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Assessing the Influence of Computational Thinking Technique on STEM Based and Non-STEM Based Subjects in Sarawak Schools

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ABSTRACT

Computational thinking (CT) has gained prominence as an essential skillset in the digital age. This study investigates the influence of integrating CT techniques into both STEM and non-STEM subjects in schools across Sarawak, Malaysia. A mixed methods approach combined surveys of 426 students and 79 teachers with interviews of 5 teachers and 8 students. Results indicate CT integration enhanced problem-solving skills, logical reasoning, and critical thinking. Over 50% of teachers reported improved student performance in STEM and non-STEM subjects with CT techniques. Interviews highlighted benefits like increased engagement, but also challenges faced regarding teacher training, resources, and curriculum integration. Recommendations include focused teacher professional development, ensuring equitable access to technology, tailored curriculum approaches, and cultural sensitivity. This study provides insights into the multifaceted impacts of CT integration in the Sarawak education context. The blended findings underscore the potential of CT to develop relevant 21st century skills, but also highlight the need for systemic support for effective implementation. This research contributes to strategic efforts to nurture computational literacy and harness the power of CT across all subject areas within the region's schools.

Keywords: Computational Thinking and Computer Science, STEM, Non-STEM, education, integration

INTRODUCTION

Starting from 2017, the Faculty of Computer Science and Information Technology (FCSIT) at Universiti Malaysia Sarawak (UNIMAS) officially became the MyDigital Maker Continuing Professional Development (CPD) Center (MYDM), recognized by the Malaysian Digital Economy Corporation (MDEC). Since then, MYDM has been dedicated to improving digital skills, especially in computational thinking (CT) and computer science (CTCS). MYDM's work includes various activities. They offer a special certification program for teachers, organize exciting events focusing on digital creativity, programming, and robotics for students, and act as a hub for Digital Making in East Malaysia's Sarawak region.

From 2017 to 2020, around 309 teachers from 246 different schools took part in MYDM's CTCS Teaching certificate program. These schools included places like SM Sains Kuching, SMK Siburan, SMK Pusa, and many more, covering a wide area from Kuching to Lawas. The program's core is a 40-hour in-person training, followed by two assignments to test teachers' skills in applying CT and programming. This leads to official recognition of their teaching abilities, aligned with the new ICT Standard Curriculum for Primary and Secondary Schools, which started in 2017 for certain grades.

In an era characterized by rapid technological advancement, the integration of CT techniques into educational contexts has gained prominence as a transformative approach to learning. Computational thinking, as described by Smith (2020) involves a structured problem-solving methodology that draws from algorithmic thinking, pattern recognition, abstraction, and decomposition. Beyond its conventional association with computer science, CT holds the potential to enhance cognitive skills applicable across various domains, whether in Science, Technology, Engineering, Mathematics (STEM) or non-STEM based subjects. As education evolves to prepare students for the complexities of the digital age, the impact of CT techniques on both STEM-based and non-STEM-based subjects within schools in Sarawak warrants thorough examination. This paper seeks to unravel the multifaceted influence ofCT techniques on learning outcomes, engagement levels, and the broader educational landscape in Sarawak. As the region endeavours to position itself as an educational pioneer, understanding the implications of integrating CT techniques stands as a critical effort in shaping effective pedagogical practices and fostering innovative problem-solving abilities among students.

LITERATURE REVIEW

The integration of CT and computer science (CS) techniques into the education has gained traction in response to the accelerating pace of technological advancement (Wing, 2006). CT involves a structured approach to solving problems, utilizing algorithmic thinking, pattern recognition, abstraction, and decomposition. Beyond the association with computer science itself, CT offers potential benefits for cognitive skill enhancement across diverse domains (Barr & Stephenson, 2011). As the education landscape adapts to the demands of this digital age, investigating the impact of CT techniques on both STEM and non-STEM subjects in Sarawak's schools is necessary. CT skills can be valuable and effective in various contexts and not limited to the scope of programming alone. CT fosters logical reasoning, problem-solving capabilities, and systematic approaches to challenges (Bundy, 2007). Such skills align with the educational goals of critical dan creative thinking skill known as *Kemahiran Berfikir Aras Tinggi* (KBAT) among students. Furthermore, incorporating CT into STEM subjects has shown promise. It promotes inquiry-based learning, enhances students' computational literacy, and encourages deeper understanding of scientific concepts (Resnick et al., 2014). The transdisciplinary nature of CT affords opportunities to bridge STEM disciplines and enhance cross-domain problem-solving.

On the other hand, for the non-STEM subjects that often regarded as distinct from technology also can benefit from CT integration. By engaging students in coding activities, CT can enrich their understanding of non-technical concepts (Grover & Pea, 2013). The "coding to learn" approach facilitates abstraction and decomposition, aiding concept comprehension. CT can also foster engagement among students, as coding projects provide a tangible context for learning. This pedagogical approach aligns with constructivist theories, emphasizing hands-on learning for knowledge construction (Papert, 1980).

Teacher professional development emerges as a crucial factor in successful CT integration. Effective pedagogical implementation requires educators to possess CT skills and understand its potential applications (Voogt et al., 2015). Professional development initiatives, as explored in Smith's (2021) research in the 'Journal of Educational Innovation,' have the potential to equip educators with the skills and knowledge necessary to craft lessons infused with CT, tailored to various subject areas. Moreover, curricular alignment is essential. Collaboration between curriculum maker, policy maker and educators ensure that CT activities harmonize with learning objectives, fostering a coherent educational experience. Assessing the impact of CT integration necessitates appropriate evaluation methods. Performance-based assessments, self-assessment tools, and rubrics designed for problem-solving processes are being explored (Brennan & Resnick, 2012). These evaluative mechanisms are designed to gauge not only students' proficiency in CT but also their capacity to transfer acquired the skills and their broader learning outcomes. Nevertheless, the development of comprehensive assessment mechanisms capable of encompassing the diverse dimensions inherent to CT remains a daunting challenge.

In the context of Sarawak, where education plays a important role in shaping the region's socio-economic development, integrating CT techniques carries significance. The digital landscape is reshaping societal demands, underscoring the need for students to possess relevant skills. CT integration aligns with Malaysia's national aspirations, propelling Sarawak towards technological advancement and innovation (MyDigital, 2020). Investigating the impact of CT techniques in Sarawak's education system is not only timely but crucial for understanding its potential to reshape learning outcomes and foster future-ready citizens.

In conclusion, the integration of CT techniques into education represents a dynamic response to the evolving technological landscape. CT holds the promise of enhancing cognitive skills, fostering problem-solving abilities, and bridging disciplinary boundaries. By investigating the impact of CT techniques on STEM and non-STEM subjects within Sarawak's schools, educators, policymakers, and stakeholders can gain insights into its transformative potential for education in the region. As Sarawak positions itself as a hub of innovation, understanding the multifaceted implications of CT integration is important in preparing students for the challenges and opportunities of the digital era.

METHODOLOGY

This research aims to investigate how the integration of CT techniques influences student engagement levels, which encompass their active participation, motivation, and enthusiasm for learning. Additionally, we aim to examine the broader educational landscape in Sarawak, considering factors such as curriculum integration, teacher professional development, equity and inclusion, economic and workforce development, and the engagement of various stakeholders in promoting CT into education. To achieve this, a mixed-methods approach is employed, combining quantitative and qualitative data collection and analysis techniques. By utilizing a mixed-methods design, this paper comprehensively investigates how CT techniques impact learning outcomes and engagement in Sarawak's education system. Considering this, we have formulated an initial study by conducting a survey involving 426 students and 79 teachers across Sarawak.

This is then followed by in-depth interviews with selected teachers who have agreed to participate. The selection of these teachers is from among the MYDM participants themselves. We also conduct interviews with students chosen by these teachers. Due to limitations in terms of location and time, we agreed to conduct virtual interviews with 5 different teachers and 8 students from selected districts and classes.

FINDING

The conducted survey revealed that more than half of the teachers indicated that the implementation of CT techniques in both STEM (Science, Technology, Engineering, and Mathematics) and non-STEM subjects effectively contributes to enhancing student performance. This is evidenced by the findings presented in Figure 1.

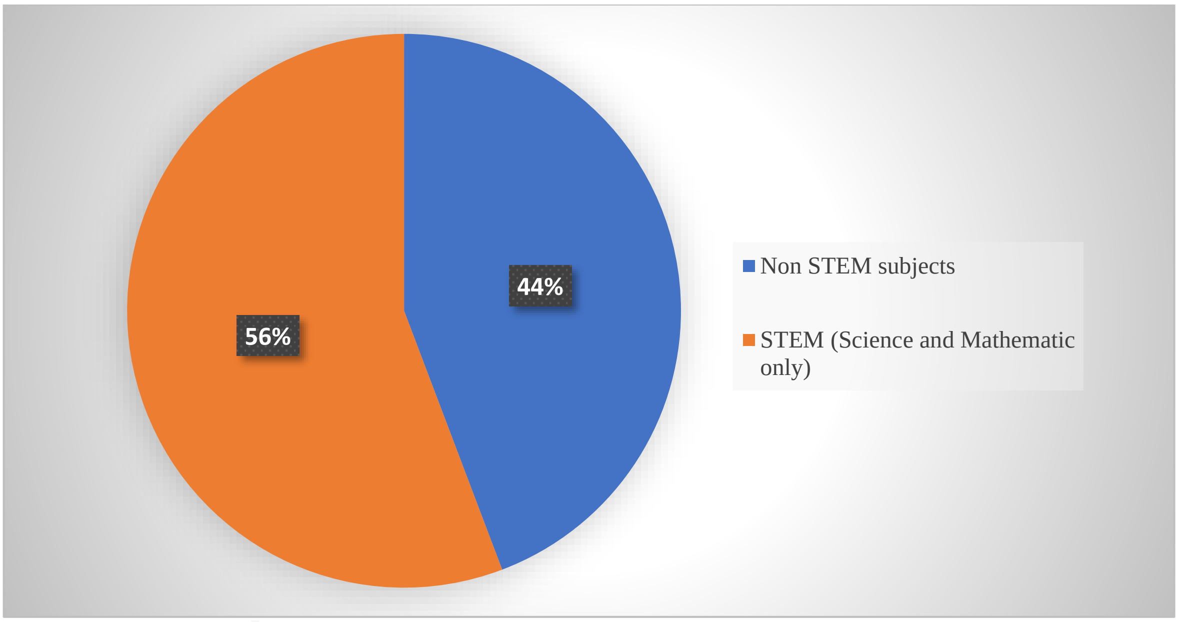

Figure 1: The total number of students taking STEM and Non-STEM subjects

These findings are corroborated by the results of our conducted interviews, where teachers affirmed that the implementation of CT techniques leads to an enhancement in students' problem-solving skills and fosters the development of their creative and critical thinking abilities. Teacher 2 expressed, "Allowing them to take initiative with simple instructions aids in their comprehension compared to traditional instructional methods where we simply deliver information, leaving us uncertain about their level of understanding."

Furthermore, teachers emphasized how exposure to CT in both STEM and non-STEM subjects improves students' problem-solving abilities. Teacher 4 emphasized that CT techniques greatly assist teachers in ensuring student comprehension. She continued, "When comparing CT techniques to conventional ones, students often lose interest when presented with lengthy, self-directed tasks. However, if they are guided to collaborate in groups, they can effectively tackle problems through discussions among themselves. I am convinced that CT techniques also contribute to a more precise understanding". This is further substantiated by the results of our survey in Figure 2, which found that 57% of teachers agree that student performance improves with the implementation of CT techniques.

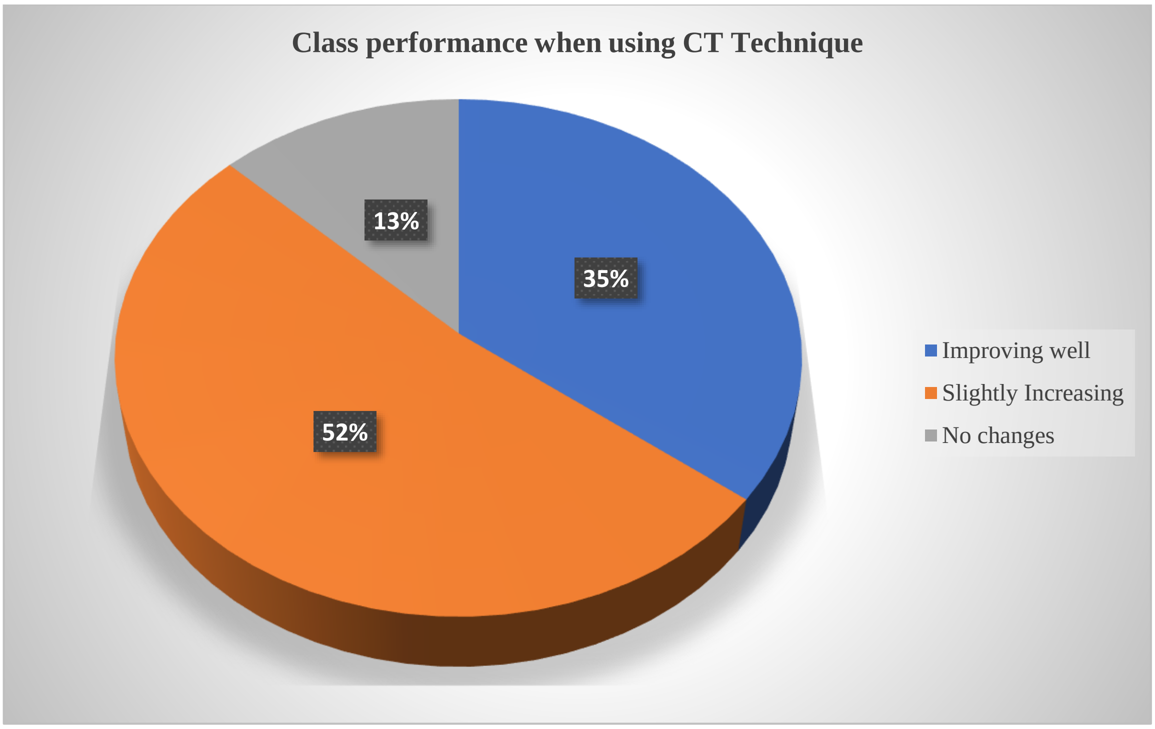

Figure 2: Class performance when using CT Technique

Teacher 3 also added, "Students learn a systematic approach to resolving complex problems, analyzing data, and generating effective solutions." All five teachers totally agree on the effectiveness of teaching and learning delivery to students with the integration of CT techniques. They are all in consensus that algorithms represent the most effective and comprehensible technique, regardless of the students' level.

Teacher 1, 2, and 5 support that the utilization of computational techniques results in increased enjoyment of STEM subject learning sessions among students. Conversely, in non-STEM subjects, CT techniques assist teachers in simplifying instructions for their students. Teacher 3 provides an example, stating, "For instance, when teaching Sirah, I guide students to identify key content to make it easier for them to remember and recall important dates in Islamic history." This illustrates how Teacher 3 indirectly employs decomposition techniques in teaching a non-STEM subject, ultimately enhancing student comprehension.

Teacher 4 lends support to the use of CT techniques in Physical Education (PJK), where students not only learn how to independently solve problems but also cultivate leadership skills. Students are empowered to select peers to lead their group, while other members collaborate to successfully complete specific tasks or sports projects.

The merging of CT into the curriculum has demonstrated a significant enhancement in students' creative and critical thinking skills, enabling them to approach intricate problems with innovative solutions. For instance, Teacher 4 emphasizes that employing the algorithm technique results in students becoming more meticulous problem solvers, as seen in sports activities during physical education where they carefully strategize their actions from the outset to secure victory. In addition, Teacher 2 assigned an unplugged task to students, requiring them to collaborate in pairs. This task was designed to deepen their understanding of abstraction techniques, as it necessitated that students grasp essential details before accurately conveying the information their partner had provided.

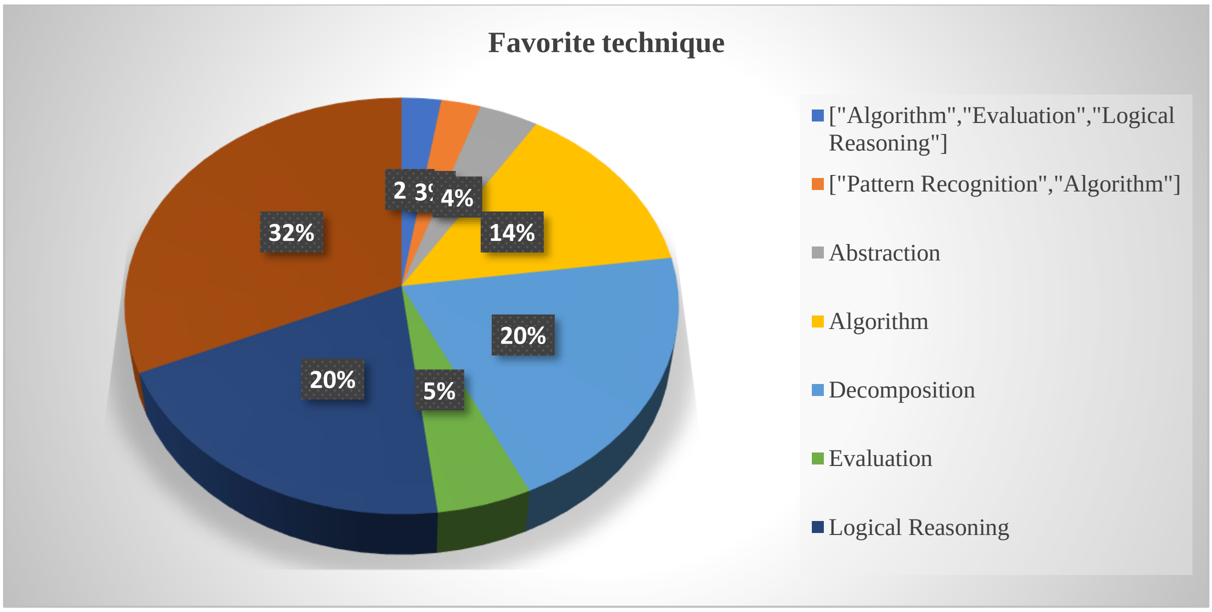

Figure 3: Most favourite CT technique among the teachers

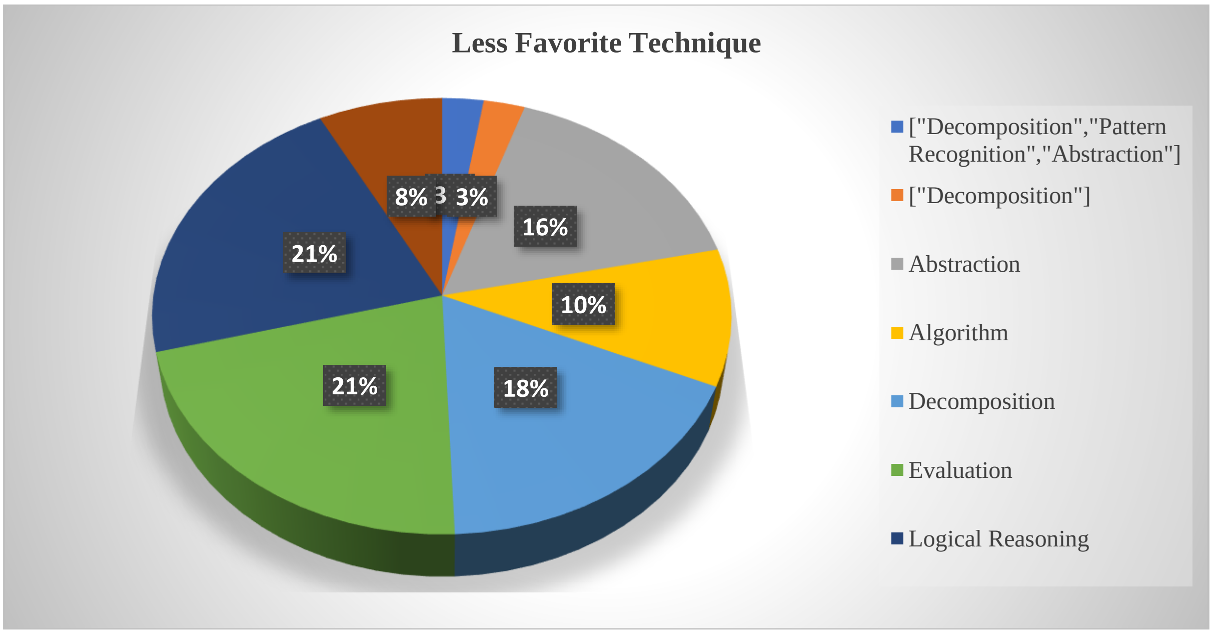

Figure 4: Less favourite CT technique among the teacher

Comparing the favoured technique category in Figure 3, it is evident that three options which are pattern recognition, logical reasoning, and decomposition. These three techniques exhibit minor differences and emerge as the favoured choices among the teachers. Notably, 32% of teachers select pattern recognition, while a marginal divergence of 12% is observed among teachers choosing decomposition and logical reasoning, with both accounting for 20% each. In contrast, techniques less favoured in Figure 4 by the teachers see a substantial majority agreeing that evaluation and logical reasoning are the least preferred methods. Although logical reasoning is present in both the favored and less favored technique options, this is attributed to varying groups of teachers. Through interview findings, it becomes evident that a substantial portion of educators share the perspective that the implementation of computational techniques with students is primarily contingent on the individual attributes of the students themselves.

Integrating CT into the existing curriculum poses challenges for some teachers. All of 5 teachers agreed they face difficulties in finding suitable ways to seamlessly incorporate this concept into various subjects (both STEM and non-STEM). Based on our survey in Figure 5, it was found that teachers believe that CT techniques are easy to apply in STEM subjects. This might be because the perception of the use of the term "computational" itself contributes to the connection with STEM subjects.

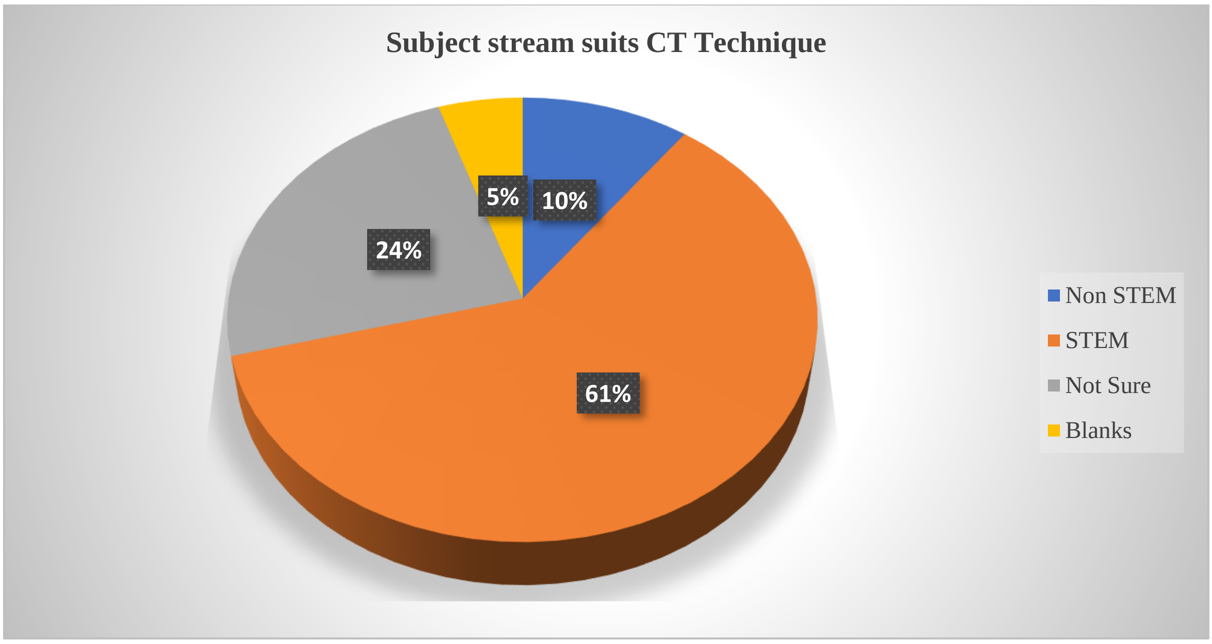

Figure 5: Subject stream suits CT technique

However, during interviews, all five teachers agreed that computational techniques are beneficial for teaching both STEM and non-STEM subjects. However, it is not denied that external challenges faced by teachers in implementing this techniques exist due to environmental factors. According to Teacher 1, the problems faced by teachers in rural areas are related to the students' and families' acceptance patterns regarding the importance of the education system. Many families in Teacher 1's area still emphasize non-formal education, which becomes a significant factor in students' struggles to comprehend certain subjects, even when teachers try to apply CT techniques to facilitate understanding. Furthermore, Teacher 1 finds that the primary issue for rural students is their very weak mastery of the 3Ms (*Membaca, Menulis, dan Mengira*). This low level of mastery makes it difficult for teachers to implement CT techniques because most of these techniques often require students to be proficient in problem-solving either individually or in groups. On the other hand, Teacher 3 feels that some students have extremely weak mastery levels and require intervention with conventional teaching methods. Additionally, language barrier is also a big issue for students and teacher to cooperate easily with each other. They must use all their own skills and knowledge by applying the techniques ofCT but without understanding the task given due to language barrier it will be hard for them to know if CT techniques are useful.

Upon analysing the survey results in Figure 2, it becomes evident that a significant majority of educators share the compromise that CT techniques contribute to their instructional methodologies. Moreover, from the interviews further underscore that teachers perceive CT techniques to be exceptionally advantageous for pedagogical approaches across both STEM and non-STEM subjects. The teachers express that CT techniques are highly beneficial, and they hold the hope that these techniques will streamline the teaching and learning process more effectively. Teacher 1 and teacher 2 is a STEM teacher, while Teacher 4 is a non-STEM based teacher. From the perspectives of these educators, the subjects taught through the application of CT techniques can encourage confidence in students and transform the learning experience into an engaging and captivating journey. By immersing of CT technique in class, the student not only exhibited enthusiasm in the learning process, which also showing their proactive approach to pursue deeper towards curriculum. Student 1 was very interested in making and building her own robot that makes her to participated into broad competition along with her partner, student 2. Teacher 1 asserts that with the implementation of CTCS, student involvement is comprehensive. For example, during group work presentations, every student participates in presenting their work, ensuring that no student is left out. The application of this collaborative approach also has a significant impact on students in rural areas compared to conventional teaching methods (e.g., "chalk and talk"). Teacher 4 also observes cooperation among students in Physical Education. When given individual tasks, students can easily accomplish them. Both Teacher 1 and Teacher 4 agree that student involvement should be comprehensive, and they should not be divided based on their mastery level in the subject. This approach helps students collaborate and assist their peers in understanding the lessons. Teacher 1 further states that active participation, to the point of qualifying students to represent the school, is one of the motivating factors for students. This is achieved through teaching techniques in CTCS that enable students in rural areas to comprehend the production process.

DISCUSSION

The discussion of this research revolves around the complex balance between the potential benefits of integrating Computational Thinking and Computer Science (CTCS) techniques into education and the challenges that educators face in implementing these techniques. The research findings brighten the multifaceted nature of this issue, shedding light on both the positive outcomes and the obstacles that impact the successful application of CTCS techniques.

The positive aspects emphasize the potential of CTCS techniques to enhance students' problem-solving skills, logical reasoning, and critical thinking abilities. The research reflects the agreement among teachers that exposure to CTCS contributes significantly to students' problem-solving skills. The systematic approach inherent in CTCS equips students with valuable skills in tackling complex problems, data analysis, and deriving effective solutions. These findings align with the broader educational paradigm emphasizing the importance of nurturing adaptable and analytical thinkers in an increasingly digital world. The 21st-century skills framework (Partnership for 21st Century Skills, 2019) underscores the significance of problem-solving, critical thinking, and technological literacy in preparing students for the future.

This compliance allows CTCS techniques to transcend traditional disciplinary boundaries, challenging the historical association with STEM subjects. Integrating CTCS techniques into non-STEM subjects creates interactive, dynamic learning experiences that promote problem-solving and critical thinking, breaking down silos between different subject areas (Grover & Pea, 2013). The holistic cognitive development observed as a result of this cross-disciplinary application empowers students with skills ranging from data analysis, algorithmic thinking, and computational problem-solving in STEM subjects to creative problem-solving, critical thinking, and logical reasoning in non-STEM subjects, aligning perfectly with the demands of the 21st century (Krumm & Black, 2017).

Moreover, this integration mitigates concerns related to the monotony of learning experiences. By infusing interactive and problem-based learning methods across the curriculum, educators stimulate students' curiosity, motivating them to explore diverse subject areas and instilling a passion for lifelong learning (Vorderstrasse et al., 2017).

However, alongside the promise of Computational Thinking and Computer Science (CTCS) techniques in education, this research brings to the forefront the significant challenges educators face when integrating these methods. One particularly prominent challenge is the insufficient training of teachers in computer science concepts, especially for educators not specializing in this domain. The study underscores the vital role of comprehensive teacher training programs in equipping educators with the necessary knowledge and pedagogical skills to effectively incorporate CTCS techniques into their teaching practices (Dennen, 2019).

Furthermore, the research underscores the critical importance of equitable access to technological resources. The limitations in technological infrastructure, often leading to disparities in resource availability, hinder the seamless application of CTCS techniques in various educational settings. To fully harness the potential of these methods and ensure a level playing field, investments in technological infrastructure are deemed essential, allowing all students to access the required tools and resources (Warschauer, 2019).

The language barrier emerges as another significant challenge. The diverse linguistic background of students necessitates innovative strategies to ensure that CTCS techniques are understood and embraced by all learners. Language disparities may slow down students' understanding of concepts and instructions, particularly in regions with multicultural or multilingual student populations (Cummins, 2020) .This highlights the need for culturally sensitive and contextually relevant approaches to ensure effective learning outcomes.

RECOMMENDATION

Based on the research findings, a comprehensive set of recommendations can be formulated to enhance the effective integration of Computational Thinking and Computer Science (CTCS) techniques into Sarawak's education system. First, there is a pressing need for focused efforts in teacher training and professional development programs, ensuring that educators are well-equipped with the necessary knowledge and skills to proficiently implement CTCS techniques in their teaching methodologies.

Furthermore, it is imperative to establish equitable access to technology and digital resources among all students and schools, bridging the digital divide and ensuring that every learner has equal opportunities to engage with CTCS concepts. A tailored approach to curriculum integration should be adopted, accommodating the unique needs and requirements of both STEM and non-STEM subjects, while also considering the developmental stages and capabilities of the students.

Nevertheless, the promotion of collaborative learning environments is paramount, as this not only encourages peer interaction and knowledge-sharing but also aligns with the collaborative problem-solving skills that CTCS techniques aim to cultivate. Deep appreciation of cultural sensitivity and active community engagement should be at the forefront of CTCS implementation efforts, acknowledging local values and perspectives while actively involving the community in shaping the educational landscape. These recommendations collectively form a robust framework for the successful integration of CTCS techniques in Sarawak's education system, fostering a more innovative and inclusive learning environment.

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