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Implementation of Computational Thinking Activities in Teaching and Learning of Mathematics Primary Schools

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Abstract

Computational thinking skills are no longer unfamiliar in mathematics education. Various activities have been carried out to integrate thinking skills into the teaching and learning of mathematics. However, studies on the implementation of computational thinking activities in mathematics teaching and learning are still lacking in Malaysia, especially at the primary school level. Therefore, this concept paper discusses the implementation activities that can be used by teachers while teaching and learning mathematics. There are three categories of computational thinking activities: plugged-in, unplugged, and a combination of both. This concept paper also discusses the importance of implementing computational thinking activities, which can enhance problem-solving skills, improve mathematical reasoning skills, and increase pupils' motivation in STEM education. The findings of this concept paper can provide guidance and knowledge to educators, especially teachers, in implementing computational thinking activities in mathematics teaching and learning in primary schools. Mathematics teachers can select suitable computational thinking activities based on pupils' proficiency levels and the classroom environment. Further research is required to investigate the impact of implementing computational thinking activities in teaching and learning mathematics.

Keywords: Primary School, Computational Thinking, Concept Paper, Mathematics, Activities

Introduction

In today's rapidly evolving world, computational thinking skills have become essential for pupils navigating the challenges of 21st-century education and the Fourth Industrial Revolution (IR 4.0). Integrating computational thinking into mathematics education can enhance pupils' problem-solving abilities, critical thinking skills, and deepen their comprehension of mathematical concepts. Mathematics education plays a pivotal role in equipping pupils with disciplinary and logical skills. Computational thinking also underscores the utilization of computational tools and problem-solving strategies to enrich mathematics learning. This holistic approach to computational thinking involves analyzing problems and designing appropriate problem-solving methods, applicable across various disciplines, for both conceptual understanding and problem-solving (Wing, 2008). By implementing computational thinking in mathematics education, pupils can cultivate a comprehensive grasp of mathematical concepts alongside honing their problem-solving skills.

The implementation of computational thinking skills in teaching and learning mathematics is crucial in today's educational landscape. However, integrating new skills into education, particularly in mathematics, presents challenges. According to Reichert et al (2020), computational thinking skills are notably difficult to incorporate into mathematics education. Furthermore, the pressure on mathematics teachers to cover the curriculum within designated timeframes often results in limited application of computational thinking skills in teaching and learning mathematics. Compounding this issue is the misconception among some teachers regarding the concept of computational thinking. Many perceive it solely in terms of computer or technology usage, especially those lacking proficiency in technology, such as experienced teachers belonging to the older generation, as noted by (Abdul Halim, 2020). This misunderstanding overlooks the broader application of computational thinking beyond computer-based activities.

Moreover, there is a lack of smoothness in implementation since teachers find it challenging to modify their methods for teaching mathematics while integrating computational thinking skills. When teachers take a long time to prepare and construct lessons, it might cause disruptions to the teaching process (Israel & Lash, 2020). Teachers play a crucial role in preparing pupils for the future by equipping them with computational thinking skills. Furthermore, teachers can effectively nurture these skills in their pupils by using teaching models related to computational thinking skills. Teachers can be supported by utilizing teaching models based on findings and references of previous studies. It is recommended that teachers attempt implementing these tried-and-tested designs into their lessons (Yusof et al., 2020). These teaching models can help teachers improve their computational thinking skills through teaching mathematics.

Computational thinking activities can also be implemented in teaching mathematics to help teachers better guide their pupils in finding new solutions. According to Asarani and Yassin (2020), computational thinking helps teachers improve certain practices in teaching and learning activities, enriching teaching techniques and pupil exploration. However, some teachers who are not interested in mastering these skills may find it challenging to implement computational thinking activities. This reluctance is due to the perception among some teachers that computational thinking is difficult to implement in the classroom. This sentiment is supported by Humble and Mozelius (2023), who found that some mathematics teachers perceive computational thinking as more advanced and struggle to integrate such activities into their teaching of mathematics.

To address these challenges, it is essential to conduct a thorough conceptual study to identify categories of computational thinking activities suitable for teaching and learning mathematics. These activities should encompass various approaches tailored to meet the needs of current mathematics teachers. Additionally, it is imperative to emphasize the significance of incorporating computational thinking activities in mathematics education to enhance pupils' problem-solving skills, critical thinking abilities, and overall mathematical proficiency.

Theoretical Framework

Theoretical frameworks serve as the theoretical basis, providing a particular perspective for a study (Nik, 2014). The primary focus of this study is to identify various types of computational thinking activities categorized according to their implementation in teaching and learning mathematics, followed by a discussion of their significance. To ensure effective teaching and meaningful learning outcomes, diverse implementations of computational thinking activities have been incorporated. The theoretical framework, as illustrated in Figure 1, integrates Computational Thinking Skills Wing (2006) and Constructivism Theory (Vygotsky, 1978).

Wing (2006) defines computational thinking as the process involved in formulating problems and designing solutions that can be implemented by information processing agents. Additionally, computational thinking skills consist of basic concepts such as algorithms, problem-solving, pattern recognition, and scaling. Constructivism Theory Vygotsky (1978) emphasizes social interactions and collaborative learning, where pupils work together to construct knowledge. Pupils can develop computational thinking skills through teaching and learning mathematics. Furthermore, the various types of computational thinking activities implemented in teaching and learning mathematics will be categorized into three methods: activities using computers (plugged in), activities without computers (unplugged), and a combination of both (plugged in and unplugged) (Wan & Effendi, 2023).Through the implementation of computational thinking, numerous benefits to mathematics education are anticipated, which are expected to have a positive impact on all aspects..

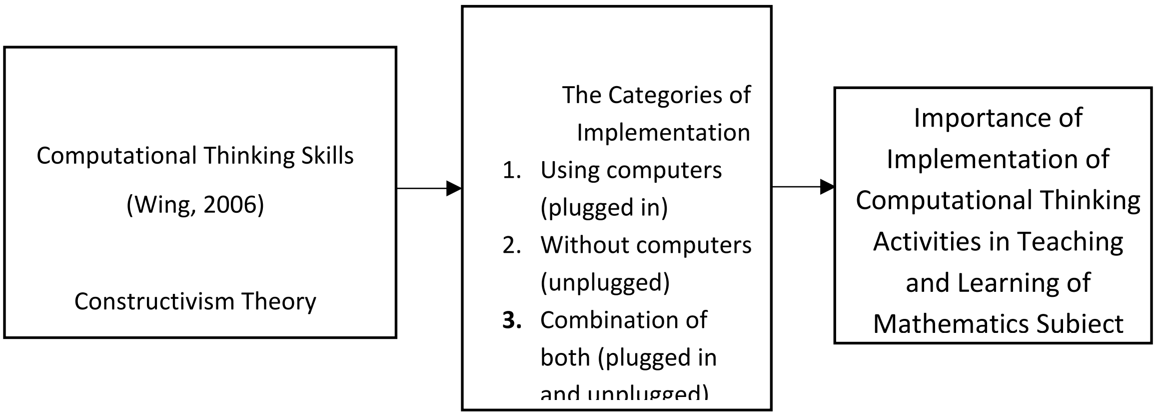

Figure 1: The theoretical framework of the theory of the activity of computational thinking in the teaching and learning of mathematics subjects.

The Categories Of Implementation Computational Thinking Activities In Teaching And Learning Of Mathematics Subject

Activities Using Computers (Plugged in)

The first category in implementing computational thinking is through activities using a computer (plugged in). These activities have the potential to enrich pupils' learning experiences and facilitate a deeper understanding of mathematical concepts. There are three primary plugged-in mathematical thinking activities in teaching and learning mathematics involving computers: programming, simulation, and data analysis.

Programming serves as one of the plugged-in computational thinking activities, enabling pupils to familiarize themselves with programming languages such as Python or Scratch (Brating & Kilhamn, 2021). Pupils can learn computational thinking practices and skills through a mix of game-based learning, collaborative learning, and project-based learning using Scratch applications (Nur, 2020). Furthermore, pupils can write programs to solve mathematical problems while actively engaging in the learning process. This approach empowers them to apply mathematical concepts using computational thinking skills. For instance, pupils can develop programs to calculate Fibonacci numbers or solve equations through iterative methods.

Simulation is another essential plugged-in activity, where pupils can utilize computer simulations, including Augmented Reality software, to illustrate mathematical concepts (Abdul Hanid et al., 2022). By manipulating variables and observing resultant changes, pupils can explore the relationships among mathematics, patterns, and functions. This interactive approach aids pupils in grasping abstract mathematical concepts by providing tangible, real-world learning experiences.

The final plugged-in activity is data analysis and visualization, where various computer software packages can analyze and interpret datasets. Pupils can learn statistical concepts such as mean, median, and standard deviation using real-world data. Additionally, they can create visual representations like graphs and charts to effectively communicate their findings. This approach enables pupils to bridge the gap between mathematical concepts and real-life applications.

In conclusion, the implementation of plugged-in computational thinking activities in teaching and learning mathematics is highly suitable for classroom settings. However, as highlighted by Majumder et al (2020), the use of technology in classrooms may encounter challenges such as computer malfunctions, limited internet access, or outdated hardware that may lead to delays in software operation. Therefore, schools, particularly teachers, must ensure the availability and functionality of adequate computer resources to prevent any disruptions in the teaching and learning of mathematics.

Activities Without Using Computers (Unplugged Activity)
Although computers are valuable tools for conducting computational thinking activities, pupils can engage in computational thinking without them. Teachers can facilitate unplugged computational thinking activities that do not require computers, such as employing algorithmic thinking elements, utilizing game-based approaches, and using concrete teaching aids. Unplugged activities are typically suitable for preschool or elementary school pupils, as supported by Humble et al (2020), who state that unplugged activities are appropriate for younger learners.

One unplugged activity in computational thinking for teaching and learning mathematics involves applying algorithmic thinking. For instance, pupils can solve sets of questions using the Polya problem-solving method. This task encourages pupils to think algorithmically by breaking down complex mathematical problems into manageable steps. Additionally, teachers can prompt pupils to use flowcharts or drawings to illustrate their thought processes, thereby enhancing their problem-solving and organizational skills.

Furthermore, teachers can incorporate mathematics into games as another unplugged activity. Engaging pupils in mathematical games fosters critical thinking and the application of mathematical concepts. Modern games like Robot Coding Toy activities Welch et al (2022) or traditional games such as sudoku, chess, or tangram promote logical thinking and pattern recognition. Teachers can also integrate computational thinking into Game-Based Learning (GBL) for topics like basic operations such as multiplication in year three (Dazid & Yatim, 2020). Computational thinking in GBL involves activities like constructing a cipher table using the Tic Tac Toe game box, followed by testing pupils with mathematical problems involving multiplication operations using the learned methods.

Finally, teachers can utilize concrete materials in mathematics to conduct unplugged computational thinking activities. These materials, such as wooden bars, clocks, or geometric shapes, help pupils grasp abstract mathematical concepts. According to Hynes et al (2019), unplugged activities offer pupils tangible experiences and early exposure to mathematical concepts before encountering more complex topics in the future. Utilizing concrete materials for unplugged computational thinking activities in mathematics can enhance pupils' understanding of computational concepts and their application in mathematics problem solving.

In conclusion, computational thinking activities in teaching and learning mathematics can be effectively implemented without computers. Such activities cater to pupils who may not be proficient with computers, ensuring that technological constraints such as computer availability do not hinder teachers from incorporating computational thinking activities into mathematics education.

Activities With and Without Using Computers *(Plugged In Activity and Unplugged Activity)*
Implementing a combination of plugged-in and unplugged activities can significantly enhance the comprehensiveness and meaningfulness of teaching and learning mathematics through the integration of computational thinking (Araya et al., 2022; Bouck & Yadav, 2022; Chan et al., 2021). This approach enables teachers to leverage a wide range of resources to ensure effective implementation of mathematics education. However, despite the benefits of combining these activities, teachers may encounter constraints that hinder their implementation in teaching and learning mathematics. Nonetheless, there are strategies that teachers can employ to overcome these challenges, such as adopting a combined approach and implementing project-based learning.

In utilizing a combination of plugged-in and unplugged activities, teachers can employ a blended learning approach by integrating online resources with traditional face-to-face instruction. For instance, teachers may assign online activities through platforms like Google Classroom or Group Telegram for homework, while facilitating in-person discussions during mathematics sessions. This approach accommodates diverse learning styles and allows pupils to progress at their own pace while receiving guidance and support from their teachers and peers.

Additionally, teachers can incorporate project-based learning activities into their instruction. This engaging approach integrates mathematical concepts with computational thinking skills. For example, teachers may conduct unplugged activities in the classroom to introduce mathematical concepts, followed by plugged-in activities using software to reinforce pupils' understanding during mathematics lessons. This collaborative and creative approach fosters critical thinking skills while reinforcing mathematical concepts.

By implementing computational thinking activities through a combined approach of plugged-in and unplugged activities, pupils can develop a strong foundation in mathematics concepts and enhance their proficiency in utilizing technologies such as computers. This integrated approach not only enhances pupils' mathematical skills but also prepares them to navigate the increasingly digital landscape of the 21st century.

Importance of Implementation Computational Thinking Activities in Teaching and Learning of Mathematics subject

Implementing computational thinking activities in teaching and learning mathematics yields numerous benefits and positive impacts. First and foremost, it enhances problem-solving skills among pupils (Ersozlu, 2023). Computational thinking emphasizes elements such as algorithmic thinking, logical reasoning, decomposition, pattern recognition, and generalization. It helps pupils think deeply, employ efficient problem-solving strategies, and apply mathematical concepts effectively in real-world scenarios. Computational thinking promotes deep learning in pupils by having them break down mathematics problems into simpler subparts and identify patterns to solve problems (Hunsuker, 2020). Pupils' knowledge and use of mathematical topics are greatly improved via computational thinking. Studies have indicated that the inclusion of computational thinking can have a positive effect on pupils' learning, encouraging the development of new mathematical knowledge, systems thinking, and problem-solving abilities.

Furthermore, computational thinking contributes to the improvement of mathematical skills. Engaging in computational thinking activities requires pupils to analyze data, establish relationships, identify patterns, and develop logical thinking (Nordby et al., 2022). By honing these computational skills, pupils also enhance their problem-solving abilities, engaging in higher-level thinking processes. Moreover, implementing computational thinking skills fosters increased motivation for mathematics. The practical and relevant nature of computational thinking approaches in mathematics enables pupils to apply mathematical concepts meaningfully. Additionally, computational skills afford opportunities for diverse activities such as practical exercises, project-based learning, and educational games, thereby making learning more engaging and impactful, ultimately enhancing pupil achievement.
Implementing computational thinking activities in mathematics is essential for developing cross-disciplinary skills. Computational thinking is not limited to computer science but is a skill set that can be applied across various subjects (Chan et al., 2023). Pupils benefit from computational thinking activities in mathematics to prepare for potential careers in STEM fields, equipping them with problem-solving skills and logical reasoning abilities. By

implementing computational thinking activities in primary school mathematics, pupils can develop a versatile skill set that can be applied in diverse fields and future endeavors.
Lastly, motivation and perception play crucial roles in pupils' ongoing enjoyment of studying mathematics and other Science, Technology, Engineering, and Mathematics (STEM) fields. The integration of computational thinking skills serves as a bridge to STEM education and careers (Ye et al., 2023). By familiarizing pupils with fundamental concepts and skills like programming and algorithmic thinking, computational thinking in mathematics education not only cultivates interest in STEM disciplines but also addresses the growing demand for technology-related skills in various professional fields.
In conclusion, integrating computational thinking skills into teaching and learning mathematics aligns with the learning demands of the 21st century and the requirements of Industry 4.0 (IR 4.0). This implementation promotes critical thinking, creativity, collaboration, and effective communication among pupils. Engaging in computational thinking activities throughout mathematics education equips pupils with essential skills to navigate the challenges of contemporary learning environments and the rapidly evolving landscape of IR 4.0, ensuring their preparedness for success in the modern world.

Conclusion

The implementation of computational skills in teaching and learning mathematics encompasses various activities, categorized into three parts: plugged-in, unplugged, and combined. Each approach offers a holistic method to enhance mathematical understanding. Unplugged activities introduce teaching aids and mathematics games, fostering real and meaningful experiences to develop creative thinking and mathematical refinement. However, the most effective approach is to combine both types of activities. This combination allows pupils to integrate technology with practical experience, maximizing the benefits of each approach. Teachers should integrate plugged-in and unplugged activities to provide pupils with a comprehensive and meaningful learning experience. Through this combination, pupils can develop digital literacy skills, critical thinking, creativity, problem-solving abilities, and a deep understanding of mathematics.
Teachers play a crucial role in selecting appropriate activities and providing support and guidance to ensure pupils benefit fully from these activities. By implementing this approach, teachers can create an engaging and relevant learning environment, fostering various interests and supporting pupils in developing academic and professional skills for the future. Introducing computational thinking skills in teaching and learning mathematics is expected to continue optimizing the potential benefits of this innovative approach to mathematics education. Further research is needed to explore and enhance the effectiveness of this approach in mathematics education.

This concept paper is intended to make a significant contribution to the field of education, specifically in the context of mathematics teaching and learning at the primary school level. By exploring the integration of computational thinking activities in mathematics education, this paper concept aims to provide valuable insights into how such activities can enhance students' problem-solving skills, mathematical reasoning abilities, and overall engagement in STEM subjects. This concept paper also contributes theoretically by exploring computational thinking skills and constructivism theory in the context of mathematics education. It also providing practical insights for educators in primary schools to enhance teaching practices and student outcomes in STEM education.

There are some practical implications for teachers by highlighting the importance of computational thinking activities. Teachers can improve their teaching practices and student engagement by emphasizing the benefits of computational thinking in mathematics education. Besides that, this concept paper will play a vital role in preparing students for the challenges of the 21st century and (IR 4.0). Students will be prepared with essential skills such as algorithmic thinking, problem-solving, and logical reasoning, which are increasingly important in a technology-driven world. Finally, implementing computational thinking activities can foster increased motivation for mathematics and other STEM fields among students. By making learning more engaging and impactful through practical exercises, project-based learning, and educational games, computational thinking activities play a crucial role in enhancing student achievement and interest in STEM disciplines. It plays a vital role in promoting computational thinking in primary school mathematics education and equipping students with essential skills for success in the digital age.

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