleshoot and fix errors while developing basic Arduino circuits.



Based on data presented in Figure 15, 50.0% of educators are neutral in overcoming the difficulties of troubleshooting and fixing errors while developing basic Arduino circuits. Moreover, 31.0% of educators agree and 4.80% of educators strongly agree that they are apt to troubleshoot and fix errors while developing basic Arduino circuits. Besides that, only a minority group of educators (14.3%) disagree that they are not able to troubleshoot and fix errors while developing basic Arduino circuits. From the data received, educators must equip themselves with the necessary support and resources to acquire these skills. In addition, effective troubleshooting enables educators to swiftly locate faults and fix them, minimising aggravation, and downtime during the development process.

10. Ability to face difficulties during the development of basic Arduino circuits.

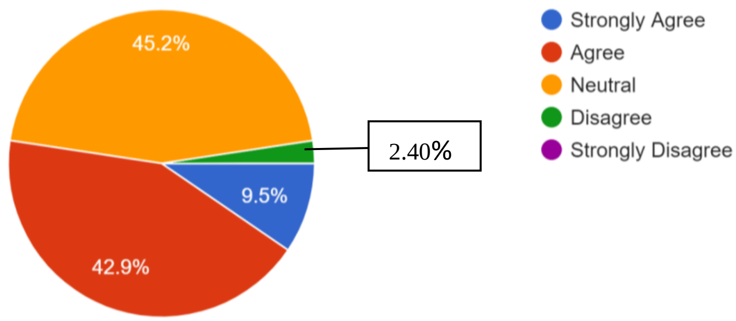
Figure 16:
Facing difficulties during the development of basic Arduino circuits.



According to Figure 16, a combination of data from strongly agree and agree (66.7%) of educators faced difficulties during the development of basic Arduino circuits. 9.50% of educators disagree and strongly disagree on this matter. Lack of prior experience, lack of resources, and technical support might be the reasons for difficulties faced by educators while developing basic Arduino circuits. These circumstances can be overcome by encouraging educators' to start with introductory materials and give them the space and tools needed to experiment. Collaboration on projects by educators also can reduce the difficulties while developing the circuits because more people will be involved with various knowledge.

11. Ability to understand and solve problems throughout the development of basic Arduino circuits.

Figure 17:
Understanding and solving the problem throughout the development of basic Arduino circuits.



The data presented in Figure 17 indicated that 45.2% of educators are neutral in understanding and solving the problem while developing basic Arduino circuits. Moreover, 52.4% of educators can understand and solve the problem while developing basic Arduino circuits which are the combination of agreed and strongly agreed data. Only 2.40% of educators find difficulties in understanding and solving the problem while developing basic Arduino circuits. Understanding and solving problems while developing basic Arduino can improve educators' critical thinking, troubleshooting, and creative problem-solving abilities by learning to comprehend and resolve issues. Moreover, educators may more effectively incorporate technology into their classroom activities and give their students top-notch educational experiences.

12. Collaboration skills with other participants to solve the problem throughout the time developing basic Arduino circuits.

Figure 18:
Collaboration skills to solve the problem while developing basic Arduino circuits.

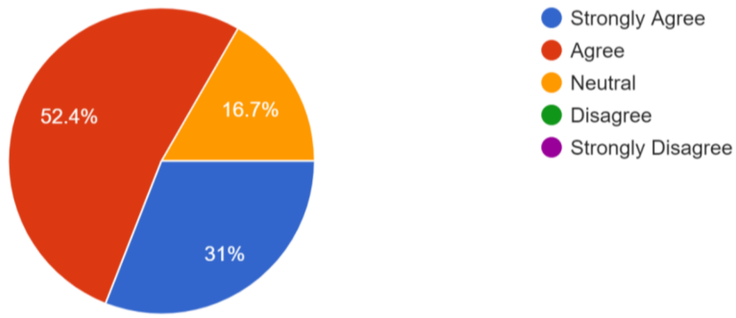


Figure 18 displays the collaboration of an educator with other participants to solve the problems during the development of basic Arduino circuits. The majority of educators (83.4%) can collaborate to solve the problems during the development of basic Arduino circuits which are the combination of agreed and strongly agreed data. 16.7% of educators are neutral in this matter. Individuals with various backgrounds, skills, and areas of competence come together through collaboration. A wider variety of creative methods and problem-solving techniques may result from this diversity. Educators also can share their expertise which may result in a more thorough grasp of the issue and possible solutions.

13. Application of Science and/or Mathematics concepts while developing basic Arduino circuits.

Figure 19:
Application of Science and/or Mathematics concepts.

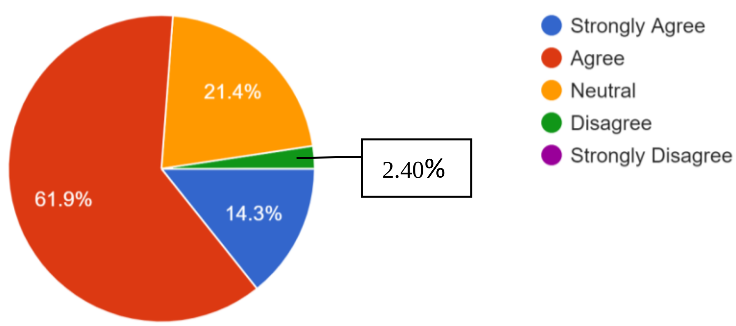
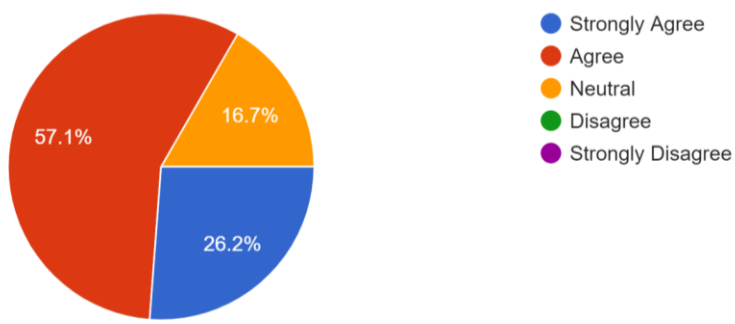


Figure 19 represents the application of science and mathematics concepts during the development of basic Arduino circuits. A combination of data from strongly agree and agree (76.2%) of educators able to apply science and mathematics concepts during the development of basic Arduino circuits. 21.4% of educators are neutral and 2.40% of educators are unable to apply science and mathematics concepts during the development of basic Arduino circuits. The combination of science and mathematics concepts in Arduino aids educators in understanding how several domains of knowledge are interconnected. Besides that, Arduino enables educators to translate scientific and mathematical concepts into real-world, useful applications.

14. Integration of IoT helps to create an extensive teaching plan beneficial for students.

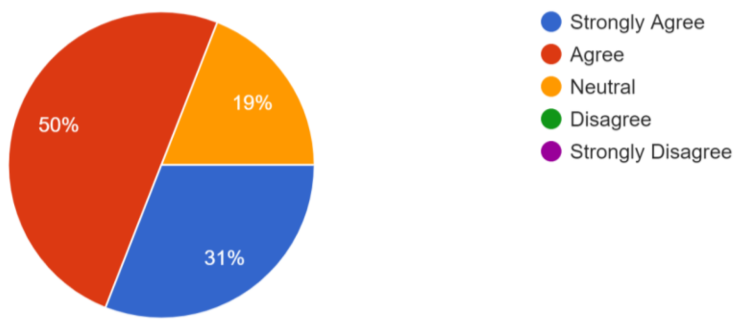
Figure 20:
Integration of IoT to create an extensive teaching plan beneficial for students



This pie chart in Figure 20 gives valuable insights into educators' perspectives on the integration of IoT in creating extensive teaching plans for the benefit of their students. The data shows a favourable trend, with a substantial 57.1% of educators agreeing and an additional 26.2% of educators strongly agreeing that IoT benefits create an extensive teaching plan that is beneficial for students. This overwhelming majority implies that the advantages and prospective benefits of integrating IoT technologies into educational practices are widely acknowledged. Besides that, 16.7% of educators are neutral. Educators and students can improve the learning environment by integrating IoT into teaching and learning. Moreover, IoT gadgets can offer interactive and immersive learning environments by using smart sensors in science projects. It enables students to gather data in real time and see events, bringing abstract ideas to life. Apart from that, the integration of IoT aids in remote learning and accessibility.

15. Personalised learning and improved student engagement with IoT activities.

Figure 21:
Personalised learning and improved student engagement.



The pie chart in Figure 21 illustrates that with IoT activities, educators can perform personalised learning and improve students' engagement. 50.0% of educators agree and 31.0% strongly agree that with IoT activities, educators can perform personalised learning and improve student engagement. Adding to that, 19.0% of educators are neutral. Based on this data, it is proven that IoT activities can aid remote learning support and interactive learning as well. Smart boards and interactive displays will encourage students to be more engaged in their studies.

16. IoT is one of the core competencies of 21st Century teaching and learning.

Figure 22:
IoT is one of the core competencies of 21st Century teaching and learning

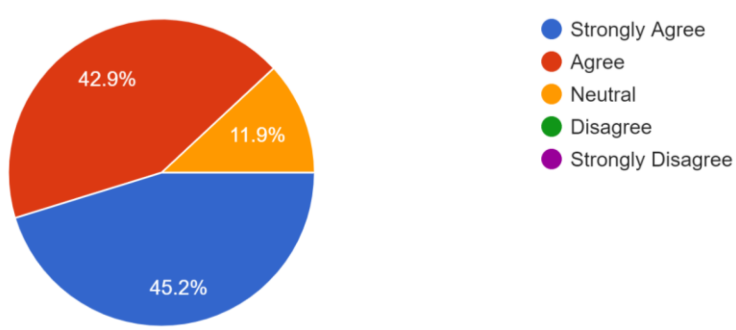
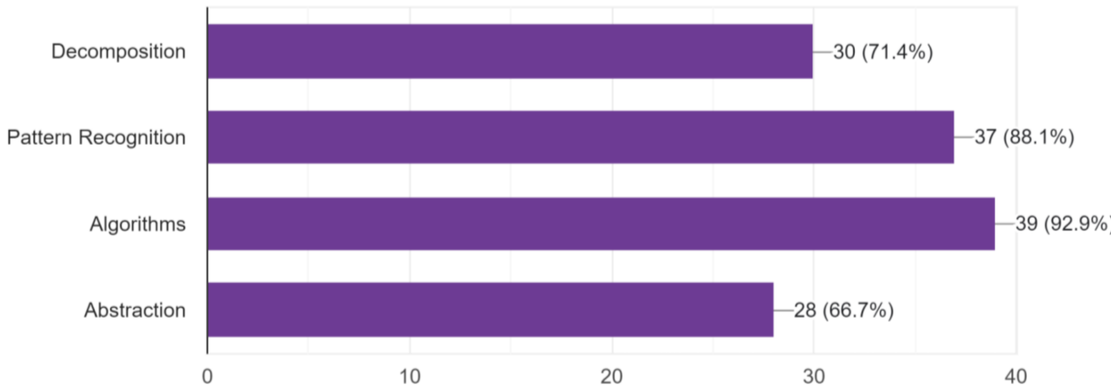


Figure 22 represents IoT as one of the core competencies of 21st-century teaching and learning. 45.2% of educators strongly agree and 42.9% agree that IoT is one of the core competencies of 21st-century teaching and learning. Besides that, 11.9% of educators are neutral in this survey and none of the educators disagree with it. IoT enables educators and students to engage with actual things and data, making learning more relevant and applicable. They can gather and analyse data from IoT gadgets like sensors and smart appliances, which may be used in various academic fields in science, mathematics, and environmental studies. Moreover, IoT delivers practical, trans disciplinary, and interesting learning experiences for the data-driven, interconnected world they will encounter, making it an essential competency in 21st-century teaching and learning. It is a beneficial addition to contemporary education since it fosters 21st-century skills.

17. STEM computational thinking skills.

Figure 23:
Core components in CT skills.



The bar chart in Figure 23 illustrates the respondents' perceptions regarding the importance of four key components. Notably, the chart reveals that all four components have received almost equal importance, as indicated by the bar heights. This result suggests a consensus among the survey participants, emphasizing that each of the four components holds an equal and essential role in the context of STEM computational thinking skills learned by educators. In STEM education, CT skills play a vital role. A problem-solving method known as computational thinking skills employs concepts and methods to deal with complicated problems methodically and effectively. Decomposition, pattern recognition, algorithms, and abstractions are the main core components of CT skills. CT skills are an organised method of problem-solving that may be used in curriculum creation, classroom management, and dealing with instructional obstacles. Moreover, by employing CT to find patterns in student performance data, educators can better understand their students' learning challenges and adapt their teaching strategies. On top of that, CT abilities give educators a deliberate and versatile approach to problem-solving and instruction. Educators indirectly comprehend students' performance and foster their skills to succeed in the modern workforce.

18. Vitalness of CT skills for teaching science and mathematics.

Figure 24:
Vitalness of CT skills for teaching science and mathematics.

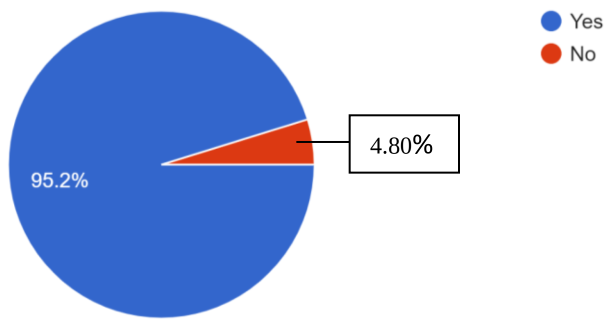


Figure 24 represents CT skills that are essential for teaching science and mathematics. 95.2% of educators agree that computational thinking skills are essential for teaching science and mathematics while only 4.80% of educators do not agree on it. CT skills give educators an organised method for approaching problem-solving, data analysis, and modelling. Moreover, these skills mould and encourage educators to work in the field of IoT.

19. Ability to apply CT skills in daily life.

Figure 25:
Ability to apply CT skills

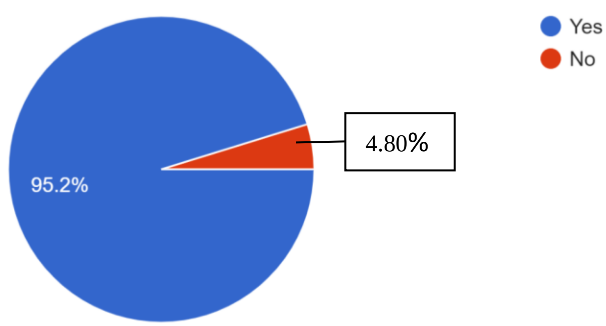


Figure 25 represents the ability of educators to apply CT skills in their daily lives. 95.2% of educators agree that they can apply CT skills in their daily lives, while only 4.80% of educators do not agree to it. The application of CT skills enables educators to handle issues and obstacles gingerly and successfully. Computational thinking skills also empower an individual to overcome obstacles more quickly and successfully, ultimately promoting success on both a personal and professional level.

20. Ability to apply CT skills for programming in Arduino.

Figure 26:
Ability to apply CT skills for programming in Arduino.

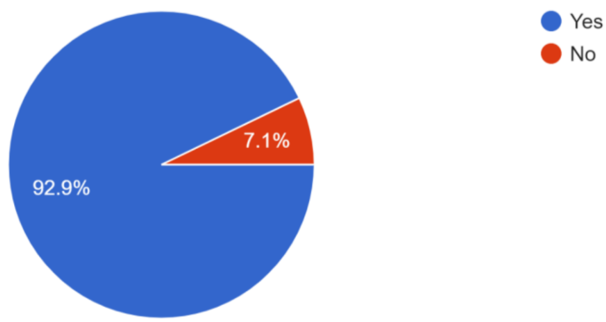
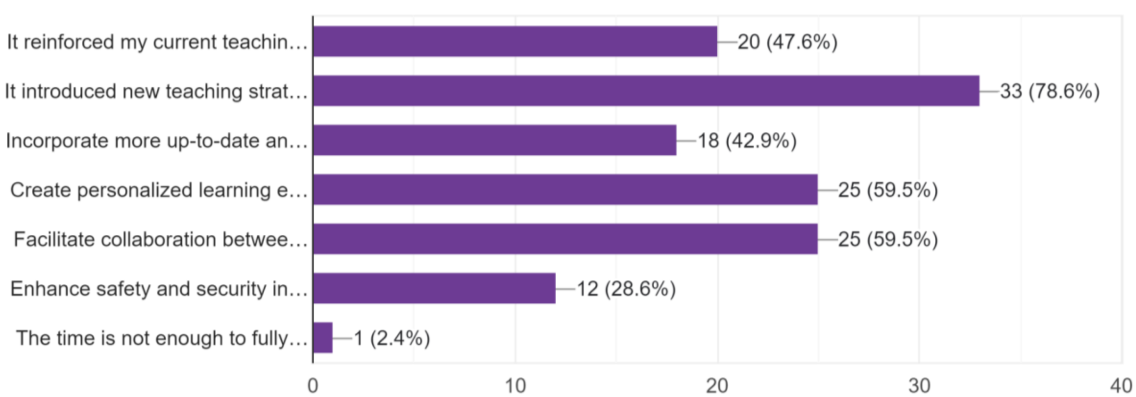


Figure 26 illustrates educators' ability to apply CT skills for programming in Arduino. 92.9% of educators agree that they can, while a minority of 7.10% do not. Applying CT skills in Arduino projects will create effective algorithms, resulting in more successful and creative Arduino-based inventions. Moreover, educators' scalability potential will increase as the complexity of Arduino projects increases. Arduino projects also help educators develop CT abilities in programming and engineering disciplines.

21. Best description of the impact of CT skills with IoT activities in educator's teaching.

Figure 27:
Impact of computational thinking skills with IoT activities in educator's teaching



Impacts experienced by educators through CT skills with IoT activities are introducing new teaching strategies and activities, creating personalised learning experiences for students, facilitating collaboration between educators and students, reinforcing current teaching practices incorporating more up-to-date and relevant information into their lessons, students can conduct research more efficiently and effectively, and enhance safety and security in the classroom. The majority of respondents describe introducing new teaching strategies and activities because an interesting and productive learning environment can be produced by introducing novel teaching techniques and exercises that blend CT abilities with IoT activities.

22. Opinions about the key elements of CT skills that students should develop through IoT activities.

From educators' perspective, all four core components in CT skills are the key elements students should develop through IoT activities. Decomposition, pattern recognition, algorithms, and abstractions are the main core components of CT skills. Resources for IoT applications are frequently constrained, such as memory, bandwidth, or power. Students can improve the performance and efficiency of their solutions by using CT skills. Moreover, CT skills play a significant role in the sustainability of IoT in terms of reducing their influence on the environment, increasing resource efficiency, and guaranteeing their long-term survival.

23. Opinions about the benefits of incorporating IoT activities into the curriculum to teach CT skills.

From the viewpoint of educators, there are various benefits of incorporating and integrating IoT activities into the curriculum to teach CT skills. Improving problem-solving skills, engaging lessons, promoting 21st-century thinking skills, promoting hands-on activities, enhancing high-order thinking skills, and introducing future job-related skills and creativity in conducting class lessons are opinions of educators through CT skills with IoT activities. CT abilities can be taught effectively by introducing IoT activities into the curriculum, providing a comprehensive and useful approach to education that readies students for the digital age and gives them useful skills for the future. In addition, it promotes imagination, invention, and a better comprehension of how society and technology are intertwined.

Conclusion

The study highlights accessing educators' perspectives on CT skills with IoT activities. By identifying the most pertinent computational thinking skills for IoT activities, educators' insights might influence teaching, learning, and curriculum creation. This guarantees that educational programs are adapted to the needs of the actual world, successfully tackling current technological difficulties. Educators must be committed to continual professional development and thoroughly understand digital tools and software, analysing and interpreting data. This can be accomplished by giving educators access to online resources and courses, mentoring opportunities, and frequent technology training sessions.

In a broader sense, developing CT skills is crucial for empowering educators to take on the opportunities and challenges given by cutting-edge technology, making them more adaptive and creative in an ever-evolving digital environment. Additionally, the practical exercises and group projects have allowed educators to use their CT skills in real-world situations, boosting creativity in IoT applications and improving CT skills. To conclude, the CT skills for IoT activities have been key in preparing educators with crucial information problem-solving skills.

In conclusion, addressing computational thinking skills with IoT activities gives an advantage by teaching new skills and equipping students with useful resources to improve their problem-solving skills, create a deeper comprehension of technology integration, and promote critical thinking.

Recommendations

Based on the research study's results on CT skills with IoT activities, many recommendations can be implemented to mould our educators for future readiness in the world of volatility, ambiguity, complexity, and ambiguity (VUCA). Several recommendations and executions for educators in the future of CT skills with IoT activities:

1. Initiatives for professional development are vital because educators are exposed to abundant knowledge and exposure to enhance their skills. Workshops and training sessions for educators can be implemented to support the integration of CT skills with IoT activities in their teaching and learning.

2. Advocacy effort on integrating computational thinking skills with IoT activities as a compulsory educational approach in teaching and learning. It can be implemented with the collaboration of education policymakers, education leaders, and private stakeholders in primary, secondary, and tertiary level education with complete resources and infrastructure for learners.

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C-BHQ: A Cybergogy Approach on Student's Achievement in Born-Haber Cycle, Chemistry Learning Motivation, and Future-Ready Learning Skills.

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Abstract

Gamification, or game aspects in educational situations, has become a viable technique for increasing student engagement and academic achievement. This study investigates the impact of gamification, which represents the cybergogy approach in transformative teaching and learning (T&L) delivery on students' achievement in the subtopic of the Born-Haber Cycle, learning motivation, and the development of future-ready learning skills. The study employs a quasi-experimental pre-test-post-test non-equivalent group design. A sample of 60 students from Penang Matriculation College is chosen and divided into treatment (N = 30) and control (N = 30) groups through cluster random sampling (intact group). The treatment group participates in gamified learning activities, while the control group receives conventional teaching. The outcomes of this study contribute to a better understanding of the effects of gamification on student success and learning motivation. It also investigates the potential of gamification in improving future-ready learning abilities using a cybergogy method. The findings provide valuable insights for educators and instructional designers interested in using gamification as a pedagogical strategy that fosters student engagement, achievement, and readiness for future learning. This research is significant for educational policymakers since it demonstrates the benefits of introducing gamified aspects into instructional design and curriculum development. Gamification can help cultivate lifelong learners with the necessary abilities to flourish in an ever-changing, technology-driven world by encouraging intrinsic motivation and delivering immersive learning experiences.

Keywords: *gamification/gamified learning activity, learning motivation, future-ready learning skills, cybergogy*

Introduction

In today's constantly changing world, educational institutions are needed more to educate students about future problems and possibilities. To meet this need, educators and academics have underlined the significance of developing a future-ready curriculum that provides students with the information, skills, and competencies they need to flourish in a dynamic and complex society. Transformative teaching delivery systems, such as cybergogy, have emerged as viable pedagogical frameworks for improving the efficacy of future-ready education. Future-Ready Curriculum (FRC) is an educational framework that prepares students for the challenges and opportunities of a rapidly changing world. It encompasses a broad range of skills, knowledge, and attitudes that equip learners to thrive in a dynamic and uncertain future. Implementing a future-ready curriculum necessitates a systematic approach as well as continuing dedication. It is critical to foster an environment of creativity, cooperation, and continual learning to achieve the objective of a future-ready education for all students (Tan et al., 2017).

An FRC is intended to provide students with the knowledge and skills needed to prosper in an ever-changing world. It exceeds standard subject-based knowledge by emphasising critical thinking, problem-solving, teamwork, flexibility, and digital literacy (Jason & Westberg, 2018). In FRC, transformative teaching and delivery methodologies are essential in developing a curriculum ready for the future. These strategies move away from conventional teacher-centred education and towards student-centred approaches that promote active participation, critical thinking, and personalised learning experiences (Ng et al., 2019). The aims of transformational educational delivery include deep learning, meaningful comprehension, and the development of higher-order cognitive capacities. It emphasises the combination of actual real-world links, technology integration, and customised learning to promote student engagement and achievement (Harrel & Bynum, 2018). One innovative education delivery method is cybergogy, which combines cybernetics with pedagogy principles. Cybergogy creates dynamic, engaging, and student-centred learning environments using technology and digital resources (Rahma et al., 2021). To improve student motivation, engagement, and information acquisition, cybergogy-based T&L can incorporate multimedia presentations, animations, gamification, and online collaborative platforms (Kingsley & Grabner-Hagen, 2015; Dominguez et al., 2013). Cybergogy acknowledges technology's revolutionary potential in education and highlights the necessity of active and immersive learning in preparing students for the future. For example, gamification/gamified learning activities can be used in a cybergogy manner by using online resources or digital technology to deliver engaging, interactive, and student-centred experiences.

To develop future-ready students and generations, it is necessary to investigate the effectiveness of transformative teaching delivery approaches, such as the cybergogy approach, in improving students' achievement in subject-specific assessments, learning motivation, and future-ready learning skills. With a blend of technology, multimedia, and student-centred strategies, the cybergogy approach offers promise in fostering engagement and deep learning (Alakrash & Razak, 2020). A future-ready curriculum through the cybergogy approach strives to provide students with the information, skills, and competencies they will need to flourish in a fast-changing world (Rahma et al., 2021). Thus, it is critical to investigate the potential of the cybergogy approach, which employs gamification/gamified learning activity, for instance, to improve students' achievement in a specific subject content while simultaneously encouraging learning motivation and future-ready learning skills. While previous research has highlighted the benefits of transformative teaching approaches and the cybergogy approach in promoting engagement, motivation, and deep learning, their specific impact on student's achievement in the Born-Haber Cycle subtopic, as well as their learning motivation and future-ready learning skills, needs to be investigated further. Understanding the connection between the cybergogy approach and these critical outcomes will give valuable insights into the efficacy of future-ready curricula and teaching practices.

In addition, compared to other chemistry topics, the Born-Haber Cycle is among the most difficult to understand, and students frequently need clarification. The Born-Haber Cycle has several phases and necessitates a thorough grasp of ionic bonding, lattice energy, and enthalpy changes. Various parameters, such as ionisation, electron affinities, and sublimation energies, must be carefully considered (Barker & Millar, 2000; Lee, 1999). Furthermore, the Born-Haber Cycle frequently includes sophisticated mathematical computations. The Born-Haber Cycle is brutal for many students because of its multi-step structure, the necessity to apply multiple thermodynamic concepts, and the demand for precise data for diverse enthalpy changes (Carbo, 2021; Read & Harrison, 2010). It usually requires a solid basis in chemistry and knowledge of related concepts (Kind, 2004).

Despite rising interest in and potential benefits of the cybergogy approach, which incorporates gamification/gamified learning activities, there is a significant knowledge gap on its successful application and effects on students' learning outcomes. More research is needed on the optimum design principles, teaching strategies, and assessment methods for gamification in a cybergogy approach (Asad & Malik, 2023). As a result, further study is required to evaluate the efficacy of the cybergogy approach through gamified learning activities and find the best practices for their implementation.

Several studies have found that gamification in education can boost motivation, engagement, and information retention. However, there is currently a lack of complete knowledge of the exact design concepts, teaching methodologies, and evaluation systems that optimise the learning results of gamified cybergogy. (Masdoki & Din, 2021). This study aims to determine the effect of a cybergogy-based learning Born-Haber Cycle subtopic called "Cybergogy-Born Haber Quest" (C-BHQ) instruction compared to conventional/existing instruction. Thus, in this study, three (3) main research questions were developed as below:

a) Is there a statistically significant effect of C-BHQ instruction compared with conventional instruction on students' achievement in the Born Haber Achievement Test (BHAT)?
b) Is there a statistically significant effect of C-BHQ instruction compared with conventional instruction on students' learning motivation in the Chemistry Learning Motivation Questionnaire (CLMQ)?
c) Is there a statistically significant effect of C-BHQ instruction compared with conventional instruction on students' future-ready assessment in the Future-Ready Learning Questionnaire (FRLQ)?

From the research questions, three (3) null hypotheses (H0) were formulated and tested in this study, which represent research questions (a), (b), and (c). The null hypotheses formulated are listed below:

H0a: There is no statistically significant effect of C-BHQ instruction compared with conventional instruction on students' achievement in the Born-Haber Achievement Test (BHAT).

H0b: There is no statistically significant effect of C-BHQ instruction compared with conventional instruction on students' learning motivation in the Chemistry Learning Motivation Questionnaire (CLMQ).

H0c: There is no statistically significant effect of C-BHQ instruction compared with conventional instruction on students' future-ready assessment in the Future-Ready Learning Questionnaire (FRLQ).

In the context of this study, the significance or impact is reviewed from four (4) main perspectives: (i) theories and concepts, (ii) methodology, (iii) empirical research, and (iv) practical contributions. The theoretical significance of this study rests in enhancing learning theory and understanding digital pedagogy. The study of the consequences of the cybergogy approach promotes learning theories by evaluating the efficacy of educational strategies that include technology. It has the potential to give empirical evidence for the applicability of theories like constructivism, connectivism, and transformational learning in digital learning. Investigating this study's cybergogy approach allows us to understand better instructional practices that employ digital technology and resources. It also helps educators and researchers maximise instructional practices in the digital era by creating a theoretical framework for efficient technology integration in education. Besides, studying gamified learning activities helps develop and enhance ideas and concepts associated with education, motivation, and engagement (Mee etal., 2021; Tsay et al., 2018). It assists academics in better understanding how gamification components such as points, badges, and leaderboards impact learners' motivation, cognitive processes, and behavioural results (Huang et al., 2019). This study advances our understanding of the underlying psychological and pedagogical mechanisms at work in gamified learning, allowing educational theories and models to be advanced.

In aspects of methodology contribution, investigating the cybergogy approach allows for developing and refining research approaches relevant to the digital learning setting (Miranda et al., 2021; Rahma et al., 2021). Researchers can experiment with new data-gathering approaches, such as digital learning analytics, online surveys, and qualitative analysis of online interactions, to help enhance research methodologies in educational technology studies. Developing and validating assessment methods and instruments specially designed to assess student accomplishment, learning motivation, and future-ready learning in the digital context can also result from research on the cybergogy approach (Masdoki & Din, 2021). This helps enhance assessment practises while ensuring the reliability and validity of study findings. Investigating gamified learning activities demands the use and development of

Innovative studies approach (Almeida & Simoeis, 2019; Patricio et al., 2018). For instance, researchers investigate novel data collection, analysis, and interpretation approaches to measure gamification's influence on learning outcomes. To thoroughly understand the intricate relationships between gamification features and educational results, they may use mixed methods approaches that combine qualitative and quantitative techniques. Thus, gamified learning studies contribute to methodological breakthroughs in education by pushing the boundaries of research methodology.

This cybergogy approach also provides empirical proof of its influence on students' success, learning motivation, and future-ready learning. This research can help instructors make educated judgements regarding teaching approaches by adding evidence that verifies the effectiveness of the cybergogy approach. Furthermore, doing an empirical study comparing the cybergogy method to other educational approaches might shed light on its relative efficacy. These comparison studies can reveal the distinctive contributions of the cybergogy approach to improving student results and help guide the selection of appropriate instructional approaches. Gamified learning activities research provides empirical information about their usefulness and impact on learning outcomes. Researchers can quantify the benefits of gamification on student motivation, engagement, information retention, and skill development by performing rigorous experiments, surveys, or case studies. These empirical findings add to the collection of evidence-based research in education by teaching educators, policymakers, and curriculum designers about the advantages and disadvantages of gamified learning techniques.

In terms of practical contributions, this study improved existing instructional design by focusing the cybergogy approach on gamification/gamified learning activity. This study assists instructors/educators in understanding the impact of the cybergogy approach on instructional design practises, hence assisting them in creating engaging and successful learning experiences. Most instructors/educators fear modifying the present instructional due to a lack of time, expertise, or abilities, particularly in using a cybergogy approach to T&L (Bingimlas, 2009; Dieker & Murawski, 2003). However, they will learn from this study that gamification is part of the cybergogy method, which also supports FRC and does not require a high level of experience or abilities. The findings might be used to make recommendations and recommend best practices for incorporating technology into curriculum creation, lesson planning, and resource selection. Furthermore, this research helps to educate policymakers and decision-makers. Research into the cybergogy approach can potentially impact educational policy and decision-making processes. Findings are based on evidence used to advocate for gamification or any cybergogy approach in the classroom, influence resource allocation, and create professional development programmes for instructors/educators.

The underlying theory associated with this study is the Cognitive Load Theory (CLT), proposed by Sweller (2010). CLT posits that the cognitive capacity of learners is limited and that effective instructional design should consider the management of cognitive load. Learning activities, according to CLT, can impose three (3) forms of cognitive burden on students: intrinsic load, extraneous load, and germane load (Sweller, 2010). The inherent difficulty of the learning material itself, such as comprehending the Born-Haber Cycle in chemistry, is an intrinsic load. It is impacted by the learners' past knowledge and cognitive ability. The study intends to minimise the internal cognitive load by offering interactive and multimedia tools that can boost comprehension and lessen the complexity of the Born-HaberCycle by using gamification/gamified learning activity, which utilises technology and online learning settings (cybergogyapproach). Extraneous burden is the cognitive stress caused by instructional design components that do not contribute directly to learning. By adding interactive elements, rapid feedback, and personalised learning experiences that engage and encourage students, a gamification/gamified learning activity strives to reduce superfluous cognitive load (Kossen & Ooi, 2021). This decrease in superfluous load enables students to concentrate on the important components of the Born- Haber Cycle learning.

The cognitive effort necessary for schema acquisition and building new information and abilities is called germane or desirable cognitive load. According to the study, the cybergogy approach, with its gamified aspects and interactive nature, can aid in developing future-ready learning skills (Ujir et al., 2020). The gamified learning activity created by the students intends to improve the relevant load and support learning these vital skills by engaging students in problem-solving, critical thinking, cooperation, and flexibility. By optimising the use of instructional design components to decrease unnecessary load, control intrinsic burden, and improve germane load, the gamification/gamified learning activity in the cybergogy approach aligns with the concepts of Cognitive Load Theory.

In addition to the Cognitive Load Theory, another theory associated with this study is the Self-Determination Theory(SDT), proposed by Deci and Ryan (1985). This theory focuses on human motivation and the factors that drive individuals' engagement and persistence in activities and learning. According to SDT, individuals have three (3) innate psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 1985). Individuals are more likely to experience intrinsic motivation and engage in self-determined behaviour when these needs are satisfied. In the study context, the cybergogy approach incorporates elements that can support satisfying these psychological needs, thus fostering intrinsic motivation and enhancing learning outcomes. Students have autonomy using the cybergogy method since they control their learning process. Students may pick their learning speed, explore alternative resources, and have greater freedom in accessing instructional materials by utilising technology and online learning settings. This autonomy fosters a sense of ownership and self-direction in the learning process, which increases motivation and engagement (Mitchell et al., 2020). Furthermore, the gamified learning activity allows students to build and display their abilities (Kiryakova et al., 2014). Students may actively engage with the Born-Haber Cycle and gamification by combining interactive components, quick feedback, and personalised learning experiences.

Students also get a sense of competence and mastery as they advance through the exercises and improve their comprehension, which increases their desire and readiness to spend effort in their learning (Mekler et al., 2017). Applying the study's gamification/gamified learning activity can foster a sense of relatedness or social connection among pupils. Students may communicate with classmates, exchange ideas, and engage in cooperative learning experiences through collaborative projects, multiplayer components, and chances for communication and collaboration. Social contact and a sense of belonging enhance students' motivation and involvement in the learning process (Thomas et al., 2014). The cybergogy approach corresponds with the ideas of Self-Determination Theory by combining aspects that enhance autonomy, competence, and relatedness in a gamified learning activity. It seeks to meet students' psychological requirements and build intrinsic motivation, which can improve their performance in the Born- Haber Cycle, chemistry learning motivation, and the development of future-ready learning abilities. The cybergogy method corresponds with the ideas of Self-Determination Theory by combining aspects that enhance autonomy, competence, and relatedness. It seeks to meet students' psychological requirements and build intrinsic motivation, which can improve their performance in the Born-Haber Cycle, chemistry learning motivation, and the development of future-ready learning abilities.

Aside from these two theories, CLT and SDT, the gamification element is also being used in the design of T&L strategies to ensure that the C-BHQ instruction has a balanced combination of gamification/gamified learning activity characteristics, CLT and SDT through the content (Born-Haber Cycle), learning motivation characteristics (SDT), and future-ready learning skills. The gamification model is a framework or strategy to increase engagement, motivation, and involvement by incorporating game design features and mechanics into non-game environments. It entails the use of game-like features to motivate desirable behaviours, increase learning, and achieve specified goals. The core gamification model's important components/distinctive parts must, at the very least, give clearly defined objectives and goals, as well as points/rewards, level advancement, leader boards, and challenges/quests (Kapp, 2012; Seaborn & Fels, 2015). Previous studies on gamification/gamified learning activities in education and their effect on student achievement, learning motivation, and future-ready learning skills have been conducted and classified into three (3) main categories: student achievement, learning motivation, and future-ready learning skills.

Gamification/Gamified Learning Activity and Student's Achievement

In education, gamification/gamified learning activity has proven to boost students' engagement, improve learning motivation, encourage experiential learning, and promote cooperative learning. Gamification/gamified learning activities can encourage active participation and engagement. Mee et al. (2022) found that respondents preferred to study through gamified learning activities that helped them subconsciously learn. Students are more motivated to interact with instructional information and actively pursue learning objectives when game features such as challenges, storylines, and leaderboards are included (O'Donovanet al., 2013). Furthermore, gamified learning activities tap into intrinsic drive by offering quick feedback, clear goals, and a sense of accomplishment. Students who experience a sense of achievement and development through game-based assignments are likelier to continue learning and demonstrate a growth attitude (Dhahak & Huseynov, 2020).

Gamification/gamified learning activities encourage experiential learning by allowing students to apply what they've learned in real-world scenarios and problem-solving situations. Gamified learning exercises improve long-term information retention and transfer by offering rapid feedback and opportunities for practice (Putz et al., 2018). Gamified learning activities in a group frequently incorporate collaborative and competitive components, promoting healthy student social interaction. Thus, combining multiplayer components and cooperative tasks fosters cooperation, communication, and peer learning. Various studies have found an association between gamification and enhanced academic achievement. Gamified learning activities have been demonstrated to boost test scores, grades, and overall academic success across various disciplines and grade levels (Laskowski & Badurowicz, 2014). Gamification/gamified learning activities promote critical thinking, problem-solving, decision-making, and other vital abilities. It improves students' capacity to analyse complicated problems and make educated decisions by providing difficult and engaging scenarios. Furthermore, gamification/gamified learning activities effectively enhance student engagement and decrease attrition rates (Litvin et al., 2020). Gamified activities encourage students to stay in school and lower dropout rates by offering an engaging and pleasurable learning environment. Gamification/gamified learning activities improve engagement, motivation, information retention, and overall academic achievement using game aspects and mechanics. However, further studyis needed to investigate gamification's long-term impacts and find best practices for its use in educational settings.

Gamification/Gamified Learning Activity and Student's Learning Motivation

Gamification/gamified learning activities enhance intrinsic and extrinsic motivation, leading to increased engagement, persistence, and improved academic performance. It taps into students' inherent curiosity and desire for mastery by delivering relevant and demanding assignments, quick feedback, and possibilities for autonomy, improving their intrinsic motivation to learn (Forde et al., 2015; Glynn et al., 2011). Gamification further aids extrinsic motivation, including prizes, badges, and levels. These external incentives act as visible acknowledgements of students' progress and successes, fostering a sense of accomplishment and an extrinsic desire to engage with the learning content in the future. Gamification fosters a sense of autonomy and competence in students by giving them options, control over their learning path, and possibilities for skill improvement. This sense of independence and competence boosts motivation and engagement.

(Deci & Ryan, 1985). Through multiplayer components and cooperative tasks, gamified learning activities frequently involve social interaction and teamwork. These qualities encourage students to feel connection, collaboration, and healthy competition, which leads to improved motivation and engagement. Gamification increases students' participation in the learning process dramatically. Gamified activities attract students' attention, maintain their interest and boost their desire to put effort into their studies by making learning more entertaining and participatory. This is proven through a study conducted by Barata et al. (2013), where they gamified a college course by integrating points, levels, badges, challenges, and leaderboards. They analysed data from gamified and non-gamified years, using different performance indicators, to see how gamification affected the learning experience, and the findings reveal considerable gains in reference material attentiveness, online involvement, and proactivity. Their findings showed that a gamified course can assist students in improving their learning and increase their commitment to learning activities. In addition, gamified learning activities inspire students to overcome hurdles, persevere in their efforts, and focus on obtaining the intended learning outcomes by giving clear goals, progress indicators, and incentives (Kummanee et al., 2020). Gamification has a favourable influence on students' learning motivation, which leads to enhanced academic achievement. Thus, highly motivated students who participate in gamified learning activities experience better knowledge acquisition, skill development, and academic achievement.

Gamification/Gamified Learning Activity and Student's Future-Ready Learning Skills

The positive impact of gamification on students' development of future-ready learning skills can be seen by incorporating game elements and mechanics into educational activities. Gamified learning improves critical thinking, collaboration, creativity, and adaptability. Gamified learning improves critical thinking, teamwork, creativity, and flexibility by incorporating game features and mechanics into educational activities. Gamification dramatically improves students' acquisition of future-ready learning skills. Students build and polish critical thinking, cooperation, creativity, and adaptability skills through engaging and immersive gaming experiences necessary for success in today's changing workforce (Asigigan & Samur, 2021).

In the O'Donovan et al. (2013) study, which investigated how an online learning management application was used to gamify a university course in computer game development, the findings showed highly positive impacts on course grades, lecturer evaluations, and lecture attendance. Despite the beneficial effects, the research also indicated that gamification deployment in a course should be weighed against the financial and time costs to ensure the success of gamification implementation. In addition, gamified learning activities allow students to practise future-ready learning skills in real-world scenarios. Students receive practical experience and improve their ability to adapt to real-world scenarios by modelling complicated events and obstacles(Bucchiarone et al., 2019). Gamification increases student engagement and motivation, both critical for developing future-ready learning abilities. Gamified learning activities attract students' attention, improve their intrinsic motivation, and build a positive attitude towards skill development and continual learning (Lamrani & Ambdelwahed, 2020; Rincon-Flores & Santos Guevara, 2021).

Methodology

This study used a quasi-experimental design with a non-equivalent pre-test-post-test control group. Researchers often used a quasi-experimental design to examine the effectiveness of treatment (intervention) when samples could not be completely random due to study process constraints (Creswell & Creswell, 2017; O'Dwyer & Beranger, 2016). For example, students may be in separate classrooms, and treatment may be administered separately. The study's samples consisted of students from Penang Matriculation College in Semester 2, Academic Session 2022/2023, which

Two (2) classes with equivalent academic backgrounds in their secondary school Chemistry grades were included. Cluster random sampling (intact group) was utilised to choose which 217 students would be the treatment and control groups. Based on a population of 217 students, the first ballot selected two (2) classes as the treatment group (N = 30), and the second ballot chosen two (2) classes as the control group (N = 30). As a result, there are only 60 students in this quasi-experimental research.

The treatment group is taught in a cybergogy-based T&L environment, whereas the control group is taught conventionally. The cybergogy approach was employed in the treatment group to teach Born-Haber Cycle subtopics utilising gamified learning activity (gamification). Students utilised this strategy to explain the Born-Haber Cycle processes by creating a gamified activity, and they can create new ones or use existing internet resources that feature animations and visualisations. This treatment instruction is called Cybergogy Born- Haber Quest gamified learning activity or C-BHQ instruction. This C-BHQ instruction engaged students in a fun and interactive way while deepening their understanding of the Born- Haber Cycle and its application in calculating lattice energies and enthalpies of formation. Students can use gamification elements such as badges, leaderboards, or reward systems to create a sense of achievement and foster healthy competition. This gamification can also be applied to quizzes, assignments, or collaborative activities, providing a fun and interactive learning experience as the students in the control group received conventional/existing instruction, where the T&L for this subtopic was implemented using a commonly used technique at this college, which is based on lecture and tutorial sessions, using existing lecture notes and tutorial exercises.

In this study, three (3) instruments were used: the Born-Haber Achievement Test (BHAT), the Chemistry Learning Motivation Questionnaire (CLMQ), and Future-Ready Learning Skills (FRLS). All three (3) instruments were given to both groups of samples before and after the interventions. The BHAT was used to evaluate the student's achievement in the Born-Haber Cycle subtopic, which consisted of 4 questions with 20 total scores. It was developed and adapted from the Matriculation Final Semester Examination (PSPM) collection. It has undergone the validity and reliability test through the pilot test (N=30) conducted earlier with similar criteria to actual samples. The validation of BHAT is done by three (3) experts chosen based on their expertise in teaching Matriculation Chemistry for more than ten years. The BHAT instrument showed a reliability value, Cronbach alpha greater than .700, which is .850.

The CLMQ was used to measure matriculation students' motivation for learning chemistry. This instrument consisted of only one (1) section of 22 items that used five (5) points Likert-scale. The instrument was developed and adapted from the Science Motivation Questionnaire (SMQII) by Glynn et al. (2011) and Glynn et al. (2009). Besides replacing the science subject with the chemistry subject, the instrument is also being translated into Malay and has undergone forward-backward-translation. The validity of the CLMQ instrument was checked before it underwent reliability analysis for a sample of 30 students, which had characteristics similar to those of the actual sample. This reliability test was conducted during the pilot test. The CLMQ instrument showed a reliability value, Cronbach alpha greater than .700, which is .950.

The third instrument, FRLS, was used to measure the student's future-ready learning skills. This instrument consisted of one (1) section of 20 items that used a five (5) Likert scale. The instrument was developed and adapted by Thomas (2016), Right (2019), and Perifanou et al. (2021). The items produced were translated into Malay, and a forward-backward-translation procedure was performed. The validity of the FRLQ instrument was checked before it underwent reliability analysis for a sample of 30 students, which had characteristics similar to those of the actual sample. This reliability test was conducted during the pilot test. The FRLS instrument showed a reliability value, Cronbach alpha greater than 700, which is 830. Since all three (3) instruments, BHAT, CLMQ and FRLQ instruments, have beenvalidated and proven reliable, these three (3) instruments can be used for the actual study.

For the procedure of implementing treatment intervention (C-BHQ instruction), first, the lecturer divided the treatment group (class) into teams of three (3) students. They were asked to discuss among their group members and design a series of three (3) levels or stages that represent different steps or calculations within the Born-Haber Cycle. Each level can focus on a specific aspect, such as calculating ionisation energy, electron affinity, lattice energy, or enthalpy of formation. They also must assign points or virtual currency to each correct answer or completed level. The gamified learning activities that the students must create can be either quizzes or any mini-games they can make. They were also asked to explain the game rules, objectives, and reward system used to motivate and engage the players/users. This intervention session occurred within six (6) weeks, and the findings were presented within two (2) weeks. In the control group, the existing/conventional intervention was used. Following the interventions, both the treatment and control groups were given post-tests.

The quantitative data obtained from the BHAT, CLMQ, and FRLS were analysed through statistical methods using SPSS version 27.8 (Statistical Package for the Social Sciences). The significance level applied was .050. The difference between the pre-test data of the treatment (C-BHQ instruction) group and control (conventional instruction) groups was analysed via an independent sample t-test. Then, the differences between pre-test scores of both groups were co-variated, and the differences among post-test scores were analysed via analysis of covariance (ANCOVA) (Pallant, 2020; Porter & Raudenbush, 1987). The ANCOVA is used to see if there are any significant differences in a dependent variable between two or more independent (unrelated) groups. This ANCOVA examines differences in adjusted means (adjusted for covariance). Thus, this ANCOVA has the added benefit of statistically controlling for a third variable (confounding variable) that may alter our result (Frank, 2000; Miller & Chapman, 2001). In other words, the ANCOVA is used to analyse the hypotheses while controlling for a covariate.

Results

Pre-test scores collected for BHAT, CLMQ, and FRLS from the treatment (C-BHQ instruction) group and the control (conventional instruction) group were analysed and compared via independent samples t-test, as shown in Table 1.

Table 1
Independent Samples t-test Results for Pre-test Mean Scores of BHAT, CLMQ, and FRLS

Scale	Groups	N	Mean	SD	t	p
BHAT	Treatment	30	9.000	4.077	-.297	.768
	Control	30	9.300	3.752		
CLMQ	Treatment	30	65.630	4.181	-.206	.837
	Control	30	65.830	3.270		
FRLS	Treatment	30	65.170	3.141	-.444	.659
	Control	30	65.600	4.328		

Notes: N= number of samples, SD= standard deviation, p = significance level, t= t value.

The independent samples t-test compares two (2) sample means from unrelated groups. This means different people provide scores for each group (Pallant, 2020). This test aims to determine if the samples are different from each other. According to the BHAT pre-test analysis in Table 1, the mean score for the treatment group (M = 9.000, SD = 4.077) was slightly lower than the control group (M = 9.300 SD = 3.752). However, there is no statistically significance difference was found between the pre-BHAT mean scores of the treatment and control groups ($p > .050$), where $t(58) = - .297$, $p = .768$.

Meanwhile, for the CLMQ pre-test, the mean score of the treatment group (M = 65.63, SD = 4.181) was slightly lower than the mean score of the control group (M = 65.83, SD = 3.270). However, no statistically significant difference was found between the pre-CLMQ mean scores of the treatment and control groups (p > .050), where t(58) = - .260, p = .837. The last comparison in the pre-test, FRLS pre-test mean scores, revealed that the mean score of the treatment group (M = 65.17, SD = 3.141) was slightly lower than that of the control group (M= 65.60, SD = 4.328). However, there was no statistically significant difference between the pre-FRLS mean scores of the treatment and control groups (p > .050), where t(58) = -.444, p =.659. After the treatment group undergoes C-BHQ instruction intervention, and the control group undergoes conventional instruction intervention, post-test scores are collected for BHAT, CLMQ, and FRLS from both groups of samples and were analysed to be compared via independent samples t-test as shown in Table 2.

Table 2

Independent Samples t-test Results for Post-test Mean Scores of BHAT, CLMQ, and FRLS

Scale	Groups	N	Mean	SD	t	p
BHAT	Treatment	30	16.270	2.803	4.086	.000
	Control	30	13.100	3.188		
CLMQ	Treatment	30	80.970	4.030	16.162	.000
	Control	30	65.670	3.262		
FRLS	Treatment	30	83.300	4.617	10.715	.000
	Control	30	68.800	5.798		

Notes: N= number of samples, SD= standard deviation, p = significance level, t = t-value.

According to the BHAT post-test analysis in Table 2, the mean score for the treatment group (M = 16.270, SD = 2.803) was higher than the control group (M = 13.100, SD= 3.188). Thus, a statistically significant difference was found between the post-BHAT mean scores of the treatment and control groups, where t(58) = 4.086, p < .050. Whereas for the CLMQ post-test, the mean score of the treatment group (M = 80.970, SD= 4.030) was higher than that of the control group (M = 65.670, SD = 3.262). Thus, a statistically significant difference was found between the post-CLMQ mean scores of the treatment and control groups, where t(58) = 16.162, p < .050. The last comparison in the post-test, FRLS post-test mean scores, revealed that the mean score of the treatment group (M = 83.300, SD = 4.617) was higher than that of the control group (M = 68.800, SD =5.798). There was a statistically significant difference between the post-FRLS mean scores of the treatment and control groups, where t(58) = 10.715, p < .050. Descriptive statistics analysis for post-tests is done with corrected means (adjusted means) and is shown in Table 3.

Table 3

Descriptive Statistics for Post-test Mean Scores of BHAT, CLMQ, and FRLS

Scale	Groups	Mean	SD	Corrected means
BHAT	Treatment	16.270	2.803	16.753
	Control	13.100	3.188	13.876
CLMQ	Treatment	80.970	4.030	81.171
	Control	65.670	3.262	65.832
FRLS	Treatment	83.300	4.617	83.556
	Control	68.800	5.798	69.289

Notes: SD standard deviation.

After controlling for the pre-test scores of the treatment and control groups, the post-test scores were compared via the ANCOVA and the result is shown in Table 4.

Table 4

ANCOVA Results for Post-Tests Mean Scores of BHAT, CLMQ, and FRLS

Scale	Source	Sum of Squares	df	Mean Squares	F	p	η^2
BHAT	preBHAT	321.613	1	321.613	91.225	.000	.615
	Groups	167.779	1	167.779	47.950	.000	.455
	Error	200.954	57	3.526			
	Total		60				
	Corrected Total		59				
CLMQ	preCLMQ	61.387	1	61.387	4.872	.031	.079
	Groups	3533.961	1	3533.961	280.455	.000	.831
	Error	718.247	57	12.601			
	Total	326811.000	60				
	Corrected Total	4290.983	59				
FRLS	preFRLS	62.624	1	62.624	2.332	.132	.039
	Groups	3091.665	1	3091.665	115.144	.000	.669
	Error	1530.476	57	26.850			

Total	351763. 000	6 0				
Corrected Total	4746.85 0	5 9				

Notes: df = degrees of freedom, p = significance level, F= F value, η^2 = partial eta squared.

Based on values in Table 3 and ANCOVA results in Table 4, the mean corrected (adjusted) BHAT post-test scores of samples (M = 16.753) in the treatment group (C-BHQ instruction) was significantly higher than the control group (M = 13.876), where F(1, 57) = 47.950,p < .050, η^2 = .455. A partial eta squared (η^2) of .455 indicates a large effect size, according to Cohen (1988). The mean corrected (adjusted) CLMQ post-test scores of samples (M = 81.171) in the treatment group (C-BHQ instruction) were also significantly higher than the control group (M = 65.832), where F (1, 57) = 280.455, p < .050, η^2 = .831. According to Cohen (1988), η^2 >.010 indicates a small effect size; η2 >.059 indicates a moderate effect size; and η^2 >.138 represents a large effect size. Thus, the partial eta squared (η^2) of .831 in the BHAT post-test indicates a large effect size, according to Cohen (1988). Final comparison, the corrected (adjusted) mean scores for post-FRLS of the treatment group (C-BHQ instruction, were also statistically higher (M = 83.556) than that of the control group (conventional instruction), (M 69.289), where F (1, 57)= 115.144, p < .050, η^2 = .669 Partial η^2 of .669 indicates a large effect size (Cohen, 1988). Since the significant difference between revised post-FRLQ scores was in favour of the treatment group, it can be concluded that the treatment group (C-BHQ instruction) had better achievement, learning motivation, and future-ready learning skills compared to the control group (conventional instruction). These findings prove that all three (3) null hypotheses formulated are rejected.

Discussion and Conclusion

There was no statistically significant difference between the treatment and control groups based on students' pre-BHAT mean scores according to independent samples t-test. However, the C-BHQ instruction implied that the treatment group had contributed more to students' achievement than conventional instruction did when BHAT post-test mean scores of both groups were compared using ANCOVA. The finding showed a statistically significant difference in favour of the treatment group through ANCOVA analysis of the post-CLMQ mean scores with a more substantial effect size. This is matched with prior research on the favourable benefits of gamified learning activities on academic achievement. (Dhahak & Huseynov, 2020; Mee et al., 2022; O'Donovan et al., 2013; Putz et al., 2018).

Rather than directly presenting concepts to students, as is typically done in conventional/existing education, C- BHQ instruction requires students to apply the concepts taught in a gamified learning activity. Relevant studies in the literature have shown that gamification/gamified learning activity provides much more memorable instruction than conventional teaching (Kapp, 2012). In C-BHQ instruction, the creation of gamified learning activities by the students themselves urged them to understand what is needed about the Born-Haber Cycle. This appears to be one of the reasons why student achievement levels in the treatment group turned out to be higher than that in the control group. The importance of need-to-know in learning has also been emphasised by Bennet and Lubben (2006).

In terms of learning motivation, there was no statistically significant difference between the treatment and control groups based on students' pre-CMLQ mean scores according to independent samples t-test. However, there was a statistically significant difference in favour of the treatment group that was detected through ANCOVA analysis of the post-CLMQ mean scores with a larger effect size. This result shows that C-BHQ instruction contributes more to student's learning motivation. The findings obtained from CLMQ demonstrated that C-BHQ instruction increased students' motivation to learn chemistry. For C-BHQ instruction (treatment intervention), linking knowledge concepts of the Born- Haber Cycle with gamification/gamified learning activity seems to have improved students' motivation to learn chemistry. The results of our study seemed in agreement with the previous studies by Barata et al. (2013) and Kummanee et al. (2020). They have proven that gamification/gamified learning activity has a good influence on students' learning motivation when used in subjective courses.

For the third dependent variable, which is future-ready learning skills, this study's findings revealed no statistically significant difference in the pre-FRLS mean scores between the treatment (C-BHQ instruction) and the control group. However, in the comparison of post-FRLS mean scores using ANCOVA, a significant difference was discovered in favour of the treatment group (C-BHQ instruction) with a larger effect size. Based on these findings, this study concludes that the treatment group has developed a more future-ready learning skills student. Therefore, C-BHQ instruction could be regarded as more efficient than conventional/existing instruction. This also is aligned with the findings of research done by Asigigan and Samur (2021) and O'Donovan et al. (2013). Therefore, there was certainly evidence that gamification/gamified learning has a good impact/effect on kids building future-ready learning abilities.

A future-ready curriculum aims to prepare students for the demands of a rapidly changing work market while also equipping them to become lifelong learners capable of navigating and contributing to a globalised and technologically driven society. Through this study, we concluded that by gamifying the learning experience, the C-BHQ instruction (treatment intervention) promoted active engagement, healthy competition, and collaborative learning. It also motivates students to actively participate in understanding and applying the Born-Haber

Cycle, making the learning process more enjoyable and memorable. In addition, their future-ready skills also elevated after the treatment intervention. Even though this gamification/gamified T&L method focuses on student-centred strategy, instructors (lecturers/educators) must also play an important part in implementing this type of cybergogy-based T&L. They must be well-versed in carrying out activities that revolve around the connection between the chemistry (or any subject content) and the gamification elements. For the next research recommendation, a bigger sample size and study are necessary, notably to improve instructors' and students' ability to conduct cybergogy-based (i.e., gamification-based T&L) in the classroom. Overall, research on gamified learning activities serves to improve educational theories, develop new research methodologies, collect empirical data, and give practical aid to educational practitioners. By studying the potential and limitations of gamification in learning, this study contributes to more engaging and successful educational experiences for students.

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Study of Pre-Service Teachers' Interest in Fundamentals of Programming toward Achievement in Decision Mathematics Courses

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Abstract

Basic programming refers to the basic knowledge and concepts required in software development or writing code using a programming language. Programming basics is an essential first step for anyone who wants to learn and master programming skills. This study aims to investigate whether there is an impact between interest in the basics of programming and achievement in the subject when attending the Decision Mathematics course at the Institut Pendidikan Guru Kampus Pulau Pinang (IPGKPP). The sample consisted of 66 IPGKPP students from Mathematics courses. The instrument used was a questionnaire with a choice of five Likert scales. The statistical test is an independent samples t-test and analysis of variance (ANOVA) with the data analysed using SPSS (Statistical Package for the Social Sciences). There is a positive impact between interest in the basics of programming, gender and achievement in Decision Mathematics. The results showed no significant difference between male and female students but an essential difference among different achievements in interest toward programming. The results also found that low-achievement students` interest in programming was the lowest of all respondents compared with high-achievement students`. In conclusion, the basics of programming and the subject of mathematics are relevant because the structure of both, which is logical, helps understand and solve problems. However, interest is not the only factor that affects achievement in mathematics.

Keywords: *Programming, Achievement, Decision Mathematics, Pre-Service Teachers*

Introduction

Programming is one of the skills in high demand in current and future job markets (Kim & Lee, 2016). Computer programming requires high-level thinking skills such as problem-solving, logical thinking, and mathematical thinking (Baser, 2013). Each subtask involves a distinct knowledge domain and cognitive process, making programming incredibly complex. In the 21st century, students and teachers must acquire programming skills. The increasing importance of programming remains challenging for students, who find learning difficult and tedious, and teaching it can present many obstacles. As the world economy changes, workers are increasingly being replaced by robots and artificial intelligence (AI). Hence, programming is crucial in the present and future job markets. Programming skills are valuable only for those who work in highly technical fields. Those working closely with developers and programmers can become valuable team members by learning basic programming. In higher education programming, students learn to break down problems into smaller pieces and design (Pang, Ishibuchi & Shang, 2020). Using decomposition and algorithm design in computational thinking processes offers students fresh perspectives on problem-solving. Moreover, the ability to code gives students excellent career prospects and makes them highly sought-after in an increasingly digital world (Dengler & Matthes, 2018; Fayer, Lacey & Watson, 2017). Despite the recent technological advancements, programming remains a young and innovative discipline. Its learning method remains unchanged. Mathematics remains the primary subject of teaching programming, while computers and computing are no longer as commonly used as calculators for solving mathematical problems.

Programming is the process of writing and designing instructions for a computer to follow. These instructions are typically written using a programming language, a formalised set of rules and syntax that allows humans to communicate with computers and tell them what tasks to perform. Programming involves a series of steps, including problem-solving algorithm design, coding, debugging, testing, optimisation, documentation and maintenance. Programming is creating computer-readable instructions or code that can be executed. It involves instructing a computer to perform specific actions, solve problems, or achieve desired outcomes. Humans communicate with computers through programming. Developers use programming to create software applications, websites, games, and other digital solutions. These instructions are written in programming languages that can be read and executed by humans or machines. Programming allows humans to create various software applications, from simple scripts that automate tasks to complex software systems that power everything from websites and mobile apps to video games and scientific simulations. Different programming languages serve various purposes and have varying levels of complexity, making them suitable for other types of projects. Programming has become an increasingly important and popular subject in education due to its relevance in today's technology-driven world.

Programming can be introduced at various levels of education, from primary and secondary schools to higher education institutions. It can be taught using multiple resources, including coding platforms, online tutorials, textbooks, and interactive coding environments. Additionally, initiatives like coding clubs, hackathons, and coding competitions can further engage students and provide opportunities for the practical application of their skills. Overall, incorporating programming into education equips students with valuable skills, a deeper understanding of technology, and the ability to participate meaningfully in the digital age. According to several commentators, programming should be included in the curriculum, just like mathematics and writing. Some individuals maintained that students must grasp the manipulation of information to program or author on computers. The students must be able to follow models of programming. Programming is a valuable learning experience due to its iterative process, ultimate goal, and feedback and error. Several commentators suggested ways to incorporate programming into the curriculum, including graphic arts and other required subjects. Time constraints and the provision of student computers are significant barriers to programming. Some suggested that programming should only be taught to students pursuing a career in programming. The outlook for a community of practice was blending school and the natural world with varying levels of experience.

a) Programming in Mathematics

Mathematical programming is a theoretical tool of management science and economics in which management operations are described by mathematical equations that can be manipulated for various purposes (Britannica, 2017). The technique is described as linear programming if the basic descriptions involved are linear algebraic equations. If more complex forms are required, the term nonlinear programming is applied. Computers are widely used in obtaining solutions.

Linear programming is a mathematical modelling technique in which a linear function is maximised or minimised when subjected to various constraints (Britannica, 2017). This technique has helped guide quantitative decisions in business planning, industrial engineering, and—to a lesser extent—in the social and physical sciences. The solution of a linear programming problem reduces to finding the optimum value (most significant or most minor, depending on the problem) of the linear expression (called the objective function). Decision problems and other problems are based on mathematical models used in programming. These terms are in contrast to computer programming, which employs algorithms that are designed to solve specific problems. Descriptive programming is a type of mathematical programming. A differentiation is taken from the problem's representation by a mathematical model to its solution. It is believed that general methods, such as branching Methods, can be used to solve the problem using the mathematical model designed to represent it.

Mathematical programming in management science and economics involves manipulable equations that describe management operations. The method is called linear programming when the fundamental explanations involved are linear algebraic equations. Nonlinear programming is used when more complex forms are needed. In applications such as planning production schedules, transportation and military logistics, equations are programmed with variables to be assumed by the user, allowing unknowns to become known. Computers are commonly employed to obtain solutions.

b) Interest in Learning Programming

Interest in learning refers to a person's curiosity, enthusiasm, and engagement in acquiring knowledge, skills, or understanding about a particular subject or topic. People with a genuine interest in learning are more likely to be motivated, attentive, and proactive in their educational endeavours. Interest plays a significant role in effective learning. In summary, interest in education is a dynamic and motivating force contributing to more effective, meaningful, and enjoyable educational experiences. Encouraging and supporting students' interests can lead to a lifelong love of learning and personal growth.

Amnouychokanant, Boonlue, Chuathong and Thamwipat (2021) determine attitudes towards programming by examining five components, namely (1) meaningfulness, (2) interest in programming, (3) self-efficacy, (4) creativity, and (5) collaboration. Interest in programming is one of the important components in attitude towards programming. Interest in programming is wanting to learn about programming (Amnouychokanant et al., 2021). Students interested in programming tend to perform better than other students (Amnouychokanant et al. (2021). They are willing to spend more time on programming. They are more likely than others to view complex programming tasks as a challenge and find practical solutions to complete them (Ryan & Deci, 2020). Interest in programming is the desire to learn and use programming languages to create software or other applications. It can be sparked by various things, such as a desire to solve problems, a creative outlet, or a career goal.

Programming is difficult (Mladenović, Rosić & Mladenović, 2016; Pendergast, 2006; Robins, Rountree & Rountree, 2003). Various studies (Guzdial & Soloway, 2002; Kinnunen & Malmi, 2006; Lahtinen, Ala-Mutka & Järvinen, 2005; Malik & Coldwell-Neilson, 2017; Sykes, 2007) report a high failure rate and lack of student interest in programming courses. Among the problems faced is the need for exceptional precision (Kuechler & Simkin, 2003; Pendergast, 2006)) since it involves correctness of logic, syntax, and semantics. Robins et al. (2003) further commented that a strong foundation in computer knowledge languages, programming tools and resources, theory, and formal methods are prerequisites to a skilled programmer. In conclusion, the problem in getting students interested in programming is due to the difficulty in learning because it requires extraordinary precision and logic.
This study aimed to investigate the relationship between students' interest in programming, gender, and achievements. The research hypotheses are:

a. Is there a significant difference between male and female students in terms of interest in learning programming?
b. Is there a significant difference between students of different achievements in the Decision Mathematics course on interest in learning programming?

Literature Review

Programming is one of the most in-demand skills these days. Basic programming skills and background knowledge are necessary for a newcomer to learn. There were two categories of skills: programming-related abilities and general educational capabilities (Medeiros, Ramalho & Falcão, 2018). In introductory programming courses, the aim is to teach students how to write answers in a language that works for computers. A suitable language is essential for teaching introductory programming. It has a significant impact on inexperienced learners. After mastering their first language, they keep coding and learn more complex programming languages. Many researchers emphasise the importance of problem-solving skills when studying programming (Mathew, Malik, & Tawafak, 2019; Veerasamy, D'Souza, Lindén, & Laakso, 2019).

Programming challenges those needing more problem-solving skills (Tavares, Menezes & de Nevado, 2012). As a result, it is believed to be essential for learning fundamental programming. Mathematics is cited as the key to programming, in addition to problem-solving abilities. Most programming educators assert that inadequate math skills are a source of difficulty for inexperienced students. Students who need more mathematical knowledge may be proficient in programming (Gomes & Mendes, 2010a). It is worth mentioning that students who possess both math and logic are always successful in a programming course (Gomes & Mendes, 2010b). Porter and Zingaro (2014) suggest that prior experience is a key factor in determining programming proficiency for newcomers in higher education. Those with previous experience in programming perform better than those without. English is a barrier to programming education, as it is used in the syntax of all programming languages. Those who possess proficiency in vocabulary and English grammar are more inclined to excel as programmers than those who do not (Horton & Craig, 2015)

Programming in higher education is a challenging task that necessitates problem-solving and higher-order thinking skills. Learning to program in higher education is problematic because it requires problem-solving and higher-order thinking skills (Mladenović, Rosić & Mladenović; 2016; Robins, Rountree & Rountree; 2003). It is difficult for first-year students to express the solution in a computer-readable format. They must have a grasp of various non-physical concepts. Even students with sufficient problem-solving skills cannot convert the pseudocode into an appropriate syntactic program. For beginners, the syntax of programming languages is crucial. Syntax errors can take a long to correct, leading to unpredictable debugging behaviour (Koulouri, Lauria & Macredie, 2014). One of the challenges that higher education students faced was deciding on appropriate control structures (sequences, loops), conditionals, recursion, and repetition to solve problems. Selecting the proper control structures (sequences, loops, conditionals, recursion, and repetition) for solving problems was also mentioned as one of the difficulties for novice students in higher education (Berglund and R. Lister; 2010; Koulouri, Lauria & Macredie; 2014). Due to the examination's difficulty level, most students failed the programming examination. Bringula, Aviles, Batalla, and Borebor (2017) found that most students failed the programming examination because the difficulty level was not suitable for the student's level and allotted time. Anxiety, panic, and stress are often felt when they fail to solve programming errors. When they usually cannot solve programming errors, they experience anxiety, panic, and stress (Rogerson & Scott, 2010).

They also feel a sense of sadness and dejection (Sheridan, Hamilton & D'souza, 2009). Those encountering programming difficulties often abandon their studies and transfer to other degree programs (Robins et al., 2003).

Programming is a challenging task for both beginners and teachers. Teachers strive to discover methods to stimulate students' curiosity in programming. Instructors attempt to find ways to arouse students' interest in programming (Gomes & Mendes, 2014). The absence of enthusiasm in a teaching style can lead to boredom. It is challenging to ignite programming enthusiasm among college students. This poses a challenge for educators when creating learning activities. Besides motivating students, instructors should also teach beginners basic skills and simple problem-solving techniques before beginning the course to ensure they have a solid foundation in programming. Past research has recommended various teaching approaches such as live coding, gaming, team-based learning, interactive computer tutoring, mentor support and peer instruction (Nurbekova, Tolganbaiuly, Nurbekov, Sagimbayeva & Kazhiakparova; 2020; Ventura Roque-Hernández, Armando Guerra-Moya, & Carmina Caballero-Rico, 2021) and pair programming. Even so, not all of these methods are effective. Active learning, demonstration, live coding, and canned examples were all employed by Hertz and Jump (2013) in their classrooms. The student performance and retention rates were inadequate.

On the other hand, solely trace-based teaching reduced dropout and grade failure rates. The interpretation suggests that integrating diverse teaching methods in courses may only sometimes be advantageous. Furthermore, the teachers are challenged to elevate programming proficiency in large classes with students of different learning levels (Gomes & Mendes, 2014). Some educators (Abiola, Moisseinen & Tedre, 2012; Nikula, Gotel, & Kasurinen, 2011) proposed that tutors and mentors could facilitate learning activities by reducing the complexity and minimising student differences. Another issue is the feedback process. Formal and summative assessments can provide positive feedback. The formative test provides the teachers with feedback on their teaching and enables improvement. The instructors employ summative assessments to assess student's readiness for the next lesson and identify areas of weakness. The instructors also use summative assessment to determine whether the students are ready to move on to the next lesson and help identify weak areas for students (Hartanto, 2015). It is crucial to pick the first programming language that new students should learn. Teachers should opt for uncomplicated languages to initiate coding as the language syntax is too challenging. Learning languages that are too challenging can negatively impact students' programming abilities and performance. Choosing complex languages can affect students' performance and attitudes toward programming (Ateeq, Habib, Umer & Rehman, 2014; Topalli & Cagiltay, 2018; Weintrop & Wilensky, 2019).

Methodology

This study uses a survey method to determine whether students are interested in programming through the Decision Mathematics courses.

Sample

The study sample consists of 66 IPGKPP students for the year 2020. The sample selection was made because only 66 students took the subject related to programming, which is decision mathematics, and the topic involved is algorithms. Algorithms are chosen because they contain basic computer programming content, such as identifying flowcharts and simple programming languages. The sub-topics in the algorithm chapter consist of:-

a. Introduction and definition of algorithms
b. Representation in algorithms such as programming languages, pseudocode, flowcharts and simple programming languages
c. Control structures in algorithms such as sequence, selection and repetition
d. Computer programming, such as structural control in programming Instrument

The research instrument used is a questionnaire. This original survey was based on the questionnaire developed by Kong, Chiu, and Lai (2018) and has been modified from the study of Amnouychokanant et al. (2021), which is related to interest in programming. The questionnaire was validated by three Mathematics lecturers who have taught the subject of Mathematics Decisions for at least three years. The total number of items in the questionnaire is ten items. Items were designed using a 5-point Likert scale (5 = “strongly agree,” 4 = “agree,” 3 = “neutral,” 2 = “disagree,” and 1 = “strongly disagree”). In this study, respondents' interest were measured through responses given to a series of statements (items) in the survey questionnaire component. Each item is formulated in a language that is easy for respondents to understand. The level of interest of respondents is measured by the extent to which they agree or disagree with each item. This scale allows respondents to determine their own choices.

A pilot test was carried out before the actual study was carried out. A pilot test was conducted on 59 IPGKPP students for the 2019 intake to obtain the validity and reliability of the constructed questionnaire. The data was analysed using Statistical Package for the Social Science (SPSS) version 22. The Cronbach's Alpha coefficient value obtained from the questionnaire was 0.85, which is defined as appropriate and can be used in the study.

Results

Based on a study carried out by Amnouychokanant et al. (2021), the study's results were divided into two, namely, interest in programming by gender and interest in programming by achievement in the subject of Decision Mathematics.

a. Interest in programming by gender

Table 1 shows the mean and standard deviation for male and female students interested in programming. The mean for male students is 4.45, with a standard deviation of 0.81, while the mean for female students is 4.24, with a standard deviation of 0.76.

Table 1

Mean and standard deviation for comparing interest toward programming by gender

	Group	N	Mean	Std. Deviation	Std. Error Mean
Interest by Gender	Male	32	4.45	0.81	0.14
	Female	34	4.24	0.76	0.11

Table 2 shows an independent sample t-test comparing gender differences in interest in programming. There was not a significant difference between male (M = 4.45, SD = 0.81) and female (M = 4.24, SD = 0.76); t(64) = -8.34, p = .0.62.

Table 2

Independent samples t-test comparing gender differences in interest in programming

	t-test for Equality of Means

		Levene's Test Equality of Variances							95% Confidence Interval of the Difference	
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.25	.62	-8.34	64	.00	-23.00	1.23	-29.23	-18.12
	Equal variances are not assumed.			-8.34	64	.00	-21.00	1.45	-29.21	-18.12

b. Interest in programming by achievements

Table 3 shows the mean value and standard deviation for three groups with three achievements. The results show that the students with the highest achievement in the decision mathematics course have the highest score, while those with the lowest achievement have the lowest score value.

Table 3

The mean and standard deviation for three groups with three different achievements

Achievements	N	Mean	Standard Deviation
High	28	4.12	0.76
Medium	32	3.97	0.89
Low	6	2.90	0.94

ANOVA test analysis was conducted on all three groups with a significant level of 0.05. ANOVA test analysis tests whether there is a substantial difference between the three groups.

Table 4 shows the Shapiro-Wilk normality test for the mean scores of the three groups. The results of the Shapiro-Wilk test for mean scores were normally distributed with $p>0.05$.

Table 4

Shapiro-Wilk Normality Test

Normality Test				
	1 = High 2 = Medium 3 = Low	*Shapiro-Wilk*		
		Statistic	df	Sig.
Interest of Programming	High	0.91	25	0.20
	Medium	0.89	29	0.10
	Low	0.92	10	0.06

Notes: a. Lilliefors significance correction

Table 5 shows the non-significant result of Levene's test, indicating that they have the same variance in the population with $p > 0.05$.

Table 5

Levene's test

Test of homogeneity of variances			
Interest of Programming			
Levene statistic	df1	df2	Sig.
2.35	2	64	0.10

Table 6 shows the significant result of the ANOVA test for interest toward programming by achievements, $F(2, 64) = 71.16$, $p < 0.05$, indicating an essential difference between the three groups of achievements.

Table 6

ANOVA test for interest in programming by achievements

ANOVA

Interest of Programming

	Sum of squares	df	Min Persegi	F	Sig.

Between groups	5.90	2	2.95	2.06	0.13
Within groups	160.05	64	1.43		
Total	165.95	66			

The Tukey Post Hoc test in Table 7 shows mean scores differed significantly for all groups, with the test mean scores at the significance level of 0.05.

Table 7

Tukey Post Hoc for interest toward programming by achievements

Multiple comparisons

Interest of Programming
Tukey HSD

(I) 1 = High 2 = Medium 3 = Low	(J) 1 = High 2 = Medium 3 = Low	Mean difference (I–J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
High	Medium	-2.44*	0.40	0.00	-3.39	-1.49
	Low	-4.82*	0.40	0.00	-5.77	-3.86
Medium	High	2.44*	0.40	0.00	1.49	3.39
	Low	-2.37*	0.40	0.00	-3.32	-1.42
Low	High	4.82*	0.40	0.00	3.86	5.77
	Medium	2.37*	0.40	0.00	1.42	3.32

*. The mean difference is significant at the 0.05 level

Table 7 shows the results of the ANOVA analysis of the mean scores for the three groups, which show significant differences.

Discussion

Independent sample t-test results show no significant difference between male and female students in interest in programming. This may be because the students admitted to IPGKPP are interested in mathematics. Mathematics is a subject that involves logic and is very synonymous with programming, which also requires logical thinking. This coincides with the study of Karaci (2016), which states that there is no significant difference between male and female students in programming. Nevertheless, Karaci's (2016) study used a sample of students who had a background in the field of computers. The findings of Karaci (2016) were supported by Amnouychokanant et al. (2021), who stated that there was no difference between male and female students and that the sample was the same as that of Karaci (2016).

Baser (2013) explained in his study that male students should have better mean scores than female students. Baser (2013) stated that the possibility is due to the negative attitude of female students towards programming. Baser's (2013) statement is based on a literature review by Gürer and Camp (2002). Some previous studies that have been stated by Gürer and Camp (2002) show that there are research results (Bebetsos & Antoniou, 2009; Chang, Shieh, Liu & Yu, 2012; Palaigeorgiou, Siozos, Konstantakis & Tsoukalas, 2005) stating how negative female students are towards programming, but there are studies (Bakr, 2011; Yldrm & Kaban, 2010) stating that there is no significant difference between male and female students. A study (Khatoon & Mahmood, 2011) states that female students are more positive than males. Various discrepancies found in studies (Bakr, 2011; Bebetsos et al., 2009; Chang et al., 2012; Khatoon & Mahmood, 2011; Palaigeorgiou et al., 2005; Yldrm & Kaban, 2010) are likely to be caused by the use of different samples and instruments.

The results of the ANOVA test show that there is a significant difference between the three groups, which are high, medium and low in achievement, showing that there is a difference between each other, with the high group having the highest interest (M=4.12, S.D=0.76), followed by the medium group (M=3.87, S.D=0.89), while low group with mean (M=2.90, S.D=0.94). In a study, Amnouychokanant et al. (2021) stated that both high- and medium-performing students had more interest in programming than low-performing students and that learning programming will be difficult and tedious if they are not interested in the subject.

Rahmat, Shahrani, Latih, Yatim, Zainal, and Rahman (2012) in Amnouychokanant et al. (2021) explained that the teacher's method of managing the class also caused students to be disinterested in the subject of programming in addition to students who have different performances having different levels of interest and motivation. The instructors need to consider ways of teaching programming to attract students' attention, especially low-performing students who are likelier to lack interest in programming than other students (Amnouychokanant et al., 2021). Various studies (Jawad, 2019; Pradhan, 2017; Xu & Jin, 2021) have been conducted to identify the methods required to attract students to be interested in programming. Xu and Jin (2017) proposed that game development workshops delivered by peer mentors could increase student curiosity and interest in introductory programming course, Pradhan (2017) suggested that an open-source electronic platform based on easy-to-use hardware and software such as Arduino could increase performance and interest in programming for first-year engineering students. Jawad (2019) suggested that Android development could increase students' interest in programming.

Conclusion

In conclusion, the interest of male and female students in learning programming during the Decision Mathematics course is the same. Independent sample t-test results support this statement. However, there are differences between students with different achievements regarding interest in programming. The results of ANOVA show a significant difference between the three groups, which are high, medium and low. Students with high achievements in the decision mathematics course are more likely to be interested in programming than those with low achievements.

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Mastering Division with MD'Teknik: Fueling Year Three Students' Math Enthusiasm and Academic Triumph

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Abstract

Division considered the most difficult basic operation for primary school students, has contributed to placing Malaysia in the lower quartile in international mathematics assessments in terms of achievement, as proven after reviewing past studies. *Lembaga Peperiksaan* has suggested that students should learn various techniques for solving mathematical problems. Therefore, this paper aims to present a newly developed technique in mathematic problem-solving, namely MD'Teknik, and its impact on year three students in mathematics problem-solving. This study uses a quasi-experimental design with a quantitative approach involving 60 students in a primary school in Seremban district, Negeri Sembilan. They were divided into two groups: 30 students in the control group and 30 in the treatment group. Analysis of Pre-Post Test scores was conducted through independent t-tests and paired sample t-tests by using the Statistical Package for Social Science (SPSS) to answer research questions and hypotheses. The independent t-test shows the results of [$t58$ = -2.323, p= .024], while the results of the paired sample t-test show that [t29=3.353, p=.002]. These results indicated that MD'Teknik significantly improved the year three students' achievement in mathematic problem-solving compared to the conventional method. Besides, results also showed that MD'Teknik significantly improved students' level of interest in mathematics by 0.46 (Pre m=2.36, sd=0.58, Post m=2.82, sd=0.53). This study proved that MD'Teknik is beneficial to education stakeholders and should serve as an alternative in mathematic problem-solving. In further studies, we hope that this technique may be effective with other types of respondents, especially inclusive or indigenous students.

Keywords: *Division, MD'Teknik, Achievement, Interest, Education Stakeholders*

Introduction

In Malaysia, the mathematics Standard-Based Curriculum for Primary School (KSSR) is a core subject that must be undergone by all students who follow the National Education System (Ministry of Education Malaysia (MOE), 2017). The aim of the Primary School Standard Curriculum for Mathematics is to develop students' understanding of the concept of numbers, basic calculation skills, simple mathematical ideas and competency in applying mathematical knowledge and skills effectively in solving problems and making decisions in daily life. In 2013, Malaysia Education Blueprint 2013-2025, an emphasis on improving the quality of teaching in Science, Technology, Engineering, and Mathematics (STEM) education to ensure that students are equipped with the skills needed to face the challenges of a changing world (MOE, 2013). Thus, it can be seen that mathematics subjects play an important role in the current Malaysian education system.

Malaysia has participated in two major assessments, the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). The latest result of PISA 2018 shows that Malaysian students still need to be on par with their peers in the region and the rest of the world. Despite a slight improvement in PISA 2018 compared to PISA 2015, Malaysia still ranks in the lower part of the chart (Kok, 2020). This statement is in line with the report by Avvisati et al. (2019), which mentioned that Malaysian students scored lower than the average score in reading, mathematics and science in PISA 2018. Apart from that, in TIMSS 2019, Mullis et al. (2020) in their report have mentioned that the results of Malaysian students are also slightly decreasing compared to the results in the previous assessment and are still at a lower point compared to other countries.

By referring to the results in both PISA and TIMSS assessments, Malaysia's education outcomes need to catch up with those of countries like Singapore, Chinese Taipei, Korea, Japan, and Hong Kong. Alarmingly, the gap in Malaysian student outcomes is also widening (James et al., 2022). In 2020, the 2019 Primary School Assessment Report (PPSR) found that 16.87% of primary students have only scored grade E in the mathematics assessment in Ujian Pencapaian Sekolah Rendah (UPSR) 2019. This grade indicates that these students have yet to reach the minimum level in mathematics, and their mastery of basic mathematical knowledge and skills is at a low level (MOE, 2020). To achieve a position in the top third in the TIMSS and PISA, MOE has set a target to achieve at least a score of 600 in the Pencapaian Pentaksiran Kompetensi dan Literasi Sekolah Rendah (PKLSR). However, in the annual report 2021 of Malaysia Education Blueprint 2013-2025, the author pointed out that the score obtained by mathematics in the PKLSR is still not on target even though there was a significant improvement compared to the result in 2020 (Unit Pelaksanaan dan Prestasi Pendidikan, 2022).

This phenomenon is believed to be affected by one of the learning areas in mathematics, which is numbers and whole numbers, as it is the first learning area that students will learn since they start to learn mathematics. This statement is further supported by a journal that was published in the Cypriot Journal of Educational Science (Maamin et al., 2021), where they concluded that prior mathematical knowledge would affect their achievement in mathematics. Basic operations are the main focus in the learning area of numbers and whole numbers. There are four types of basic operations: addition, subtraction, multiplication, and division. In further studies, these calculation processes will be linked to all other mathematics topics such as fractions, decimals, percentages, money, time, measurement and so on (Manikabasagan, 2020). Among the basic operations, which are addition, subtraction, multiplication, and division, most students consider division to be a complex operation (Safiati et al., 2021).

According to Incikabi et al. (2020), students often had difficulties in solving division problems. Therefore, it is important to ensure that students can solve the basic operations, especially for the operation of division, because if students fail to acquire the basic skills of operation, they will face problems in learning further mathematics topics.

Problem Statement

According to Ng (2020), students seem to have much trouble with the mathematical operations of addition, subtraction, multiplication and division. Among these operations, the division operation can be considered the most difficult for primary school students (Ahida Suci et al., 2018). The findings of Madihah and Zulmaryan (2019) indicate that students had problems dividing whole numbers and were unable to operate division correctly. Researchers have found that students cannot correctly divide the number using a standard algorithm for division, namely long division, because they were confused about why the division procedure is performed from left to right, which is different from the other operations (addition, subtraction, and multiplication) that are all performed from right to left (Goh, 2019 & Li & Schoenfeld, 2019). Meanwhile, Mukunthan (2021) found that most of the errors students made in the operation of division occurred during the calculations using long division. This situation will have a significant impact on the students because if students cannot acquire the basic skills of operation, then they will face problems in learning further mathematics topics (Manikabasagan, 2020).

Regarding the students' problem in learning basic operations, especially division operations, teachers play an important role in helping students acquire this basic skill in mathematics by providing adequate training (Ng, 2020). Therefore, teachers have to change their teaching methodologies when teaching mathematics to help students acquire the basics of divisions (Alshatri et al., 2019; Mukunthan, 2021). According to Ahida Suci et al. (2018), teaching methodologies need to be sorted and developed according to the 18 purposes and characteristics. In this case, the teaching methodologies should focus on the student's problem in mathematics problem-solving so that they can learn effectively and efficiently. Consequently, teachers need to look for a teaching methodology that can have a positive impact towards students' learning of division operations (Ng, 2020). Safiati et al. (2021) stated that a good technique can make it easier for students to solve division problems quickly and accurately.

Besides, the report of TIMSS 2019 has revealed that 20% of Malaysian students like to learn mathematics very much, 57% of students like to learn mathematics, and 23% of students do not like to learn mathematics (MOE, 2020; Mullis et al., 2020). Hendriana et al. (2019) stated that students show their interest in learning mathematics after they can solve the mathematical problem using appropriate methodologies. Meanwhile, Jogi et al. (2015) also found that higher mathematical skills lead to a higher interest in learning mathematics. The appropriate learning methodologies in mathematics can improve their mathematical skills and then improve the students' spirit and interest in learning mathematics (Ahida Suci et al., 2018). Therefore, MD’Teknik is innovative in tackling the problems related to division in the hope of solving the struggles faced by the students in solving division problems through an alternative method, hence raising their interest in mathematics.

Research Objective and Research Question

Research Objective

Specifically, the objectives of this study are:

1. To determine the impact of MD’Teknik towards Year Three students’ achievement in mathematic problem-solving.
2. To determine the impact of MD’Teknik on Year Three students’ level of interest in mathematics.

Research Question

Based on the objectives of the study above, several questions have been raised, which are:

1. Is there any significant difference between the overall mean score of students’ achievement in mathematic problem-solving in the Post-test for the control group and treatment group?
2. Is there any significant difference between students’ level of interest in mathematics in the pre-test and post-test for the treatment group?

Research Hypothesis

The null hypothesises have been constructed to achieve objectives one and two. The null hypothesises that has been constructed is as follows:

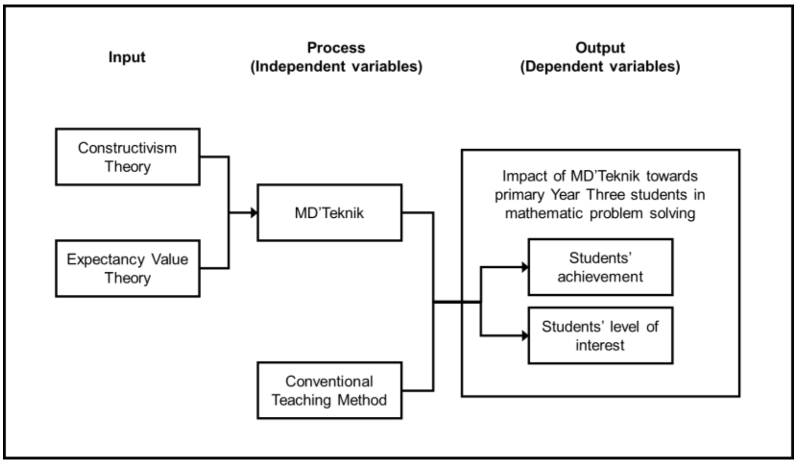
Ho1: There is no significant difference between the overall mean score of students’ achievement in mathematic problem-solving in the Post-test for the control group and treatment group.

Ho2: There is no significant difference between students’ level of interest towards mathematics in the Pre-test and Post-test for the treatment group.

Conceptual Framework

Figure 1

Conceptual framework



The conceptual framework used in this study consists of two theories: constructivism theory and expectancy-value theory (EVT). According to Suparlan (2019), constructivism is the process of using existing frameworks of thinking to complete new concepts and ideas. Putri et al. (2021) also stated that the concept of learning, according to constructivism, is generating knowledge from experience or information obtained before. Rayner and Tan (2020) believe that constructivism theory is a learning theory that emphasises that knowledge is only acquired during the learning process based on the student experience. Students will use their existing knowledge and experience to build new knowledge, where they use the mathematical skills they have learned to solve new problems (Wong & Kamisah, 2018). In this research context, the development of the MD'Teknik was based on the constructivist theory, which aimed to help students solve division operations easily by connecting them with other basic operations, such as addition, subtraction, and multiplication. This is because students struggled more in the division operation than in other operations. Connecting the operation of division with the student's previous knowledge and experience, which is the operation of addition, subtraction and multiplication, may help students solve division problems more easily and effectively.

Next, the Expectancy value theory (EVT) has been widely used to predict and explain students' task choices, learning persistence, and academic achievement towards their interest in learning (Loh, 2019). By targeting students' expectancies, EVT was able to increase their interest in learning and academic achievement (Rosenzweig et al., 2019). Galla et al. (2018) note that students are more likely to participate in learning activities and persist when they perceive a high chance of success and find the task interesting and useful. Students' expectancies and values are also predictive of their school achievement and activity choices, with positive expectancies and values helping them better cope with change and uncertainty, such as the increasing difficulty of school subjects (Wigfield & Gladstone, 2019). The implementation of MD'Teknik in this study aims to enhance students' ability to solve division problems. According to EVT, when students can solve the division problems that plagued them easily and efficiently, their expectation for their ability to solve mathematical problems can be fulfilled. Hence, their level of interest in learning mathematics will also increase. As a result, when students are more interested in learning mathematics, this will also have a positive impact towards their overall achievement in mathematics.

Both theories were applied in the development of the MD'Teknik. After that, the impact of MD'Teknik towards primary Year Three students in mathematic problem solving was identified by comparing the students' achievement in mathematic problem solving and also their level of interest towards mathematics after using MD'Teknik and conventional method. Figure 1 shows the conceptual framework and overall input, process and output of this study.

Methodology

This study used a quasi-experimental design with a quantitative approach involving 60 students. The convenience sampling method was used in this study, and the researcher chose a suitable sample from the population that may fit into the study. In the context of this study, the researcher chose two classes, 60 students from a primary school in the Seremban district, Negeri Sembilan, as the sample. They were divided into two groups: 30 students in the control group and 30 students in the treatment group. The control group went through the teaching and learning (TnL) session using the conventional method, while the treatment group received the TnL session using MD'Teknik in mathematic problem-solving.

Before the intervention session started, respondents were first exposed to the pre-test. After conducting the Pre-test, the researcher calculated the effect size for the difference between the achievements in the Pre-test for both groups. Cohen's d value (*d* = .040) showed that there was a small or smaller than normal effect size by referring to the interpretation of Cohen (1988), as shown in Table 1 below. Therefore, it was proved that the achievements in the pre-test for both groups were the same and that they would not affect the research result. This is important because it helps us ensure that the observed differences in the Post-test are more likely to be attributed to the intervention rather than pre-existing group disparities.

Table 1

Mean Differences for Effect Size

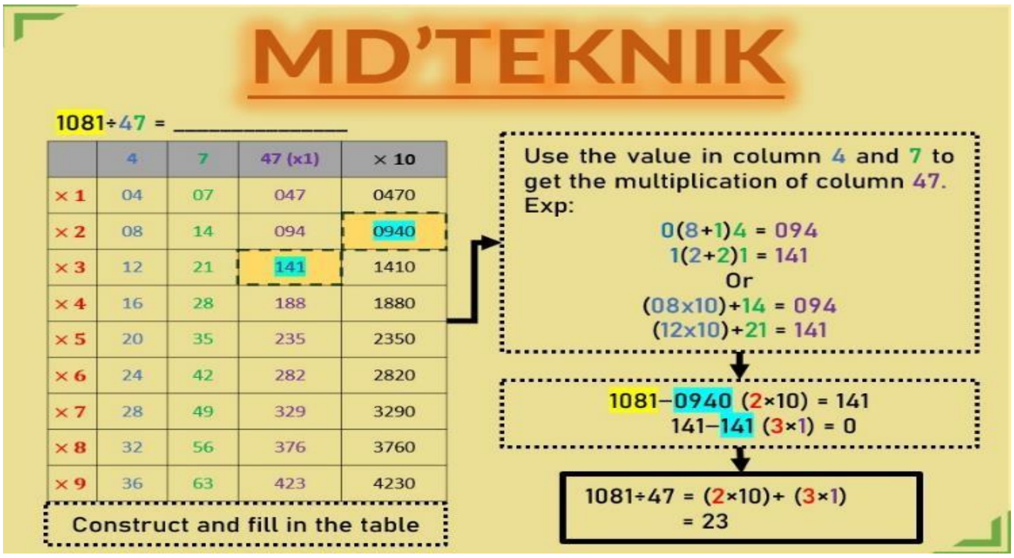
Value	Significant
$0 < d < 0.2$	Small or smaller than normal
$0.2 \le d < 0.5$	Medium or Normal
$0.5 \le d < 0.8$	Big or bigger than normal
$d \ge 0.8$	Large or Larger than big

Source: Cohen (1988)

After that, the TnL process was conducted and lasted for two sessions for both groups, and the duration of each TnL session was one hour. After completing the intervention session, the respondents underwent a Post-test to determine if there was a significant difference between the overall mean scores for the Pre-test and Post-test in both groups. Two sections in the test involve the instrument for students' achievement and the instrument for students' level of interest in mathematics. The instrument of students' achievement consists of 10 problem-solving questions, while the instrument of students' level of interest consists of 10 questionnaire questions with the 4-point Likert Scale. After the data was collected, the analysis of Pre-Post Test scores was conducted through independent t-tests and paired sample t-tests by using the Statistical Package for Social Science (SPSS) to answer research questions and hypotheses.

Product Description

Figure 2:
MD'Teknik



The MD'Teknik is a combination of the term's multiplication, division and technique. It is an alternative technique for solving multiplication and division problems using "Easy Column". Figure 2 shows an overview of how to use the "Easy Column" to solve division problems. Detailed steps are shown below using an example of 1081 divided by 47:

1. A table of the divisor, which is 47 in this example, is constructed as shown on the left side of Figure 2. Columns 4 and 7 are written out first.
2. The column 47 could be calculated by combining the column 4 and 7. There are two methods for combining them. The first one is adding the ones for column '4' and the tenth for column '7'. After adding both numbers, we will first write the tenths from the '4' column; if the answer exceeds ten after adding, we will add it to this number as well. Then, we write the answer, and lastly, we write the ones from the column '7'. For example, in the 'x2' row, we add the ones from column '4' and the tenths from column '7', which is (8+1). Then we remain the ones from column '7', which is four and tenths from column '4', which is 0. Thus, the result is 0 (8+1) 4 = 094. The second method is by adding numbers where the '4' column starts from the tenth while the '7' column starts from the ones. For example, in the 'x9' row, column '4' is placed as tenth by multiplying ten and adding it with column '7'. Thus, (36x10) + 63 = 423.
3. Next, we will add more columns to the right, multiplying it by ten each time we add a new column (x10, x100, and x1000). We stop adding more columns where the last result has exceeded the question.
4. Then, we check the closest number to our remaining numbers by referring to the table we

built. After we determine the number, we subtract the remaining number from the number that we found. The steps are repeated until no more steps can be made again. In this example, 1081 – 0940 = 141. Then we repeat it, 141 – 141 = 0.

5. We then highlight the numbers that were used, which in this case were 0940 and 141.
6. Lastly, we add the highlighted numbers in corresponding to their placement in the table. For example, the number 0940 will represent (2x10) while the number 141 will represent (3x1).
7. The answer to the question will be calculated by adding both the numbers we got from referring to the table. In this example, it will be 20 + 3 = 23. Therefore, 1081 divided by 47 would be 23.

Results and Findings Analysis for Achievement in Mathematics Problem Solving

Researchers conducted a pre-test before the intervention session and a post-test after the intervention session using MD'Teknik on the respondents for both the control group and treatment group to compare their achievement in mathematic problem-solving. Figures 3 and 4 below illustrate the comparison graph of achievement in the Pre-Post test for every respondent in the control and treatment group.

Figure 3:

Comparison graph of achievement in the Pre-Post test for respondents in the control group

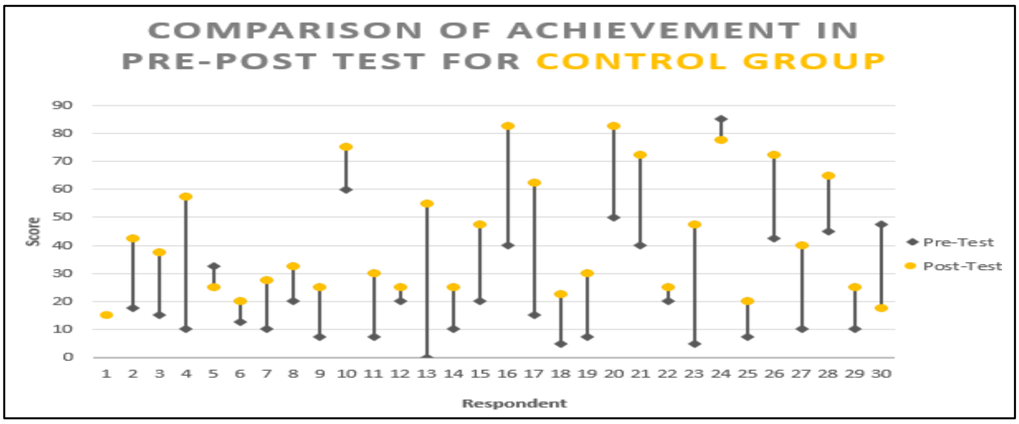
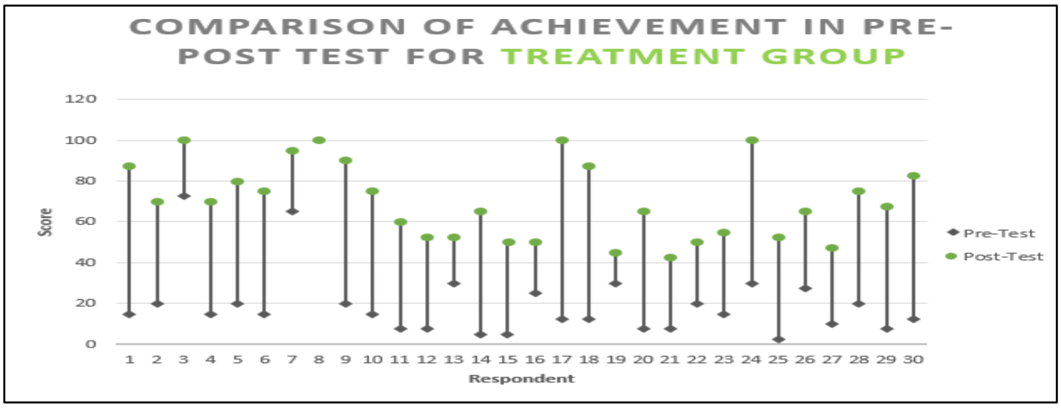


Figure 4:

Comparison graph of achievement in Pre-Post test for respondents in treatment group



If we were to compare Figure 3 and Figure 4, we can see that the increment of score is higher in Figure 4, which is the treatment group. In other words, the treatment group showed greater improvement than the control group. Table 2 below shows the descriptive statistics for achievement in mathematic problem solving between Pre-test and Post-test.

Table 2

Descriptive statistics for achievement in mathematic problem solving between Pre-test and Post-test

Group	Test	Mean score (%)	N	Std. Deviation	Std. Error Mean
Control	Pre	22.92	30	19.85	3.624
	Post	42.75	30	21.91	4.000
Treatment	Pre	21.75	30	21.50	3.925
	Post	70.25	30	18.55	3.387

Based on Table 2 above, the mean score of the Pre-test (*m*=22.92%, *sd*=19.85) and Post-test (*m*=42.75%, *sd*=21.91) for the control group showed an increase of 19.83%. Although the control group did not undergo the intervention, they still showed improvement through conventional methods. However, the mean score for the treatment group before (*m*=21.75%, *sd*=21.50) and after (*m*=70.25%, *sd*=18.55) the intervention shows an increase of 48.50%, which can be said to be more outstanding if compared to the control group.

To answer the first research question, an independent sample t-test was conducted to compare the overall mean scores in the Post-test between the control group and the treatment group. The comparison of overall mean scores in the post-test between these groups was used to determine the impact of MD'Teknik on the achievement of solving mathematical problems. Table 3 shows the independent t-test for achievement in mathematic problem solving between the control and treatment groups in the Post-test.

Table 3

Independent t-test for achievement in mathematic problem solving in Post-test

	Levene' Test		t-test for equality of means		
Group	Sig.	t.	df	Sig. (2-tailed)	Mean score Difference
Control Treatment	.063	-2.323	58	.024	-15.900

Based on Table 3, the significant value of Levene's test was greater than .05 (*p* = .063 > .05), indicating that the variances for the control group and treatment group were not significantly different to each other. Therefore, it has met the prerequisites for using the independent sample t-test. The result of this test shows that [*t58* = -2.323, *p* = .024]. Since the significant value (2-tailed) was lower than .05 (*p* = .023 < .05), then the null hypothesis Ho1, that is, there is no significant difference between the overall mean score of students' performance in solving division problems in the Post-test for the control group and treatment group is rejected.

Table 4

Independent Samples Effect Sizes for Achievement in Post-Test

		Standardiser	Point Estimate	95% Confidence Interval	
				Lower	Upper
Control Treatment	Cohen's d	20.298	1.355	.787	1.913

Cohen's d value (*d* = 1.355) shown in Table 4 above has indicated that there was a large or larger-than-big effect size. This showed that MD'Teknik is significantly different from the conventional method, which is a standard algorithm that measures the overall mean score of students' achievement with a large or larger-than-big effect size.

Analysis of Level of Interest

Researchers have also conducted a pre-test and post-test on the respondents in the treatment group to compare their level of interest in mathematics. The level of interest in mathematics was determined through a questionnaire that consisted of 10 items and was based on a four-point Likert scale. The mean score achieved by the respondents in answering the questionnaire was interpreted according to Table 5 below.

Table 5

Interpretation of mean score for level of interest

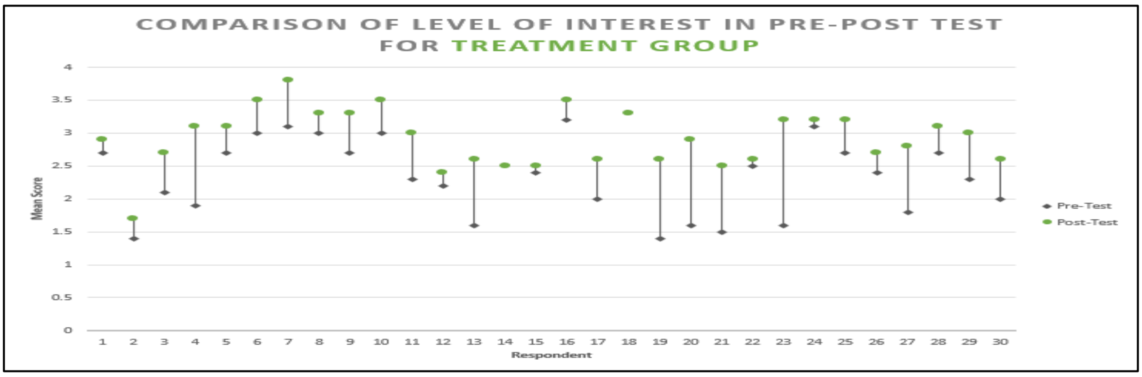
Mean Score	Interpretation
1.00 – 1.99	Low
2.00 – 2.99	Moderate
3.00 – 4.00	High

Source: Schober & Schwarte (2018)

To see the positive effect of MD'Teknik on all respondents involved, the analysis continues with the illustrations of the comparison graph of the level of interest in the Pre-Post test for respondents in the treatment group, as shown in Figure 5 below.

Figure 5:

Comparison graph of the level of interest in the Pre-Post test for respondents in the treatment group



Through Figure 5, we can see the increment of students' mean scores in the Pre-Post test. This shows that the student's level of interest in mathematics experienced an elevation after the intervention with MD'Teknik. Table 6 below shows the descriptive statistics for the level of interest in mathematic problem solving between the Pre-test and Post-test.

Table 6

Descriptive statistics for level of interest in mathematic problem solving between Pre-test and Post-test

Group	Test	Mean score (%)	N	Std. Deviation	Std. Error Mean
Treatment	Pre	2.36	30	.58	.106
	Post	2.82	30	.53	.097

Based on Table 6 above, the mean score for Post-Test (*m*=2.82, *sd*=.53) was higher compared to the mean score of the Pre-Test (*m*=2.36, *sd*=.58).

In order to answer the second research hypothesis, a paired sample t-test was used to measure the overall mean score difference of level of interest in the Pre-Test and Post-Test for the treatment group. The increase in mean score obtained can evaluate the extent to which the MD'Teknik can influence the sample of the treatment group in improving the level of interest towards mathematics. The table below shows the paired sample t-test for the level of interest for the treatment group.

Table 7

Paired Sample T-test for Level of Interest for Treatment Group

Test	Paired Differences			t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean			
Post Pre	.463	.757	.138	3.353	29	.002

Based on Table 7, the mean score difference between the two tests was .463. The result of this test showed that [*t*29 = 3.353, *p* = .002]. Since the significant value (2-tailed) was lower than .05 ($p = .002 < .05$), then the null hypothesis Ho2, that is, there is no significant difference between students' level of interest towards mathematics in Pre-test and Post-test for the treatment group was rejected.

Table 8

Paired Samples Effect Sizes for Level of Interest for Treatment Group

		Standariser	Point Estimate	95% Confidence Interval	
				Lower	Upper
Post Pre	Cohen's d	.757	.612	.217	.999

Cohen's d value (*d* =.612), shown in Table 8 above, indicates that there was a bigger or bigger than normal effect size. This showed that the use of MD'Teknik in teaching the operation of the division had a big or bigger than normal effect size towards the level of interest in mathematics.

Discussion, Recommendation and Implication

Discussion

Overall, this study has successfully answered all the research questions presented, and the MD'Teknik has indeed had a positive effect in improving the students' achievement in solving mathematical problems and interest level towards mathematics. This can be proven through the analysis of the pre-test and post-test data for the control group and the treatment group.

For the first research question, the independent sample t-test was carried out, and the results showed that the first null hypothesis was rejected. Based on the analysis, there was very strong evidence showing that the overall mean score of students' achievement in solving division problems in the Post-test for the control group and treatment group was different. Cohen's d value (*d* = 1.355) has indicated that there was a large or larger-than-big effect size between these two groups. In relation to this, Cohen's d value for TnL with MD'Teknik (*d* = 1.914) was much higher compared with Cohen's d value for the TnL with the conventional method (*d* = .888).

Based on the results of the analysis, it can be concluded that the MD'Teknik has significantly improved the Year Three students' achievement in solving division problems by comparing to the conventional method with a large or larger-than-big effect size. This result was in contrast with the findings of Cordero & Gil (2018), who said that conventional teaching methods have a positive influence on students' achievement in mathematics, while the implementation of more innovative teaching methodologies seems to have a negative impact on students' achievement. In this study, it was proven that the MD'Teknik has largely contributed to the improvement in students' achievement with a large or larger-than-big effect size compared to the conventional method. The contrasting result might be caused by the main idea of MD'Teknik, which focuses on addressing students' weaknesses when dealing with a large divisor. Students often encounter difficulties when multiplying large numbers as a precursor to performing division. Additionally, some students need clarification on the standard division algorithm, which involves operating left to right. Therefore, MD'Teknik has effectively solved these problems by providing a simpler method for calculating the multiplication of a large divisor and making the division process easier to understand.

Moreover, the result of this study also aligns with the previous findings which have proven that the implementation of appropriate methodologies can effectively improve students' achievement in solving basic operations problems (Ahida Suci et al., 2018; Alshatri et al., 2019; Anis et al., 2019; Ardana et al., 2017; Huang et al., 2019; Joutsenlahti & Kulju, 2017; Kullberg et al., 2017; Laila et al., 2019; Moser Opitz et al., 2017; Mukunthan, 2021; Musiran, 2020; Mustafa, 2021; Safiati et al., 2021; Santri et al., 2019; Schifter & Russell, 2022; Shin et al., 2017). Students have a significant improvement in their mathematics achievement after they have mastered and are able to apply these methodologies in solving basic operations problems (Goh, 2019; Jagadesan, 2013; Manikabasagan, 2020; Ng, 2020; Owi & Ang, 2015). MD'Teknik has proven to be a highly effective methodology in enhancing students' proficiency in solving mathematical problems. This effectiveness was attributed to the characteristics of MD'Teknik that simplify complex mathematical processes, making them more accessible to students by breaking them down into manageable steps. Besides, this technique also fosters a clearer understanding of fundamental concepts, enabling students to apply their knowledge with confidence.

Besides, the paired sample t-test was used to answer the second research question, and the second null hypothesis was rejected. This result showed that there was a significant difference between students' level of interest in mathematics in the pre-test and post-test for the treatment group, as shown in Figure 5. By referring to the overall mean score in the Pre-Test (*m*=2.36) and Post-Test (*m*=2.82), the overall mean score for the level of interest increases to 0.46. Even though the students' level of interest was still at a moderate level, Cohen's d value (d =.612) showed that the use of MD'Teknik had a bigger or bigger than normal effect size towards the level of interest after the intervention. Therefore, it showed that the MD'Teknik has significantly improved the student's level of interest towards mathematics.

This finding was supported by several studies which found that students will become more interested in learning mathematics after they can solve mathematics problems (Hendriana et al., 2019; Jogi et al., 2015; Milton et al., 2019; Schukajlow & Rakoczy, 2016; Widyastuti et al., 2019). When students are able to solve mathematical problems easily and effectively by using MD'Teknik, they will be satisfied with their effort, hence generating motivation and interest in mathematics. This can be further proved by the elevation of the level of interest that corresponds to the improvement in the achievement of respondents in the treatment group. Therefore, it is evident that the MD'Teknik method has had a significant and positive impact on Year Three students' achievement in solving mathematical problems and their level of interest in mathematics.

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Recommendation

Based on the results from this study, researchers encourage teachers and educators to include MD'Teknik as an alternative when solving mathematical problems as it could increase their achievement level and interest level towards mathematics.

This study may be revised or replicated with other types of respondents, such as a bigger sample size, different levels of students, and inclusive or indigenous students. Other topics involving division could also be included in future studies to analyse the impact of MD'Teknik towards students accurately.

Implication

The application of MD'Teknik has significant implications for various stakeholders, such as students, teachers, the Malaysian Institute of Teachers Education (IPGM), and the Ministry of Education (MOE). The significant increase in students' mean scores between the Pre-test and Post-test for the treatment group shows that the intervention of MD'Teknik can assist students in solving mathematical problems more efficiently. In addition, it has been demonstrated that the use of MD'Teknik is effective in increasing students' level of interest towards mathematics, keeping them motivated to learn mathematics. Through the adoption of appropriate methodologies, such as MD'Teknik, students are expected to engage and be more interested in learning mathematics. For teachers, the results indicated that the MD'Teknik demonstrated a significant and positive impact on students in solving mathematical problems, and it can be implemented in the classroom to help students solve them. This study also serves as an important reminder to the IPGM regarding their role in cultivating proactive future teachers. It highlights the significance of equipping aspiring teachers with innovative methodologies, such as MD'Teknik, to enhance their teaching effectiveness and address students' learning needs. The MOE could prioritise the development and implementation of suitable methodologies in mathematics education. By emphasising the use of appropriate methodologies, students' problem-solving abilities in mathematics can be improved. This is significant in elevating Malaysian students' mathematics achievement and enhancing their competitiveness on the global stage.

Conclusion

The findings showed that MD'Teknik has had a significant and positive impact on Year Three students in solving mathematical problems. In connection with that, the implementation of MD'Teknik has significantly improved the Year Three students' achievement in solving mathematical problems compared to the conventional method. With the improvement in the achievement level in mathematic problem solving, they will perform better in mathematics. It has also significantly improved the Year Three students' level of interest towards mathematics. Thus, it is recommended that MD'Teknik be practised as an alternative technique in solving mathematical problems. The observed positive impact of using MD'Teknik can serve as a point of reference, encouragement, and motivation for stakeholders to consider the implications and recommendations that are recommended to enhance the implementation of this study.

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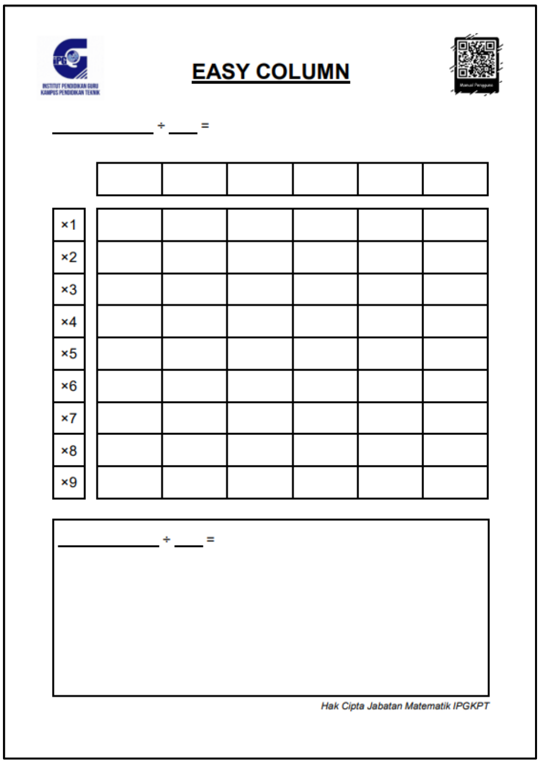
APPENDIX A

Easy Column Tool

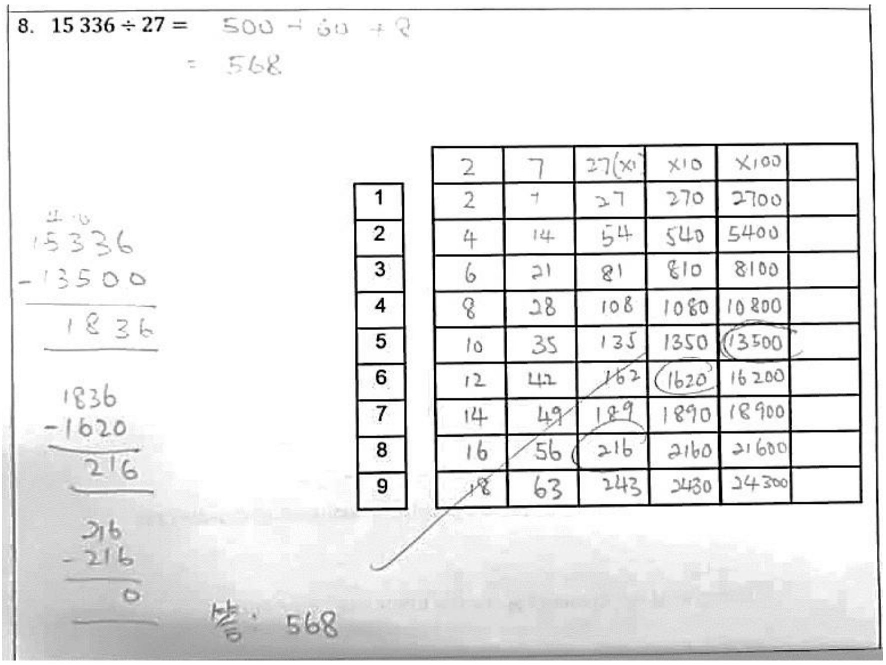


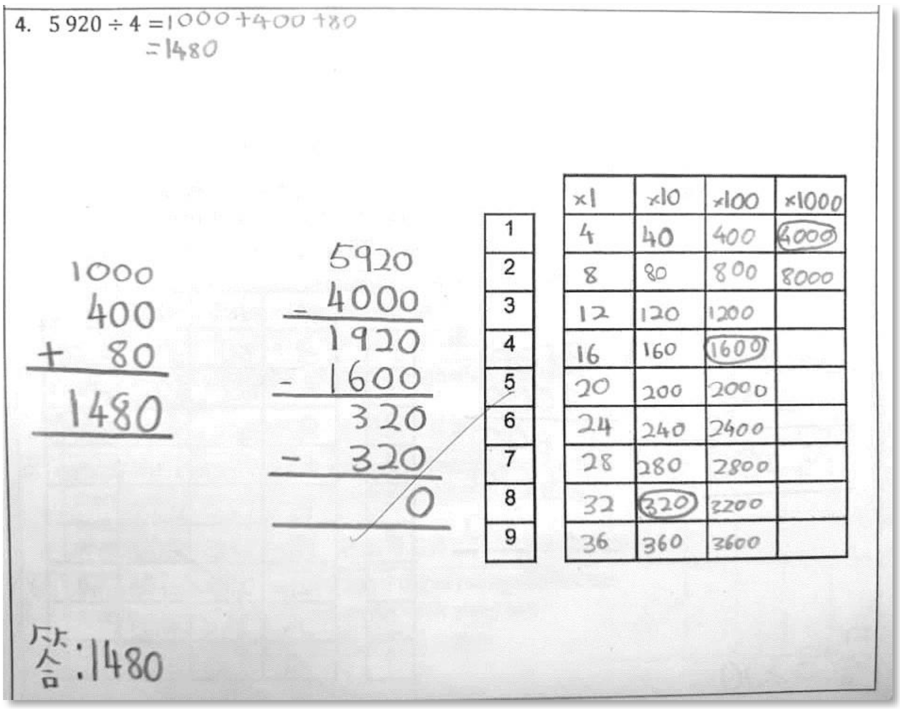
APPENDIX B

Intervention by using MD'Teknik

APPENDIX C

Students answer by using MD'Teknik





Exploring Project CREATE Mathematics and Peer-Assessed Gallery Walk in Teaching Functions

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Abstract

The study aimed to evaluate the effectiveness of Project CREATE Mathematics combined with Peer-Assessed Gallery Walk in teaching functions. The research followed a pretest-posttest control group experimental design. Two groups of thirty-three (33) and thirty-five (35) grade 11 students were purposively selected, considering that sectioning in grade 11 is grouped heterogeneously. Before the lesson, both the control and experimental groups were given a pretest. The experimental group was taught using the Project CREATE Mathematics and Peer-Assessed Gallery Walk, while the control group received instruction through the traditional chalkboard discussion method. After eight weeks of exposure to the respective teaching methods, both groups were assessed with a post-test. The post-test results were compared to their pretests, and conclusions were drawn from the findings. After one week interval, the delayed post-test was administered. The study showed that students' performance in both the control and experimental groups had improved, indicating the effectiveness of both teaching methods. Both groups demonstrated higher mean scores in the post-test compared to the pretest, and their gain scores increased. However, the experimental group exhibited greater gains compared to the control group. As a result, it can be concluded that the Project CREATE Mathematics and Peer-Assessed Gallery Walk as a teaching strategy was more effective than the Traditional Method. Also, their delayed post-test scores, given after a week, increased. Both the control and experimental groups obtained higher mean scores. Consistently, the experimental group performed better compared to the control group. The study's findings indicated that both the control and experimental groups demonstrated improved student performance, suggesting the effectiveness of both teaching methods. Moreover, the use of Project CREATE Mathematics and Peer-Assessed Gallery Walk as a teaching strategy for mathematics indicates its potential to enhance student performance. These findings can be valuable for educators, curriculum developers, and policymakers seeking evidence-based approaches to improve mathematics education.

Keywords: *Project CREATE, Peer-Assessed Gallery Walk, Mathematics teaching, Students' performance, Teaching Strategy*

Introduction

One of the most formidable challenges facing educators is the task of inspiring students to engage with the subject of mathematics. It is a pervasive issue in nearly all classrooms that many students struggle with mathematics, often perceiving it as a daunting and even traumatic experience. For various reasons, mathematics has become closely tied to notions of intelligence in students' minds. There is a prevailing belief that only those with innate intelligence can excel in mathematics, while others feel incapable (Ozarka, 2018).

This challenge demands the constant attention and concern of every teacher. Their ability to transform their classroom into an inviting environment for learning mathematics is paramount. Recognising that every student's pace of learning varies, a teacher's competence and effectiveness in nurturing students' creativity in mathematics is crucial. However, it is a collaborative effort; teachers and students must work harmoniously to achieve their learning objectives (Le et al., 2017). The successful attainment of these objectives should be evident through improved learning outcomes driven by students' enthusiasm, interest in learning, and ability to apply mathematics in their daily lives.

Moreover, teaching and learning mathematics engagingly is a continual responsibility for every educator. The selection of materials and pedagogical approaches plays a pivotal role in assessing whether students have mastered the skills they are taught, particularly those essential for life, such as critical thinking and problem-solving (Banabatac, 2017). The teacher's role is to maximize students' learning potential by carefully choosing instructional materials and strategies that align with their learning objectives.

The swift advancement of global science and technology demands reevaluating the curriculum in the Philippines, leading to a new and improved primary education curriculum. This initiative, driven by the Department of Education (DepEd), aims to equip citizens with the skills required for global competitiveness. A prominent aspect of this curriculum is strengthening the Science, Mathematics, Engineering, and Technology (STEM) culture, aiming to nurture learners who can absorb information, solve complex problems creatively, and think critically and analytically – essential qualities for national progress. However, the Philippines has consistently ranked low in international assessments, including the Trends in International Mathematics and Science Study (TIMSS), highlighting the need for improvement (IEA, 2004). Even in TIMSS-Advanced, intended for schools with specialized science curricula, the Philippines lagged behind other participating countries (Ogena et al., 2010).

In response, the responsibility now rests primarily on teachers to deliver exceptional mathematics instruction. Teachers must possess the necessary skills and competence to enhance mathematical proficiency and foster a positive attitude toward learning mathematics among their students. Continuous reflection on teaching practices is vital to ensure the mathematics classroom aligns with the ever-evolving and dynamic world students will encounter (Educational Origami, 2010). Moreover, the mathematics classroom should become an engaging learning environment rooted in 21st-century pedagogical approaches, encompassing the development of technological, information, and media literacy, critical and creative thinking, project-based learning, problem-solving, and 21st-century assessments with prompt, relevant feedback and reflection (Kim et al., 2019).

As noted by Noraini Idris (2005), mathematics can facilitate the development of logical, analytical, systematic, and critical thinking skills and problem-solving abilities. These thinking skills and innovation are globally recognized as crucial elements (Juan et al., 2017). Mathematics education aims to produce students who can effectively, creatively, and innovatively apply mathematics in the real world. Given the abstract nature of mathematics, it should enable students to connect what they learn in the classroom to their real-life surroundings.

One of the crucial topics that students encounter in this phase is the concept of functions. However, many students grapple with comprehending and mastering functions. One of the primary struggles that students face is a need for conceptual understanding. Functions, at their core, involve an input-output relationship. However, the abstract nature of this relationship can be daunting. According to Vinner & Dreyfus (1989), students often need help distinguishing between functions and equations, and this confusion hampers their ability to work with functions effectively. Functions can be represented in various ways: algebraically, graphically, numerically, and verbally. While multiple representations of functions offer diverse perspectives, students may need help understanding and effectively utilizing these representations. Hitt (1998) found that students and teachers face difficulties articulating different representations of functions. Di Biase and Eisenberg (1995) highlight that the traditional teaching approach discourages using visual intuition in understanding functions, which may contribute to students' struggles. Another significant challenge is understanding the real-world applicability of functions. Breidenbach et al. (1992) suggested that when students cannot relate mathematical concepts to real-life situations, their motivation wanes, and comprehension suffers. Therefore, the inability to see the practical utility of functions often acts as a barrier to learning.

More specifically, high school students encounter challenges when learning about inverse, exponential, and logarithmic functions. Stevens and colleagues (2020) emphasize the tensions between students' understanding of inverse functions in the context of curricula. Weber (2002) finds that students need help to reason about the exponentiation process, limiting their knowledge of exponential and logarithmic functions. Okur (2013) identifies students' learning difficulties and misconceptions related to inverse functions, particularly in demonstrating surjection and understanding the meaning of inverse function expressions.

Traditional teaching methodologies sometimes fail to bridge these gaps in understanding. With the increasing importance of collaborative learning, the gallery walk teaching strategy, particularly when peer-assessed, has become a promising method to address these challenges. A gallery walk is an active learning strategy where students move around the classroom, stopping at various stations to interact with displays, answer questions, or discuss topics (Francek, 2006). In the context of teaching functions, these stations can have graphs, equations, or word problems related to different types of functions. Peer assessment in the gallery walk method incorporates collaborative learning, where students work together to understand and explore the topic. As Vygotsky's sociocultural theory suggests, social interaction is a crucial component of cognitive development (Vygotsky, 1978). When peers explain concepts to one another, they reinforce their understanding and articulate and address misconceptions that might not surface in a teacher-led discussion. During the gallery walk, students can deepen their conceptual understanding by discussing and questioning various aspects of functions. Peer discussions allow for multiple representations and perspectives on functions, which resonate differently with individual learners (National Council of Teachers of Mathematics, 2000). With its collaborative nature, the peer-assisted gallery walk method can help unearth and correct these misconceptions. When students explain concepts to peers, they might recognize and rectify their flawed understanding (King, 1997). Peer-assisted learning can boost students' confidence. Interacting and solving problems with peers can reduce intimidation, making the subject less daunting (Topping, 1996). The active nature of the gallery walk, combined with peer interactions, makes the learning experience more engaging. Active engagement is crucial for understanding abstract concepts like functions (Prince, 2004).

The Project CREATE Mathematics (PCM) initiative, developed by the researchers, is an innovative learning strategy. "CREATE" stands for "Creating Rich and Engaging Activities Through Effective Mathematics Learning." It is designed to nurture students' abilities to create activities, including equations, diagrams, graphs, illustrations, and word problems with solutions. These activities are carefully crafted to be rich, engaging, and applicable to the real world, especially in their local communities. A key feature is problem posing, which aims to help students utilize higher-order thinking skills (HOTS) and creativity in applying mathematical concepts. Students create problems using pictures, models, and illustrations (e.g., graphs and tables), and their solutions serve as the basis for peer assessment. Reflections are required after each activity.

On the other hand, Peer-Assessed Gallery Walk (PAGW) is a kinesthetic learning strategy that promotes active learning and discussion among learners. It encourages participation and higher-order thinking skills as students share their work, review for tests, introduce new concepts, and master and apply concepts. A crucial aspect of gallery walk is the differentiation of instruction, as it allows students to move around the room, engaging kinesthetic learners physically.

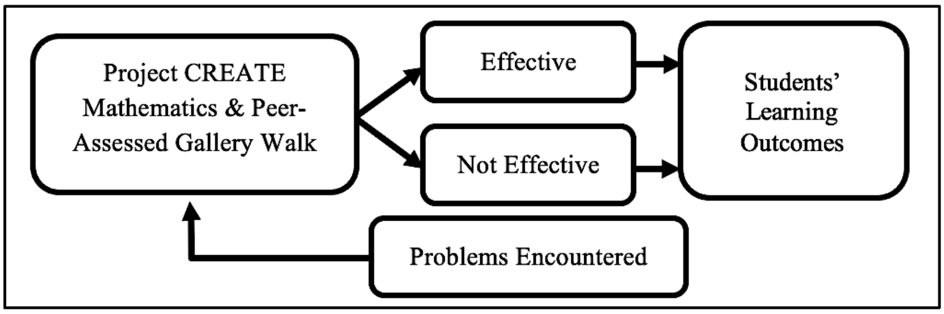
In this study, a gallery walk was conducted in groups. After each group creates their activities (e.g., equations, word problems), they post them on the classroom wall. Students then move around, solving each other's problems. Presentation and discussion of their solutions to the class follow. A rubric is provided to encourage critique and evaluation of the activities created by each group. This approach enhances engagement and fosters collaborative learning and critical thinking.

The main objectives of this study were to: 1) describe the initial knowledge in Mathematics of Grade 11 students before and after they were exposed to PCM and PAGW; 2) to what extent do students' mathematics achievements vary as affected by PCM and PAGW; 3) determine if PCM and PAGW promote retention of learning; 4) determine students perceptions on the effectiveness of PCM and PAGW; 5) identify problems encountered in the utilization of PCM and PAGW; 6) propose solutions to address the problems encountered using PCM and PAGW.

Conceptual Framework

In order to achieve the educational goals set by a teacher, he should remain receptive to various approaches that have the potential to enhance the learning experience for his students. Figure 1 illustrates the research framework, depicting the study's progression. The research aimed to assess the efficiency of utilizing Project CREATE Mathematics in conjunction with Peer-Assessed Gallery Walk as a teaching strategy for General Mathematics. This was accomplished by implementing a pretest-posttest-delayed post-test experimental design. Any noticeable difference between the two groups, favouring the experimental group, would signify the effectiveness of this approach.

Figure 2
Paradigm of the Study



Research Design

The quasi-experimental research design was used in this study to test the effectiveness of PCM and PAGW in teaching mathematics. The research design is:

R_1	O_1	X_1	O_2
R_2	O_3	X_2	O_4

Where:

R_1 = Control Group

R_2 = Experimental Group

O_1, O_3 = pretest of the student's achievement

O_2, O_4 = post-test of the student's achievement

X_1 = Traditional Method

X_2 = Project CREATE Mathematics and Peer-Assessed Gallery Walk

O_2, O_4 = post-test of the student's achievement

X_1 = Traditional Method

X_2 = Project CREATE Mathematics and Peer-Assessed Gallery Walk

Sampling Method

Before the study, the respondents were purposively selected, considering that sectioning in grade 11 is done heterogeneously. In addition, the two sections are the only classes handled by the researcher in the subject of general mathematics. Also, no significant difference between the entry behaviours of the two groups was observed.

Proposed Innovation/ Intervention/ Strategy

Anthony and Walshaw (2009) describe mathematics teachers as "effective" if they have a sound grasp of relevant content and can articulately teach it. Articulation comes in when teachers have the big ideas they need to teach the content with due consideration, strategies, materials, and even examples they will use. They engage students in making connections among mathematical representations to deepen their understanding of mathematics concepts and procedures as tools to allow students to become critical thinkers and problem solvers. Also, effective mathematics teachers can critically evaluate students' processes, solutions, and understanding and give necessary and helpful feedback to further illuminate their mathematical skills. Furthermore, teachers continuously guide students individually and collectively by providing the needed support and encouragement to engage them in productive struggle as they explore and understand mathematical ideas and relationships (NCTM, 2014).

One focus in teaching and learning mathematics in the 21st century is to deliver effective lessons that engage students actively in the classroom (Anthony & Walshaw, 2009). Moreover, introducing Project CREATE Mathematics and the Peer-Assessed Gallery Walk will significantly maximize the students' engagement and active participation in mathematics.

Project CREATE Mathematics (PCM) is an innovative instructional strategy developed by the researcher to develop students' ability to create rich and engaging mathematics activities. Rich is defined as various mathematical activities that the students can do. It could be in equations, models, graphs, tables, illustrations and word problems that depict the application of mathematical concepts learned. On the other hand, engaging would refer to the manageability to complete these activities by their classmates with considerations on applying higher-order thinking skills (HOTS) and critical thinking.

Peer-Assessed Gallery Walk (PAGW) in this study is a teaching strategy that engages students to actively complete a particular task, which is the product of Project CREATE Mathematics. Based on the finished lesson, they created the activities provided by Solution and had them for the gallery walk. Students were to move from one station to another, and after completing all the activities, a presentation followed. They worked in groups of five members. The teacher provided materials such as markers, large-format papers and others. A 7 – 10 minute interval was required for each station in the gallery walk.

Instruments

The instruments used in this study were the pretest and post-test, composed of 40 multiple-choice items. The test underwent reliability using Kuder-Richardson Formula 20 (KR20) to ensure that the instrument consistently measures its intended measure (Siegle, 2013). The difficulty and discrimination index of the test was likewise established. It was found that the test has a 0.73 difficulty index, 0.43 discrimination index, and a reliability coefficient of 0.82. The post-test was the same as the pretest. An 18-item Likert scale, which identified the level of students' perception of PCM and PWG as an effective strategy, was prepared. Questions are anchored on the revised Bloom’s Taxonomy of Anderson and Krathwohl (Wilson, 2016). Also, Cronbach’s alpha was used to determine the internal consistency of the 18–item18–item Likert scale on the student's perception of the effectiveness of the said innovative instructional strategy since the intervention had not been introduced to any group of students in the school before.

Data Collection Procedure

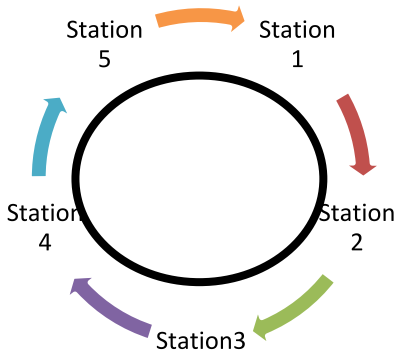
Before the beginning of the experiment, the two groups were given a pretest. The PCM and PAGW were used in the experimental group, while the other group was exposed to the traditional teaching method. They were taught the same lesson for five weeks. The topics covered were inverse function, exponential function and logarithmic function. After exposure to their respective strategies, the PCM and PAGW and the traditional teaching method, a post-test was given to both groups.

PCM features the ability of the students to create their own rich and engaging mathematical activities as a result of their effective learning in mathematics. After each lesson, PCM was carried out. Students worked on creating their mathematical activities in groups. Their outputs were checked by the teacher and then finalized. This included and was limited to making equations, illustrations/model graphs/tables, and word problems supported with solutions used in the gallery walk. The gallery walk was done in groups. Their outputs in PCM were in the gallery walk, which were executed in the procedures below:

1. Give students instructions on the tasks they need to accomplish as they move around. Then, provide them with the rubric for evaluating each group's output from PCM.
2. Begin the gallery walk—direct teams to different stations. A drawing lot was done to determine what station was the starting point of each group.

Figure 2

Gallery Walk Cycle



3. Rotate to New Station. After 7-10 minutes, the teacher says "rotate". The group rotates clockwise to the next station. At the new station, the group completes the activity posted by the other group and adds new comments and critiques to the group's activity. To involve all group members, switch recorders at each station.
4. The teacher monitors progress. As groups rotate, the teacher nurtures students' discussion and ensures the involvement of all group members. The teacher sees that groups are guided, especially those who still need help understanding how to conduct the gallery walk.
5. Return to starting point. Teams continue to review their answers and their comments using the rubric. This procedure continues until groups visit all the stations and return to the station where they started.
6. Report Out. The groups finalize, synthesize, and summarise what has been solved and gathered from each station. After finalizing it, a presentation follows. Groups note the solutions common to other groups to save time in the presentation. A representative from the other two groups chosen randomly evaluates or critiques the output of other groups based on the rubric provided to them. Group outputs will then be improved and compiled for future use.

After eight weeks of exposure, the students were given a post-test, the same as the pretest, and then compared. The increase in means was the determinant of the effectiveness of PCM and PAGW in teaching mathematics. After the post-test, a questionnaire about students' perceptions of PCM and PAGW in teaching mathematics was administered. It was tested to find its relationship with their performance.

Data Analysis

The mean was used to describe the pretest and post-test scores of the students in each group. The standard deviation was employed to determine the variability of the groups' pretest and post-test scores. The t-test determined the significant difference between the two groups' performances. Spearman rank correlation was utilized to establish the relationship between the effectiveness of PCM and PAGW in teaching, as perceived by the students, and their performance.

The following were also used in the analysis and interpretation of data. They were presented in tabular forms to be easily understood. Frequency and percentage distributions were utilized to facilitate the analysis of data. Graphs were also used to show the difference in performance between the groups at a glance.

For the interpretation of students' performance, the following Mean Percentage Score (MPS) range was considered (based on DepEd Form 138):

MPS Range	***Description***
90% - 100%	Outstanding
85% - 89%	Very Satisfactory
80% - 84%	Satisfactory
75% - 79%	Fairly Satisfactory
74% - below	Did Not Meet Expectations

In terms of the student's perception of the effectiveness of PCM and PAGW, the following indices were also considered:

Numerical Rating	***Students' Response***	***Descriptive Ratings***
3.26 – 4.00	Strongly Agree	Very Effective
2.51 – 3.25	Agree	Effective
1.76 – 2.50	Disagree	Ineffective
1.00 – 1.75	Strongly Disagree	Very Ineffective

The Spearman's Rho was used to establish the relationship between the students' perception of the effectiveness of PCM and PAGW and their performance. Spearman rank correlation is a non-parametric test that is used to measure the degree of association between two variables, which are measured on a scale that is at least ordinal, and the scores on one variable must be monotonically related to the other variable (Chen & Popovich, 2002). The following indices were used in interpreting the coefficients of correlation (De Guzman, 2017, p. 224):

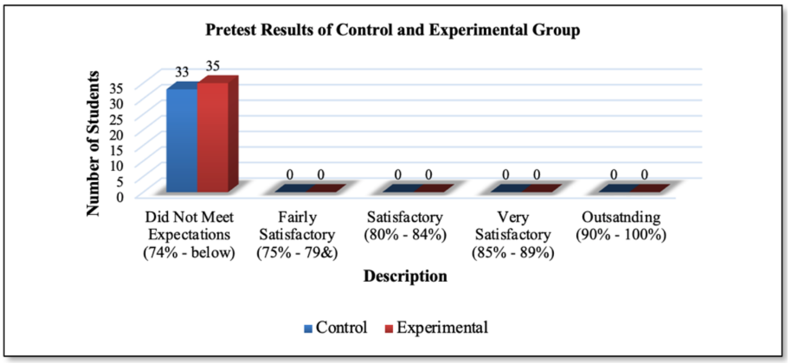
Correlation Coefficient	***Interpretation***
± 0.80 - ± 1.00	Very strong
± 0.60 - ± 0.79	Strong
± 0.40 - ± 0.59	Moderate
± 0.20 - ± 0.39	Weak
± 0.00 - ±0.19	Very weak

Results and Discussion

One of the objectives of this study is to describe the students' performance in general mathematics before they were exposed to the use of PCM and PAGW. The graph below shows the student's performance in general mathematics before the start of the experimentation.

The pretest results of the control and experimental groups showed that they scored almost the same mean. The control group had 13.52 with a standard deviation of 3.88, while the experimental group had 13.26 with a standard deviation of 3.88. The two groups occupied the same Mean Percentage Score (MPS) ranges (Control = 33.79% and Experimental = 33.14%) and levels of description (Did Not Meet Expectations).

Figure 3
Pretest Results of Control and Experimental Group



Based on the graph shows that the students needed more prior knowledge of the competencies of inverse functions, exponential functions and logarithmic functions. This means the two groups' initial knowledge of general mathematics subjects needed to be higher.

Table 1 compares the pretest results of the control and experimental group. The statistical analysis in Table 1 shows the t-test of the difference between means of independent samples. Since *t*he value is found to be 0.378 and the *p*-value > 0.05, it can be noted that the result was not significant. This indicated that the students were of the same standings and equally low on their initial knowledge of the selected topics in general mathematics subject.

This is because the students still needed to be exposed to and taught formally about the topics included in the study.

Table 1

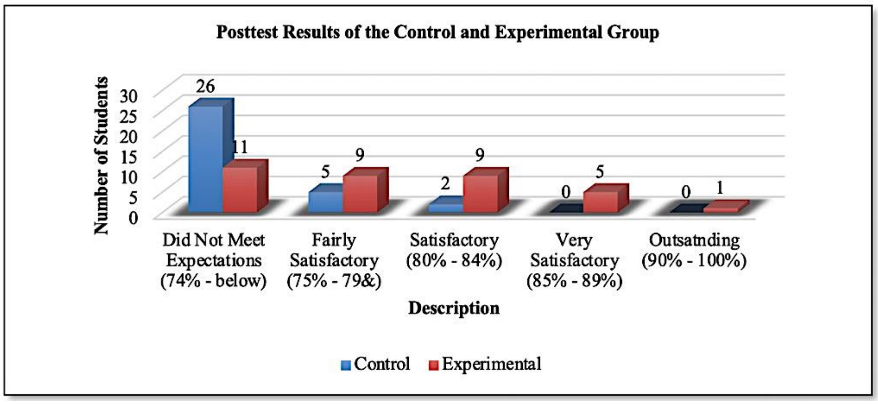
Comparison between the Pretest Results of the Two Groups' T-test

Groups	N	$\bar{x}$	MPS	sd	*t*	*df*	*p*
Control	33	13.52	33.79	3.88	0.307	66	.7597
Experimental	35	13.26	33.14	3.01			

In their post-test results, the control group had a mean of 26.42. The highest score was 32, and the lowest was 19. On the other hand, the experimental group's mean was 30.89. The lowest score was 26, and the highest was 38.

Figure 4

Post-test Results of the Control and Experimental Group



There were 26 (78.78%%) of the control group who were still in the "did not meet expectation" level, 5 or 15.15% in the "fairly satisfactory", and only 1 or 3.03% in the "satisfactory level, whereas in the experimental group, there were still 9 or 25.71% that fell under the "did not meet expectations" level. Meanwhile, there were 26 or 74.29% students who had significantly improved their performance over their scores in the prestest. Notably, 9 or 25.71% of them were on the "fairly satisfactory" and "satisfactory" level, 5 or 14.29% in the "very satisfactory" level and 1or 2.86% performed "outstanding".

Table 2 shows the statistical analysis of the difference between means of independent samples using a t-test. The higher mean of the post-test of the experimental ($\bar{x}$=30.89) with a lower standard deviation (sd=2.77) over the control group ($\bar{x}$=26.42, sd=3.11) led to the *t*-test result equal to 6.428 with a *p*-value < 0.01. This meant that at a 99% level of significance, there was a significant difference in the student's performance in the post-test given to them in favour of the experimental group. Moreover, the scores of the students in the experimental group were more compressed (sd=2.77), leading to the conclusion that they performed better than the control group (sd=3.11).

Table 2
Comparison between the Post-test Results of the Two Groups' t-test

Groups	N	$\bar{x}$	MPS	sd	*t*	*df*	*p*
Control	33	26.42	66.42	3.11	6.248	66	.000
Experimental	35	30.89	77.21	2.77			

With regard to the results obtained, PCM and PAGW were effective. The same is true for the Traditional Teaching Method. However, PCM and PAGW are more effective than the Traditional Teaching Method for this study. This result could be attributed to the use of the said teaching strategy. PCM allows the students to experience authentic learning by having a deeper understanding of the lessons through creating rich and engaging activities, such as writing equations, graphs, tables, illustrations and word problems that represent the application of mathematical concepts they have learned. Similarly, PAGW helped them be more critical of the activities each group prepared during the presentation. An increase in their confidence empowered them to be more engaged in the learning process (Chin & Aquino, 2019). Each group had the chance to solve and critique the other groups' outputs, enhancing their prepared activities. Also, their skills in communicating math were remarkable. The way they presented and solved the activities showed their clear understanding of the concepts covered in each session. With the guidance of the teacher and the active engagement of each group member, the students could create relevant materials for each unit covered.

In addition, their output served as an evaluation tool for the teacher to check whether the students have learned the desired learning objectives. The students' created outputs allowed the teacher to check if they were progressing and were able to think of other ways to address the problems encountered during instruction and identify those that needed clarification and reinforcement.

Variation of General Mathematics Achievement in terms of performance

Variation in performance showed that the students in the two groups displayed positive behaviour and responded better when exposed to the teaching strategies. The mean scores of the control and experimental groups in their post-test increased over their mean scores in the pretest.

Table 3
Variation in Mean Scores in the Pretest and Post-test using the t-test

Groups	N	$\bar{x}$ (Pretest)	$\bar{x}$ (Post-test)	Mean Difference	sd	*t*	*df*	*p*
Control	33	13.52	26.42	12.91	3.11	18.278	32	.000
Experimental	35	13.26	30.89	17.63	2.77	35.948	34	.000

The two groups showed a positive response to the methods used. However, the students under the PCM and PAGW performed better than those in the Traditional Teaching Method. After the post-test was administered, the experimental and control groups obtained a mean of 30.89 and 26.42. This resulted in a mean difference of 4.47 in favour of the experimental group, with a standard deviation of 2.77.

Variation of General Mathematics Achievement in terms of Gain Scores

The experimental group got a higher mean of 17.63 with sd=2.90, compared to the other group, which has $\bar{x}$=12.91 and sd = 4.06. The computed *t*-value is 5.542, with a *p*-value < 0.01. This strongly suggests that at a 99% level of significance, there is a significant difference even in the gain scores of the two groups in favour of the experimental group.

Table 4

Variation of Gain Scores of the Control and Experimental Group using the t-test

Groups	N	$\bar{x}$	sd	*t*	*df*	*p*
Control	33	12.91	4.06	5.542	66	.000
Experimental	35	17.63	2.90			

This result implied that teaching using PCM and PAGW enhanced the students' learning. The result further shows a significant difference between the gain scores of the control and experimental groups; the latter group gets a higher gain score, giving them an edge over the control group. Using the PCM and PAGW engaged the students in the lesson more since the strategy was activity-oriented. PCM helped them improve and deepen their level of understanding, manifested by their ability to create activities such as writing equations and conceptualizing word problems involving the application of inverse functions, exponential functions, and logarithmic functions, including illustrations and graphical representations of these said concepts.

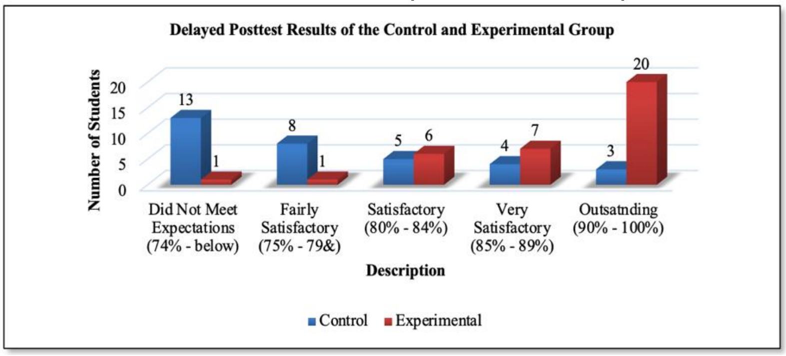
PAGW, on the other hand, helps the students to become more engaged during group presentations since each member plays an active role. The group presentation allows them to communicate what they have learned and exchange ideas with the rest of the groups. They were able to make acceptable comments and suggestions, which helped improve the activity outputs of their group. Likewise, they displayed better confidence in doing math, as shown by their ability to solve each group's problems when they took turns in the gallery walk activity. Moreover, it helped the teacher highlight each student's strengths, identify their weaknesses, and make necessary interventions to reinforce them.

Retention of Learning

Another indicator of the effectiveness of PCM and PAGW is the retention of skills on the topics of inverse functions, exponential functions, and logarithmic functions. Students' retention of skills is measured by comparing their post-test and delayed post-test scores. An increase in their delayed post-test scores over their post-test scores determined the effectiveness of PCM and PAGW in this regard. The graph on the next page shows the delayed post-test results of the two groups.

Figure 5

Delayed Post-test Results of the Control and Experimental Group



Their delayed post-test results showed that their performance had even further improved. Though both groups exhibited higher delayed post-test results, the experimental group, which used PCM and PAGW, enhanced the students' learning and understanding of the concepts and skills covered in the lessons. In the control group, 13 (39.39%) students still did not meet expectations, and 20 (60.61%) met the required MPS. The experimental group exhibited higher performance in their delayed post-test. Only one student did not meet the necessary mastery, and 34 (97.14%) of them met the expectations, whereas the majority of the entire group (20 or 57.14%) were identified to have an "outstanding" MPS.

This result can be attributed to the use of PCM and PAGW, which helped students promote a more profound understanding and enhanced retention of learning on the concepts and processes involved in the study. Their ability to create engaging activities such as writing equations, worded problems, illustrations and graphs helped them become more engaged in the teaching-learning process. This provides them with the venue to be more creative since they were allowed to showcase their understanding through PCM. PAGW also played a significant role in the retention of students' learning. The learning and deepened understanding brought by PCM resulted in improved confidence in communicating their learning through solving, presenting, and discussing their work during the gallery walk. Students could give necessary and acceptable comments and suggestions that helped improve the outputs of the other groups. The findings implied that PCM and PAGW are good teaching strategies to enhance students' learning outcomes through active participation and involvement in teaching-learning (Uzun, 2015).

Table 5 shows the statistical analysis of the scores tested using a *t*-test of the difference between means of independent samples. The table shows that the control and experimental groups exhibited higher means in their delayed post-test, with a mean difference of 4.34 and 4.74, respectively. Since $t(66) = 7.336$ and the p-value < 0.01, it can be noted that this is highly significant. This indicates strong evidence to reject the null hypothesis that no significant difference exists between the groups' scores in the post-test and delayed post-test. Though both groups obtained higher delayed post-test mean scores than their post-test, the experimental group performed better than the control group. Students who were taught using PCM and PAGW remarkably improved their performance. The performance of the students in mathematics still improved significantly from an MPS of 77.21% (Fairly Satisfactory) to 89.07% (Very Satisfactory) even after a week of teaching the lessons.

Table 5
t-Test between the Means of Post-test and Delayed Post-test

Groups	N	$\bar{x}$ (Post-test)	$\bar{x}$ (Delayed Post-test)	Difference	MPS	sd	*t*	*df*	*p*
Control	33	26.42	30.76	4.34	76.89	2.92	7.336	66	.000
Experimental	35	30.89	35.63	4.74	89.07	2.54			

Students' Perception of the Effectiveness of PCM and PAGW and its Relationship to Their Performance

Another study objective was to determine the relationship between the student's perception of the effectiveness of using PACM combined with PAGW in teaching mathematics and their performance, presented in the following table. This is to verify further that the use of PCM and PAGW can account for the high performance of the students. Cronbach alpha was used to determine the reliability and internal consistency of the research instrument items regarding the students' perceptions of the effectiveness of EJW. It was found to be 0.78, an acceptable alpha coefficient (Multon, 2006; Tavakol & Dennick, 2011; Andale, 2014), which means that the items included in the 4-point Likert scale are accepted and intend to measure what they should. Table 6 summarises the students' responses on their perceptions of the effectiveness of PCM and PAGW, including the correlation coefficient value obtained using Spearman's rho. Spearman rank correlation is a non-parametric test to measure the degree of association between two variables. It is the appropriate correlation analysis when the variables are measured on a scale that is at least ordinal (Chen & Popovich, 2002).

Table 6
Students' Perception of the Effectiveness of PCM and PAGW

Group	N	Min	Max	sd	Overall Mean	Descriptive Rating
Experimental	35	3.20	3.56	0.29	3.38	Very Effective
Students' Perception					Delayed Post-test .821**	

***Correlation is significant at the 0.01 level (2-tailed)*

Table 6 presents the significant relationship between students' perception of the effectiveness of using PCM and PAGW in mathematics and their performance (delayed post-test). The table shows that at a 0.01 level of significance, there is sufficient evidence that the students' perception of the effectiveness of using PCM and PAGW is significantly and positively related to their performance (r = 0.821, p < 0.01). The correlation shows a strong positive relationship between the two variables involved. This indicates that students who perceived that using PCM and PAGW is effective tend to have better or higher performance in mathematics. It implies further that the higher the students' perception of its effectiveness, the greater the possibility that they exhibit excellent performance in mathematics.

Conversely, students whose perception of the effectiveness of PCM use is low tend to have lower performance. This further indicates that using PCM and PAGW enhanced the students' learning outcomes. Students are more engaged in the teaching-learning process since they are given different opportunities to learn and understand the lessons.

Findings revealed that students had a positive attitude towards using PCM and PAGW. Therefore, PCM and PAGW are good teaching strategies to improve student's learning outcomes through active participation and confidence in communicating mathematics. Using these combined teaching strategies encouraged students to be active in the teaching-learning process and allowed them to become independent learners over time, even outside the classroom.

PAGW also improved students' learning outcomes. The more the students involved themselves in learning the lessons, the better their retention of concepts and ideas was evident. During the gallery walk activity, students could deepen their understanding by communicating what they had learned to their peers through presentation and discussion.

Problems Encountered in Teaching Mathematics Using PCM and PAGW

Some minor problems were encountered during the implementation of PCM and PAGW. Some of the problems identified were the insufficiency of time to present and discuss their outputs after the gallery walk activity and the difficulty in expressing oneself using the English language during the presentation and discussion of their work. Also, some students prefer to comment on the other groups' output.

Proposed Solutions to Maximize the Use of PCM and PAGW Effectively

The following solutions are proposed to maximize the use of PCM and PAGW effectively: (1) Encourage students to follow the time guidelines in the presentation and discussion of outputs, highlighting only the important concepts. (2) Students should practice using English comfortably and be considerate in allowing them to use the Filipino language occasionally. (3) Students should be confident enough to critique the works of their peers for better quality of outputs.

Conclusion

Changing students' overall approach to school mathematics presents a task for which one cannot hope to find a simple or even unique solution. Nevertheless, Project CREATE Mathematics and Peer-Assessed Gallery Walk (PCM and PAGW) can provide students with a valuable means to deepen and facilitate their understanding of mathematics.

The following conclusions were derived based on the results and findings: 1) The student's performance in both the control and experimental groups improved. Both methods were effective. The two groups registered higher mean scores in their post-test compared to their pretest. 2) Gain scores were increased. However, the experimental group exhibited higher gains than the control group. Thus, Project CREATE Mathematics and Perr-Assessed Gallery Walk as a strategy was more effective than the Traditional Teaching Method with the control group. 3) The performance of the students in the delayed post-test given after a week further improved in both groups. However, the experimental group had a higher mean score than the control group. 4) There was a strong positive correlation between the student's perception of the effectiveness of the PCM and PAGW and their performance. 5) Some of the problems met by the researcher during the implementation were the insufficiency of time in the presentation and discussion of outputs after the gallery walk activity, difficulty of some students in expressing themselves using the English language during the presentation and discussion of outputs and hesitations to critique and give comments and suggestions on the outputs of other groups. However, these may be addressed with the proposed solutions. Also, these problems helped the teacher determine what needs to be improved, reinforced and maintained when using the PCM and PAGW.

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Preliminary Investigation: Teachers' Perception of Computational Thinking (CT) Skills for Mathematics Classroom

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Abstract

This paper aimed to investigate primary school mathematics teachers' perceptions of CT in mathematics classrooms. Two virtual webinars were conducted to cover the teaching and learning mathematics activities. At the end of the webinars, a questionnaire to acquire teachers' perceptions of CT was disseminated to participants. The questionnaire consists of teachers' comprehension of the CT concept, teachers' interest in problem-solving abilities related to CT, perceptions of the integration of CT in teaching and learning practice, and perceptions of a teacher's competencies in teaching and learning using CT. The survey forms were distributed using Google Forms and were emailed to the respondents. SPSS and Nvivo software were used to analyse the data collected. Eighty-four teachers attended the webinars, and only 41 primary school mathematics teachers responded to this study. The studies demonstrate that teachers comprehend the concept of cognitive theory and value cognitive skills in their classroom activities as a component of the thinking process. However, it is essential to consider teachers' concerns about time constraints when utilising these skills to improve students' learning. The study will show that CT skills can be used for problem-solving in mathematics classrooms, which is essential to prepare future teachers and students for CT skills. The participants also stated that CT skills are necessary for students in the future because the students can apply CT skills to solve problems in daily life.

Keywords: *Computational thinking, mathematics classroom, problem solving*

Introduction

In the article published in 2006, Jeanette Wing described computational thinking (CT) as a way of "solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science." She stated, "computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, computational thinking should be added to every child's analytical ability". Computational refers to using or relating to computers, while thinking refers to considering or reasoning about something. Wing (2006) sparked a discussion about how teachers should prepare students for careers influenced by computing and where core computational thinking concepts could be integrated into mathematics classrooms. (Yadav et al. 2016).

Computational thinking skills have permeated all elementary and secondary school levels. This integration is being done through computer science education programmes as well as in other content areas such as mathematics and science (Winthrop et al., 2016). With this increased interest comes critical questions about how in-service teachers conceptualise computational thinking, especially teachers who are not trained in computer science (Sand et al., 2018). The question, namely, how do these teachers understand computational concepts as they work to apply them in their classrooms? Further, what steps must we take to help in-service teachers integrate computational thinking into their curriculum? What are computational thinking skills? The essence of computational thinking skills involves breaking down complex problems into more familiar/manageable sub-problems (problem decomposition), using a sequence of steps (algorithms) to solve problems, reviewing how the solution transfers to similar problems (abstraction), and finally, determining if a computer can help (Yadav et al. 2011, 2014).

This research is designed to identify primary mathematics teachers' perceptions of integrating CT in mathematics classrooms in Malaysia, the Philippines, and Thailand. This study gained a better understanding of 4 issues, namely 1) teachers' understanding of the concept of CT, 2) teachers' interest in problem-solving abilities related to CT, 3) teachers' perceptions of the ability of CT in the classroom practices, and 4) teachers' competencies on the usage of CT skills towards teaching and learning which responded by the teachers, and it can lead to better effort in improving CT skills for mathematics teachers. Nevertheless, CT has been suggested as a tool for 21st-century learning skills in mathematics classrooms. It is a type of reasoning that teaches students how to solve complex problems using computer-aided strategies (Wing, 2006; 2008). The integration of CT into the education system increases students' motivation by encouraging student-student interaction (Kwon & Kim, 2018). CT methods have yet to be widely applied to support mathematics learning, and few studies have explored the use of CT for mathematics (Jacob et al., 2018). Furthermore, according to Cheah (2018), teachers continue to use the teacher-centric approach in their classroom activities. On the other hand, students are now more advanced in receiving data from the Internet. The number of jobs requiring creativity and innovation is increasing. As a result, it is critical to allow students to incorporate creative thinking into their learning process.

Therefore, this study addresses teachers' perceptions of integrating CT skills (decomposition, pattern recognition, abstraction, and algorithm) in the mathematics classroom. A survey was carried out to investigate teachers' perceptions of integrating CT skills through problem-solving. By utilising computational thinking skills to facilitate the teaching process, this study provides a scaffold for teachers.

Theoretical Framework

Computational thinking (CT) represents a "universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (Wing, 2006, p. 33). Accordingly, CT is fundamental for any discipline, including mathematics, physics, engineering, and many more. It may have far-reaching practical implications from which mathematics, in particular, can benefit.

Computational thinking is procedural thinking

Papert (1996) defined computational thinking as "procedural thinking," which defines the relationship between a problem and its solution and data structuring. CT's four components, namely decomposition, pattern recognition, abstraction, and algorithms are used to embed procedural thinking in problem-solving. What exactly are these components described as? The following are descriptions of these four CT components:

Decomposition	**Pattern recognition**	**Abstraction**	**Algorithms**
Instruct students to break down complex problems into more minor, straightforward ones.	Assists students in drawing parallels between similar problems and experiences	Encourage students to identify important information while ignoring irrelevant or unrelated details.	Algorithms are used by students when they design simple steps to solve problems.

According to an article (Thorson, 2018), the best method to improve computational thinking abilities, according to many educators, is to incorporate it into other subject areas. This better uses computational thinking skills and relieves some of the pressure to schedule discrete classes. Integration produces a learning environment that is more engaging and real.

Integration of CT skills for mathematics problem-solving

The pedagogy style in the teaching and learning process is related to the concept of the integration CT skills approach. This will determine how well the skill is taught. Integrating this element into a creative approach also prepares students as problem solvers and critical thinkers (Deschryver & Yadav, 2015). Teaching mathematics topics can be deeply enhanced using computational tools and skill sets (Eisenberg, 2002; Repenning et al., 2010). However, it is also true: computational thinking can be used in relevant contexts (and challenges) provided by mathematics (Jona et al., 2014). CT is "an approach to solving problems in a way that can be implemented using a computer" and goes beyond computer programming (Barr & Stephenson, 2011). Moreover, it is assumed that CT improves logical and reasoning skills in mathematics education (Martínez-García, 2021).

Digital Learning (DL) for the mathematics classroom

Since the COVID-15 pandemic hit the world, almost all students worldwide have been affected by this phenomenon. The educational environment has resulted in more digital learning opportunities at both the primary and secondary levels. Since 2020, most schools have attempted to infinitely back-up face-to-face experience through blended learning during the COVID-19 pandemic. In addition, the term "digital learning approach" refers to a technique in which students engage in active learning and is associated with constructivism, self-directed learning, and interaction. Those processes engage the learner in an active rather than passive mode (Rennie & Smyth, 2019).

It has undoubtedly been investigated for use in classroom teaching and learning activities. Digital learning has spread beyond formal classroom interaction and is now routinely used for educational interactions and all other social media activities. Almost no school in the world does not use digital resources for educational purposes in some way. A digital learning strategy entails learning via digital assets such as videos, Facebook, podcasts, and articles. Students have a variety of learning styles, including visual, kinesthetic, auditory, and others. Learners nowadays prefer to participate in the learning process; they dislike lecture-style learning. Instilling a learning culture through a solid digital learning strategy focuses on developing learners' skills and motivating them to take charge of their learning.

As a McKinsey report states, "To be meaningful and sustainable, we believe that digital should be seen as less of a thing and more of a way of doing things." This encapsulates the importance of a digital learning strategy for success in the digital age.

Methodology

Unfortunately, due to the Covid-19 pandemic, school closures and movement restrictions were strictly enforced. The project's original goal of training students and teachers' perceptions has been changed to host a webinar for primary mathematics teachers. As a result, two webinar series were conducted on 'Introduction to Basic Computational Thinking for Primary Mathematics Teachers,' held on September 9th and 21st, 2021. Two facilitators from SEAMEO RECSAM led these webinars. The participants' responses were generally positive. It was regarded as a prerequisite for developing and improving an instrument.

Therefore, this preliminary study was guided by the research questions as follows:

1. Do the teachers understand computational thinking (CT) concepts?
2. Are the teachers interested in problem-solving abilities related to CT?
3. What are teachers' perceptions of integrating CT into their classroom practices?
4. What are teachers' perceptions of competencies in teaching and learning using CT?

A mixed-method approach was designed, and it involved three phases:

Phase 1: Webina series

In this phase, two webinars were conducted to cover the teaching and learning activities. At the end of the webinars, a questionnaire was disseminated to participants. Out of 84 teachers who attended the webinars, only 41 primary school mathematics teachers responded to this study. The survey forms were distributed using Google Forms and were emailed to the respondents. The questionnaire consists of four parts, namely: (i) teachers' comprehension of the CT concept, (ii) teachers' interest in problem-solving abilities related to CT, (iii) perceptions of the integration of CT in teaching and learning practice, and (iv) perception of a teacher's competencies in teaching and learning using CT. Nevertheless, open-ended questions were also used to express their concerns and elaborate on their opinions and perceptions.

Phase 2: Data Collection

Respondents Information

Descriptive statistics were used in the analysis of quantitative data. Quantitative analysis primarily consisted of frequency, percentages, and mean. Qualitative data were collected from the open-ended response items that formed an integral part of the questionnaire. Quantitative and qualitative techniques were used to analyse the data generated by the questionnaire. Most of the respondents were from Malaysia, and some were from Southeast Asia, as shown in the following table:

Table 1

Mathematics teachers

No	State/Country	Frequency
1	Penang	20
2	Sabah	1
3	Putrajaya	2
4	Selangor	2
5	Sarawak	1
6	Kelantan	1
8	Pahang	1
9	Johor	1
10	Malaysia (unknown)	3
11	Philippines	1
12	Thailand	2
16	RECSAM Staff	8
	Total	**41**

The 5 Likert-type scale questions were adapted and modified based on resources from Ling, Saibin, Labadin and Norazila (2017). The perception of the teacher's comprehension was assessed. Four items were used to assess the results in the first part of the survey form. This part was composed to evaluate teachers' understanding of the CT concept:

1. I have attended workshops related to computer programming,
2. I have attended workshops related to CT,
3. I have attended workshops related to computers and
4. I understand the concept of CT.

This section was designed to arouse teachers' interest in problem-solving abilities related to CT. Eight items were adapted to perceive teachers' interest in using CT for problem-solving:

1. Problem-solving using mathematical, scientific or problem-solving skills,
2. Teaching & learning based on ICT & computer usage,
3. Using a computer to complete a task or to solve a problem,
4. Higher-order thinking skills,
5. A process of solving problem,

6. Problem-solving based on information processing,
7. Computer literacy, and
8. Solving the problem by segmenting the problem into smaller segments.

In order to acquire teachers' perceptions of the integration of CT in teaching and learning in classroom practices, four items were created to assess teachers in this section:

1. Perceived Usefulness,
2. Perceived Ease of Use,
3. Behavioural Intention, and
4. Computer Attitude.

This part of the survey assessed the perception of teachers' competencies in teaching and learning using CTwas. Five items were used to assess respondent's competencies on perception of teachers' competencies in teaching and learning using CT:

1. The workshop on CT skills is sufficient for mathematics teaching,
2. There are sufficient CT skills to engage students to use for teaching mathematics problem-solving,
3. I think that I can connect the CT to mathematics problem-solving using digital tools,
4. I think that I can apply CT in mathematics subjects,
5. I wonder, why should I learn? Where were they used? What kinds of benefits exist during mathematics teaching?

The reliability of the obtained data was then analysed using Cronbach's alpha in SPSS version 26. Cronbach's alpha was used to assess the strength of the correlation between questionnaire items within each construct. All items show high values of Cronbach's Alpha, 0.936. Finally, the questionnaire's final section is made up of open-ended questions. These questions were designed to supplement the survey data by allowing respondents to express their concerns and elaborate on their opinions and perceptions. All these responses were analysed in NVivo version 12.

Phase 3 - Result (Data analysis)

This study aimed to determine teachers' attitudes toward incorporating CT skills into their mathematics classroom activities. Data collected were analysed and presented here descriptively to inform readers.

Teachers' understanding of the concept of CT

According to Table 2(a), 47.8 per cent (n = 11) of respondents have taken computer programming classes or received training. Table 2(b) shows that 60.9 per cent (n = 14) of respondents have received CT skill training. Furthermore, Table 2(c) depicted that 73.9 per cent (n = 17) of respondents have had computer training. In Table 2(d), only one mathematics respondent needed clarification on whether he or she understood the concept of CT. Nonetheless, many mathematics respondents agreed with a mean score of 4.11. This shows that they comprehended the CT concept.

Table 2(a)

Several mathematics teachers attended computer programming classes

		Math		Mean
		Freq	Percentage (%)	
Valid	Never attended	3	13.0	
	Not sure	9	39.1	
	Attended	11	47.8	3.58
	Total	23	99.9 ≈ 100	

Table 2(b)

A number of mathematics teachers received CT skill training

		Math		Mean
		Freq	Percentage (%)	
Valid	Never attended	2	8.7	
	Not sure	7	30.4	
	Attended	14	60.9	3.74
	Total	23	100.0	

Table 2(c)

A number of mathematics teachers attended computer training

		Math		Mean
		Freq	Percentage (%)	
Valid	Never attended	0	0.0	
	Not sure	6	26.1	

		Math		Mean
		Freq	Percentage (%)	
	Attended	17	73.9	4.00
	Total	23	100.0	

Table 2(d)

Several mathematics teachers needed clarification on whether they understood the concept of CT or not

		Math		Mean
		Freq	Percentage (%)	
Valid	Not sure	1	4.3	
	Understand	22	85.7	4.11
	Total	23	100.0	

Teacher's interest in problem-solving abilities related to CT

Table 3 demonstrates the eagerness of mathematics teachers to apply CT skills to problem-solving situations. The average mean score is 4.24, which indicates that they agree that CT skills will aid the process of higher-order thinking skills in problem-solving. They also agree that CT skills necessitate computer literacy and that segmenting problems into smaller parts helps students see them.

Table 3

The percentage of eagerness of mathematics teachers to apply CT skills to problem-solving situations

No	Items	Math		Mean
		Freq	Percentage (%)	
1.	Problem-solving using mathematical, scientific or problem-solving skills	23	100	4.26
2.	Teaching learning based on ICT computer usage	22	95.7	4.21
3.	Using a computer to complete a task or to solve a problem	21	91.3	4.16

No	Items	Math		Mean
		Freq	Percentage (%)	
4.	Higher-order thinking skills	23	100.0	4.26
5.	A process of solving the problem	23	100.0	4.26
6.	Problem-solving based on information processing	23	100.0	4.32
7.	Computer literacy	21	91.3	4.16
8.	Solving the problem by segmenting the problem into smaller segments	23	100.0	4.26

Teachers' perceptions of the utility of CT in the classroom practices

According to Table 4, many teachers believe that CT skills are important and can be used in classroom activities. Perceived usefulness also influenced teachers' behavioural intentions (mean score greater than 4.0). This result was aligned with Davis (1986), who believed that using certain technologies could improve their work performance. Perceived ease of use and computer attitude also show a significantly high mean score of greater than 4.0, which means teachers believe that their understanding and perception of integrating CT skills in teaching and learning is significantly relevant and can be implemented in classroom activities.

In conclusion, teachers' behavioural intentions to integrate CT into their teaching and learning practices are significantly influenced by how easy they consider CT integration to be. Another important factor is the teachers' positive attitudes toward CT, which are strongly correlated with their behavioural intentions to incorporate CT into their teaching and learning practices.

Table 4

The percentage of mathematics teachers believe that CT skills are essential and can be used in classroom activities

No	Items	Maths		Mean
		Freq	Percentage (%)	
1.	Perceived Usefulness	19	82.6	4.05
2.	Perceived Ease of Use	14	60.8	3.84
3.	Behavioural Intention	19	82.6	4.05

4.	Computer Attitude	20	87.0	4.05

Teachers' competencies on the usage of CT skills towards teaching and learning

According to Table 5, 82.6 per cent of respondents believe that a workshop on CT skills is adequate for teaching and learning and could engage students. 78.3 per cent believed they could solve mathematics problems by integrating CT skills and a digital learning approach. They could connect CT skills to mathematics problem-solving using digital tools. Table 5 also shows that 52.3 per cent of respondents believe they comprehend the importance of learning and incorporating CT skills into their teaching and learning strategies. 13.0 per cent disagree on the reason for learning CT, the usage, and the benefits they receive when learning on CT. At the same time, 34.8 per cent were unsure of their opinion.

Table 5

The percentage of teachers' competencies on the usage of CT skills towards teaching and learning mathematics

No	Items	Maths		Mean
		Freq	Percentage (%)	
1.	The workshop on CT skills is sufficient for math’s teaching,	19	82.6	3.95
2.	There are sufficient CT skills to engage students to use for teaching math problem-solving,	19	82.6	4.00
3.	I think that I can connect the CT to math problem-solving using digital tools,	18	78.3	3.84
4.	I think that I can apply CT in math subjects,	20	87.0	4.05
5.	I wonder why I should learn. Where are they used? What kinds of benefits exist during math teaching?	12	52.2	3.58

According to the findings, 59.62 per cent of the 4 participants understood that computational thinking is all about problem-solving, and 7.69 per cent understood it is about algorithms and four elements of CT skills, respectively. On the other hand, on the second research question, teachers had mixed feelings. However, many teachers expressed that they saw it as a computer skill that students should be able to master. In response to the third research question, most teachers demonstrated a conceptual understanding of CT skills. Nonetheless, many teachers still do not value incorporating CT and digital learning into a creative approach. Most teachers emphasise the importance of introducing it using problem-solving strategies.

Discussion and conclusion

This preliminary study led to the conclusion that mathematics teachers have a better understanding of CT concepts, are interested in problem-solving abilities related to CT, have a perception of integrating CT into their classroom practices, and have perceptions of competencies in the usage of CT skills towards teaching and learning. The study shows that they agreed that CT skills are necessary for mathematics classrooms. It is the discussion of the research questions as follows:

(i) Do the teachers understand the CT concept?

Results presented in this paper provide preliminary insights on how primary school mathematics teachers perceived CT skills can be integrated with the digital learning approach in mathematics classroom activities. Integrating these two learning tools promoted a deeper conceptual understanding of mathematics in this study. They may also improve content mastery and metacognitive abilities. According to this preliminary study, teachers have grasped the concept of CT. They were prepared to receive training to integrate CT capabilities into their teaching and learning activities. Teachers were also believed to value CT skills in their classroom activities as part of the thinking process, and this result was consistent with Wing's (2006) conclusions that CT is a talent that 21st-century persons should acquire and use to solve problems that arise in life effectively. As discussed by Halil İbrahim Haseski, Ulaş İlic, UfukTuğtekin (2017), CT is a social consensus skill that enables people to make active and methodical decisions in real-life circumstances utilising ICT and collaborative ways like the digital learning approach, resulting in the best and most ethical decisions and contributing to their environment, self-discovery, and self-esteem.

Furthermore, in this technological age, the roles of teachers and students have shifted. Teachers are no longer simply content transmitters but rather facilitators, and students become creators of knowledge rather than mere receivers in the classroom. Teachers believe integrating CT skills and a digital learning approach could improve students' performance in mathematics. As described by Husaina Banu and Ghavifekr (2019), the combination of these tools resulted in blended learning (BL) for instructional delivery, which has the potential to be more effective than isolated traditional face-to-face instructional delivery.

(ii) Are the teachers interested in problem-solving abilities related to CT?

The result indicated that mathematics teachers agreed to apply CT skills to problem-solving situations. They also agree that CT skills necessitate computer literacy and that segmenting problems into smaller parts helps students see them. Furthermore, having CT skills among teachers would improve students' problem-solving abilities more.

Technology, too, can present challenges. These impediments to learning can have a significant impact. Allow these impediments to motivate teachers and students to learn more about CT skills and the digital learning approach. Furthermore, having CT skills among teachers would improve students' problem-solving abilities more. Besides that, the digital learning approach can strengthen students' problem-solving skills. These problem-solving skills can be developed effectively using digital tools such as Padlet, Google Classroom, Canva, etc.

(iii) What are teachers' perceptions of integrating CT into their classroom practices?

Integrating CT in teaching and learning practices is meant to be a 21st-century learning skill. Teachers' positive attitude has shown a willingness to integrate CT skills into their teaching and learning in classroom activities (Table 4). However, as described by Ling, Saibin, Labadin and Norazila (2018), further works in developing teachers understanding towards CT skills needed to facilitate teachers on how to integrate CT concepts in their existing lesson plan or by developing/introducing any suitable teaching pedagogy (teaching approach, assessment method, teaching material) to assist their teaching and learning practices, especially to suit teachers teaching and learning environment. Teachers should encourage students to participate in the design and creation of technology, as well as address challenges and explore multidisciplinary skills and knowledge (Ling et al., 2018). According to Denning (2009) and Lee et al. (2011), CT is becoming a necessary talent for everyone because it is thought to be a survival skill and will be rewarding in career pursuits. Therefore, as proven in Table 4, teachers believe that integrating CT skills in teaching and learning practices is important.

With time, these data revealed a varied picture of teachers' perceptions of integrating CT skills and digital learning approaches in teaching and learning classroom activities. Researchers perceived that teachers have been using digital learning approaches during the

COVID-19 pandemic, and it helps teachers enhance their digital learning skills in their teaching and learning approaches in their classrooms.

In conclusion, teachers' behavioural intentions to integrate CT into their teaching and learning practices are significantly influenced by how easy they consider CT integration to be. Another important factor is the teachers' positive attitudes toward CT, which are strongly correlated with their behavioural intentions to incorporate CT into their teaching and learning practices.

(iv) What are teachers' perceptions of competencies regarding using CT skills in teaching and learning?

This study has revealed that the digital learning approach and CT skills have greatly enhanced teaching and learning procedures. Mathematics teachers must receive further training on applying CT methods with a teaching and learning approach. Teachers' worries about time restrictions must be considered while harnessing these skills to enhance students' learning. Schools should also have an ICT infrastructure and students adept at using it. The digital learning approach has been the medium for teaching and learning processes since the Covid-19 pandemic, and many teachers have been exposed to CT skills since 2017. This proved that teachers are willing and able to integrate the digital learning approach and CT skills into teaching and learning activities in the classroom. Other concerns addressed by teachers are designing the classroom activities for mathematics as this is part and parcel of a five steps plan suggested by Angeli and Giannakos (2019), namely: (i) CT competencies, (ii) CT metaphors, (iii) technologies and pedagogies for CT, (iv) teachers/educators development for CT, and (v) measurement and assessment of CT.

Conclusion

The term "computational thinking" refers to the increasing emphasis on students' understanding of developing computational solutions to problems, algorithmic thinking, and coding. There is a growing interest in CT Education and its contribution to children's digital and analytical skills development in some K-12 schools. Several countries have incorporated computational thinking and digital learning into their curricula in response to this demand. The integration of CT skills and the digital learning approach is used to speed up, ease, and deepen the learning process. The role of the digital learning approach is to enhance learning, whereas CT skills will assist learners in applying solutions to real-world problems. Teachers must also understand how to transition away from traditional lessons without jeopardising student success.

Using CT skills in the classroom requires applying a new lens to past pedagogical practices for meaningful learning and attempting to replace outdated, ineffective ones. Teachers must also take an innovative approach by incorporating digital learning into CT skills for classroom activities. To maximise impact, leverage digital, and accelerate learning, they must also develop deep instructional and assessment practices expertise. Teachers' CT skills must be improved in order to improve student learning. Teachers must be systematically prepared in terms of designing CT learning activities, teaching CT, assessing CT, and using technology to teach CT concepts, according to Angeli and Giannakos (2019). Thus, as a result, there is a need for future research to develop CT skills modules that can serve as a guideline for teachers in the context of authentic problem-solving across all subjects and disciplines.

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Enhancing Higher-Order Thinking Skills (Hots) through Project-based Learning (Pbl) in Preschool Classroom

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Abstract

This study investigates the implementation of Project-based Learning (PbL) as a pedagogical approach aimed at enhancing Higher-Order Thinking skills (HOTs) among preschool children. This case study employed a qualitative approach to collect data using interviews, observation, and documentation. The participants were twenty-five preschool children aged 5 to 6 years old enrolled in a public school in Klang, Selangor. The study focused on a specific preschool teacher with over three years of experience in PbL implementation. Results indicate that PbL effectively enhances critical thinking skills in early childhood. By implementing systematically planned PbL activities, children showed significant progress in identifying problems, generating creative solutions, and considering different perspectives. Based on the study findings, implementing PbL in early childhood education is recommended to follow a structured process. This includes defining clear learning objectives, selecting exciting and relevant project topics, providing necessary materials and resources, and offering guidance and support throughout the learning process. This research contributes to the existing literature by providing insights into implementing PbL effectively to enhance HOTs in early childhood education. The findings underscore the importance of well-structured planning, implementation, and evaluation to maximise the benefits of PbL.

Keywords: project-based Learning, Higher Order Thinking Skills, Preschoolpreschool

Introduction

Early childhood education forms a critical cornerstone in the developmental journey of young learners. Providing practical, meaningful, and enjoyable educational experiences at this stage equips children with essential skills, instils self-confidence, and fosters a positive outlook towards lifelong learning. Commencing from preschool, nurturing sustainable thinking necessitates a scaffolded approach encompassing cultivating attitudes, knowledge, and skills. In a systematic review addressing education for sustainable development among children aged four to ten, Bascope et al. (2023) advocate for integrating sustainable thinking across diverse disciplines, underscoring the importance of instilling a global perspective from an early age to cultivate resilience. Children's thinking skills, especially in the context of HOTS, are a priority in determining the success of education transformation as outlined in Malaysia Education Blueprint 2013-2025 (Ministry of Education Malaysia, 2013). Previous research, such as that conducted by Bascope et al. (2023) and Andiema (2016), has elucidated a significant correlation between child-centred or active-learning methodologies—such as inquiry-based learning, the project approach, and problem-based learning—and the development of learners' thinking abilities. These active learning approaches encourage higher-order and creative thinking and social learning. Children who experience this type of learning have better problem-solving skills and learning capacity (Pekdogan & Kanak, 2016). Moreover, these approaches empower children to take ownership of their learning journey, rendering knowledge acquisition more meaningful and enduring (Nachiappan et al., 2019)."

Problem Statement

In the complex journey of a child's education, preschool plays a crucial role as, at this stage, children grow and acquire patterns of behaviour and thinking that affect their future performance. These 21st-century skills aim to shape pupils more readily in solving daily problems and being able to compete globally, as explicitly stated in the National Preschool Standards-Based Curriculum (NPSC) (MOE, 2017). In addition, HOTs have been stipulated in NPSC, where preschool teachers are required to integrate HOTs in the teaching and learning process, namely, applying, evaluating, analysing, and creating (MOE, 2017). However, despite these guidelines, traditional teaching methods still need to be revised, leaving little room for more engaging approaches, as Bascope et al. pointed out (2023). Hence, MOE Malaysia has highlighted PbL as one of the suitable teaching and learning strategies based on the development of preschoolers (MOE, 2017). Due to different preschoolers' thinking levels, teachers can choose what is appropriate when the teaching and learning process occurs.

However, there needs to be more clarity about how well preschool teachers are adopting innovative methods like PbL, especially for teaching essential skills like critical thinking. Hafsah and Zahyah (2020) suggest that Malaysia's Early Childhood Care and Education (ECCE) needs a fresh approach, focusing on natural and enjoyable learning activities for each child. However, many teachers need help to make this happen (Hafsah & Zahyah, 2020).

Studies have revealed a common assumption among educators that students naturally apply higher-order thinking Skills (HOTS) when engaged in (PbL) (Alves et al., 2016; Dole et al., 2016; Habók & Nagy, 2016). However, no comprehensive method exists for evaluating HOTS within the contexts of PBL pedagogy, its resultant products, and underlying processes (Du & Han, 2016; Schulz & FitzPatrick, 2016). Hence, the focal research question of this study addresses how preschool teachers employ PbL methodologies with young learners to cultivate the development of higher-order thinking Skills.

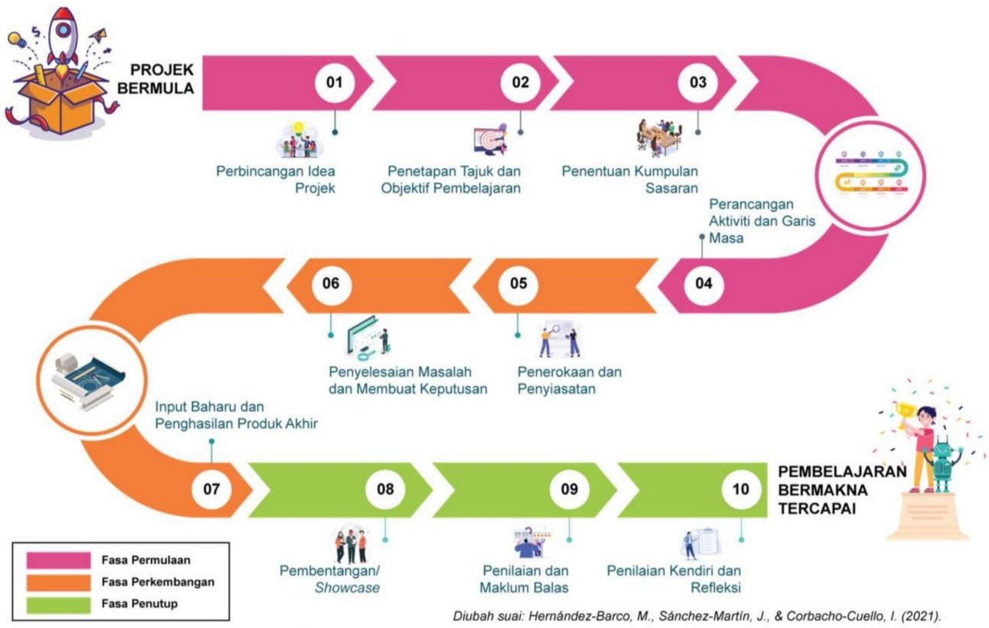
Literature review

Project-based Learning (PbL)

PbL is a dynamic educational approach centred on immersing learners in practical, real-world projects to deepen their comprehension of subjects and hone vital skills (MOE, 2017)). This educational strategy nurtures scientific processes and critical thinking and enhances their problem-solving, research and decision-making abilities. It allows students to learn by asking questions to find solutions, communicating with others, debating ideas, and designing plans. Hence, through PbL, children can develop their interest in exploring and discovering and cultivate a positive attitude in solving problems problems. In this study, the researcher and the participating teacher cooperated to design a project promoting children's acquisition of basic science process skills and thinking skills in a preschool in Klang, Selangor. The PbL approach developed by Curriculum Development Division (MOE, 2022) was employed to implement the designed module for this study. There are three phases in PbL, namely Beginning, Developing and Concluding, with ten steps for the teacher to implement during PbL (Figure 1).

Figure 1

Ten Steps in Implementing PbL (MOE, 2022)



PbL in Malaysian Preschools

According to Helm and Katz (2016), teachers need to facilitate the children's learning and development through projects, which are defined as an in-depth investigation of a real-life, worthwhile topic of their interest. PbL entails delving into real-life, meaningful issues of interest to children, fostering characteristics like being child-centred, inquiry-driven, process-oriented, and constructivist, aligning with children's innate tendencies, including their curiosity about the environment and their desire to comprehend experiences (Helm & Katz, 2016). Projects can be generated from any subject, often stemming from children's passions. For example, at a kindergarten in Perak, a group of children aged five years old embarked on a PbL journey, immersing themselves in studying butterflies (Mohd et al., 2018). Through this exploration, the children learned about various aspects of butterflies, including their structure, life cycle, eating habits, and camouflage. The learning process involved diverse activities such as discussions, investigations, and field trips to a butterfly park, representing knowledge gained and creating exhibitions. The chosen project theme is 'Colors of Food,' where children pursue their curiosity by exploring the hues derived from different foods and the processes involved in extracting colours from fruits and plants.

Higher Order Thinking Skills (HOTs)

In this study, HOTs refer to three dimensions: the transfer process, the critical thinking process, and the problem-solving process (KPM, 2014; Brookhart, 2010). Preschool children must understand and use what they have learned, which is considered a transfer process. As a critical thinking process, children need to decide what to believe and do, which involves logical and reflective thinking. As a problem-solving process, children will solve problems they identified.

Past studies have shown the effectiveness and benefits of PbL in promoting HOTs among learners (Moallem, 2019; Bilgin et al., 2015; Catapano & Gray, 2015). For example, some studies showed a positive relationship between PbL engagement and academic achievement (Han et al., 2015) and more excellent long-term knowledge retention (Karaçalli & Korur, 2014). However, these studies also pointed out that the positive result is dependent upon the teacher's skills.

HOTs can be defined in different ways. According to the Malaysian Education Blueprint (MOE, 2013), HOTs are the ability to apply knowledge, skills, and values in making sense and reflecting to solve problems, make decisions, innovate, and create something new. Table 1 explains each skill.

Table 1

Thinking Levels in HOTs (MOE, 2017)

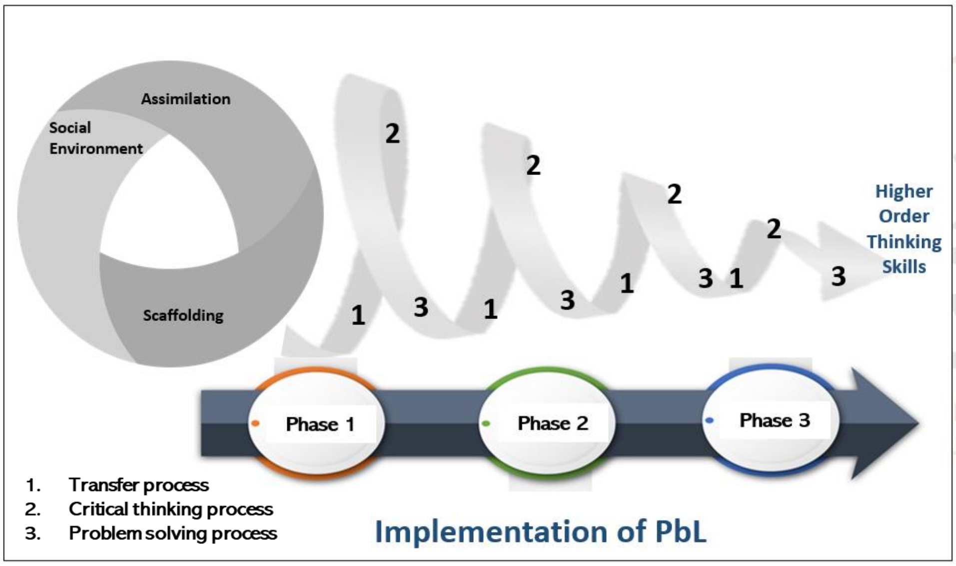
HOTs Skills	Explanation

Application	Using knowledge, skills, and values in different situations to complete tasks.
Analysis	Ability to break down information into smaller parts to understand and connect these parts.
Evaluation	Ability to consider and make decisions using knowledge, experience, skills, and values and justify decisions made.
Creation	Produce creative and innovative ideas, products, or methods.

After synthesising the literature about PbL and HOTs mentioned above, this study offers an alternative solution in the form of a conceptual framework for HOTs empowerment through PbL, as shown in Figure 2.

Figure 2

Conceptual Framework - HOTS empowerment through PbL



Assimilation is a crucial aspect of the learning process in PbL and is closely tied to the principles of constructivism. This learning theory emphasises the active role of learners in constructing their knowledge. During the implementation of PbL, children are expected to develop their thinking skills through an assimilation process through which they integrate new knowledge, skills, and experiences into their existing understanding or cognitive framework. In this study's framework, Lev Vygotsky's sociocultural development theory and the concept of scaffolding are interwoven to enrich the PbL experience within a social environment. Vygotsky's theory underscores the indispensable role of scaffolding amidst a rich social environment. Teachers and peers play pivotal roles in guiding children through their projects, fostering collaborative learning, and creating a context where knowledge construction (in this study, HOTs) is a collective and dynamic process. The process of gaining HOTs is spiral in nature.

Methodology

This case study uses a qualitative approach to describe how PbL was used to promote HOTs in preschool classrooms. A descriptive case study design (Yin, 2009) was used in this project to gain a deep understanding of actual classroom situations and formulate analytical generalisations. In this study, the researcher cooperated with a participating preschool teacher to brainstorm on a proper project. It was decided to use "Colors in Food" as a focal theme, aligning with both the children's interests and the aim to foster real-world issues. The participating preschool teacher took responsibility for implementing the designed module. The findings of this case study are based on observations from children's journals, video recordings, interviews, and pictures taken during PbL. At the end of the project, children could create something new that is a natural colour essence extracted and saturated from natural ingredients such as butterfly pea flowers, yellow gardenia flowers, beetroots, and lemons. From the colour essence produced, children produced "Rainbow Noodles" that help reduce food waste among preschoolers.

Participants

This study's participants were preschool teachers (with more than three years of experience in implementing PbL) and twenty-five children (aged 5 to 6 years old). All the children's parents provided written consent for their participation. The purposive sampling method was employed to select the participants. This method is appropriate when selecting individuals for study when subjects are readily available and willing to participate (Creswell, 2012). The study was conducted from August 2022 to February 2023.

Data Collection

To establish “methodological triangulation” using multiple sources of data (Denzin, 2017), on-site observation, document analysis and in-depth interviews were conducted with teachers and children, respectively, to gain further insights on the PbL Classroom observation notes help to answer how teachers and children interact in their teaching and learning process as well as the development of children’s thinking skills, and audio-visual taped learning processes help to indicate the challenges and supports of the teacher in cultivating thinking skills.

Data analysis

This study analysed qualitative data using open coding and axial coding strategies (Corbin & Strauss, 2014). From the analysis of interview data, relevant themes were categorised, and general patterns were identified from the study of observation data. Additionally, documents were analysed to help clarify, complement, and even supplement analyses from the interview and observation data.

Research Objectives

This qualitative study aimed to explore a preschool teacher's lived experiences in using PbL to develop HOTs with preschool children. To this extent, the objectives of the study are:

1. How does PbL facilitate the development of HOTs in young children?
2. What challenges and barriers exist in implementing PbL and HOTs in preschool settings?

Findings

This section addresses RQ1 and RQ2. The data analysis revealed several themes regarding how PbL fosters HOTs, including prompting and modelling structured and open-ended questions and increasing inquiry-based activities. Both participating teachers and field experts corroborated these findings. During the project's process, from the beginning to the development stage and then to the finishing stage, HOTs were implemented occasionally. From the data collected, their skills improved during the learning process via PbL.

Prompting and Modelling Structured and Open-ended Questions

In the beginning stage of the project, preschool children were prompted and stimulated by a letter mentioning that the food provided in the class was wasted.

Figure 3

Letter of Complaint

Dear teachers and students,

Good day!

We are the kitchen helpers who used to cook for your meals in school. Recently we found that there was a lot of leftover food from your classes, and this caused a lot of food was wasted.

Many of the students did not finish their food especially every Tuesday, Thursday and Friday. Menu for these three days are plain noodles with mixed vegetables; Vermicelli with chicken soup; as well as mix vegetables porridge.

We know that all of you are helpful, creative and dedicated in solving problem. Can you help us to find out the causes of the problem and propose us a good solution for this problem?

Thank you so much!

Cikgu Linda and Cikgu Ayu

To address the issue, they were guided through a series of questions to identify the underlying problem they encountered. They visited the kitchen to understand the problem of "food waste". This was considered a "critical thinking process". During this stage, the participating teacher prompted the children with the following questions: What food was wasted most daily? Why was the food wasted? How much food was wasted? How much was wasted in a day? With all the questions asked by the teacher, the children planned a visit to the kitchen and interviewed the kitchen helper personally. At this stage, children go through a critical thinking process. They had to categorise the information given by the kitchen helper and decide on who and how to get further information.

Figure 4

Output – Children took the photo above to prove the food wasted

Following their encounter with the kitchen helper, the children resolved to survey their peers, seeking insights into the reasons behind uneaten food. During this process, it was found that preschool children can learn how to ask questions and communicate with kitchen helpers and peers to get answers and data. The decision to use interviews and pictograms to record their interview findings reflects children's engagement in the problem-solving process. This process enabled them to find the causes of the food waste problem and design their solution.

Figure 5: Rui investigated the causes of the problem by interviewing peers.

With little guidance, the children, Yuruii (YR), learned to investigate and ask questions (peers). Jie Yu (JY):

YR: 你做么不要吃这个面？ 不好吃么？

JY: 那个面很白，我的妈妈煮不是白色的。

Translation: YR: Why didn't you finish these noodles? Are they not tasty?
JY: The noodles look plain. My mom does not cook them this way.

YR: 白色不好吃么？ 你喜欢怎样的？

JY：我喜欢美一点的颜色，还是黑色的面也可以，但是不要白色的。

Translation: YR: Is plain, not tasty? What do you like?
JY: I prefer noodles with more appealing colours. Black sauce noodles are fine, but not plain ones.

YR: 要怎样你才会喜欢吃？

JY: 很美的啦我喜欢，我不喜欢吃菜菜，看到菜菜我就不要吃了。

Translation: YR: What can I do to ensure you like eating them?
JY: I like vegetables when they look nice. I don't like eating vegetables, so if there are vegetables, I won't eat them.

In the discourse with their peers, it became apparent that modelling the art of questioning and articulating responses is a pivotal technique in cultivating HOTs among children. This approach has children explain their thinking, and questioning is crucial to pushing HOTs. In this case, answering and asking higher-order levels' questions enables the children to apply their current knowledge to daily life by gathering information, making connections, detecting the cause of the problem, and then suggesting a solution to improve the situation during the transfer process.

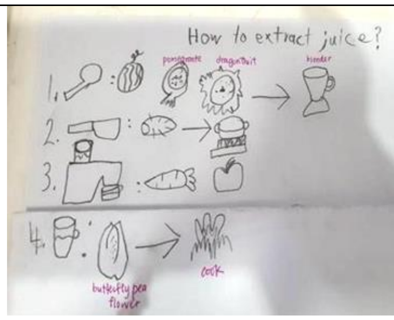
Increase Inquiry-based Activities

From the observation, it was found that inquiry-based learning activities engaged children in deep learning. In this project, children used their prior knowledge. For example, colours can be produced from vegetables or fruits, as the knowledge was constructed by themselves while conducting observations and experiments. For example, during Phase 2: Developing project, children discussed and decided types of fruits and vegetables to be used to extract juice with proper tools and manners. Through the activities, children engaged in a more profound thinking process. They tested and made conclusions about the following:

1. Which plants should be chosen as ingredients to produce colours? For example, green apple, spinach, broccoli and *pandan* leaves. Which plants would provide their ideal colours?
2. How can you extract the juice/colour from plants with tools? (Cut, juicer, cruncher, dig by spoon, etc.)

The teacher created these questions to guide and direct inquiry activities. Children engage in prediction, explanation, hypothesis formation, design, and task direction throughout the inquiry process. Most tasks during this phase require hands-on, experimenting, testing, and synthesising. Children are encouraged to formulate and refine questions, devise plans, design experiments, conduct analyses, exchange ideas, and interpret data. Throughout this problem-solving process during PbL, children attended many experiential learning opportunities, for example, extracting juice from different types of fruits or vegetables using various activities aimed to provide students with more opportunities to investigate, empathise with, and comprehend the problem in new ways.

Figure 6
HOTs emerged during inquiry-based activities.

	
Decision Making: Types of fruits and vegetables	Analysis: Compared different types of sweet potatoes
	
Testing: Equipment to extract the juice	Synthesising: Process of Colour extraction

Diversity of Tools and Materials

Throughout Phase 2, children engaged and discovered various tools and methods to extract juices. This problem-solving process in PbL has strengthened the critical thinking skills among children. In this study, children were allowed to experiment with various tools and apparatus when extracting the juice from fruits and vegetables. These opportunities promote active learning in which they interact directly with materials (fruits and vegetables brought) and tools such as juicer, cruncher, spoon, blender, and steamer. With various tools, children started to observe, analyse, and draw conclusions from their observations and experiences to choose a better way of performing tasks (Figure 7).

Figure 7

Discovering a varied range of tools and materials during PbL

			
Crunch yellow gardenia flowers.	Crunch yellow gardenia flowers.	Utilise a juicer to extract juice from the prepared ingredients.	Utilise a juicer to extract juice from the prepared ingredients.

With the freedom of tool selection, children had to analyse and compare the most appropriate tools and methods for extracting juices. This decision-making process required them to assess the advantages and drawbacks of each option, thereby nurturing critical thinking and problem-solving skills. Collaboration among children further enriched the process, as their diverse insights and knowledge, rooted in varied methodologies, compelled them to weigh the merits and demerits of multiple approaches, ultimately guiding them to select the most optimal solution.

Encourage Knowledge Application and Productive Output

The learning processes during this project, such as the application of knowledge and productive output, were found helpful in promoting HOTs. Through observation, it was evident that children engaged in activities, including problem identification, colour extraction, and noodle-making, culminating in producing colour essence, which addressed their initial challenge. For instance, children investigated factors contributing to food waste, conducted interviews, analysed collected data, and ultimately devised solutions. These processes developed their ability to think beyond the surface and generate new ideas. With the ideas they generated, children also tested their ideas in producing colour from plants and finally came up with colour essence in making rainbow noodles. Throughout this endeavour, children continuously tested and evaluated their hypotheses, refining their critical and creative thinking abilities.

***Figure 8*:**
Testing on how many flowers are needed to get better colour

Throughout the production of colour essence, children engaged in research, data analysis, and evidence-based reasoning, all integral components of HOTs (Figure 9).

Figure 9
Children invented colour essence as a product that allowed children to research real-world problems (healthy and convenient lifestyle)

Challenges

Measuring the Learning Outcomes

Through project-based learning, it is essential to assess children's progress and the effectiveness of their learning experiences. PbL actively engages children in real-world problem-solving and knowledge application, prompting various assessment methods to gauge their growth. However, during PbL implementation, the participating teacher raised concerns regarding outcome measurement. It was noted that comprehensive rubrics should be devised to delineate specific skills and attributes to be assessed in the project. These rubrics should cover content-related abilities like research, critical thinking, creativity and process-related skills like collaboration, communication, and time management.

Limited Resources

This project required many materials for the children to explore. The interview revealed that participant teachers faced financial problems in getting all the teaching and learning materials. Children needed to discover and test their ideas, such as how different types of fruits produce different colours and tastes. Thus, much money was spent. To secure additional resources, the teacher collaborated with parents, community organisations, and local businesses, seeking cost-effective, innovative alternatives to facilitate enriching higher-order thinking experiences.

Discussion

The findings of this study show that empowering PbL is effective in enhancing HOTS, and this idea has been discussed in the previous study related to STEM education and HOTs (Ngadinem & Sulisworo, 2020). Findings showed that active participation in PbL requires many thinking skills, such as analysing the problems, evaluating their solutions, applying the skills, and creating products and ideas. For example, in this study, children unearthed significant insights into food wastage, scrutinised feasible remedies, and employed evidence-based reasoning to make informed judgments while tackling these challenges. This approach assists them in developing problem-solving abilities by improving their capacity to break difficult situations down into manageable bits and apply innovative solutions. These findings proved that PbL could benefit young children by boosting their problem-solving ability (Karan & Brown, 2022).

Furthermore, the findings of this study also indicated that asking good questions is crucial to making our learners think and relate their learning with real-world phenomena. Children were scaffolded to ask questions, seek solutions, and investigate topics independently. Following each activity, they convened to reflect on the process, successes, and setbacks encountered, fostering an environment conducive to inquiry and idea-sharing. All these processes provide an opportunity to ask questions and to share ideas. This approach cultivates a sense of ownership among students regarding their learning journey, nurturing their capacity for critical and independent thinking (Trzaskowski, 2019). Through PbL, children collaborate on ideas, allocate responsibilities, and capitalise on one another's talents (Priyatni

& As'ari, 2019). This helps the children to develop interpersonal skills such as active listening, conflict resolution, and effective communication. Children learnt how to convey their discoveries and solutions to their peers and teachers and defend their decisions. The 21st-century skills (4Cs), namely communication, collaboration, creative and critical thinking, were infused into PbL learning.

Scaffolding plays a crucial role in PBL for aiding the development of higher-order thinking Skills (HOTS), and it is suggested to be formulated to develop HOTs among preschool children (Alrawili et al.; K. S., 2020). Scaffolding is the assistance and direction teachers provide to assist children in learning and doing activities that are initially above their existing skills. Teachers help children develop meaningful questions and guide them through the research process to scaffold PbL. In this study, the teacher encourages children to pursue more profound levels of investigation and thinking skills through scaffolding. Children are urged to document their questions and answers, regardless of their perceived complexity, fostering an environment where their contributions are acknowledged and valued, alleviating any hesitancy to participate. During the process, teachers may initially assist with such activities or resources. However, as children gain proficiency, teachers gradually step back, allowing students to take more ownership of their learning and problem-solving processes.

PbL assessments go beyond traditional exams and tests, focusing on a holistic evaluation of learners' skills, abilities, and personal growth (Helm & Katz, 2016). Therefore, some studies suggested using rubrics with clear expectations and criteria for evaluating different aspects of the project (KPM, 2019). Peer and self-review throughout the project are also essential to engage deep learning among children (Yu, 2013). Peers' feedback and self-reflection helped the children evaluate their work and enhance their communication skills and awareness of their strengths and areas for improvement (Chyung et al., 2017).

Conclusion

In conclusion, implementing PbL in preschool settings enables children to engage in hands-on and child-directed activities, fostering essential skills such as critical thinking, problem-solving, and creativity. By exploring real-world subjects that interest them, preschoolers can develop and cultivate HOTs, which will prove beneficial throughout their academic journey and beyond. In the future, the outcomes of this study could also catalyse researchers to expand their investigations, encouraging more teachers to embrace PbL with younger learners and other underserved communities. Additionally, these findings encourage educators to prioritise formative assessment practices within PbL frameworks, fostering continuous growth and development among students.

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