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Effects of ME-CoT Teaching Module on Students' Biology Achievement, Computational Thinking, and Metacognitive Awareness

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Abstract

During the Industrial Revolution 4.0 (IR 4.0), the rise of a young generation that is creative, innovative, able to adapt to technology, competitive, and productive to meet the needs of globalization begins at the school level by elevating the quality of pedagogy in the classroom. This initiative can be achieved through active learning applied through the practice of computational thinking (CT) as a problem-solving skill. Nevertheless, due to an insufficient understanding of CT skills and the absence of particular modules to direct teachers, the integration of CT as a problem-solving skill is still declining in the classroom. Therefore, the ME-CoT module has been developed to provide a platform to help teachers and students apply CT as a problem-solving skill in the classroom to improve achievement in STEM subjects, especially Biology, build CT, and develop metacognitive awareness. Thirty-one secondary school students from the Jempol district (16 in the control group whereas 15 in the treatment group) engaged in this research. Furthermore, to analyze the efficiency of the ME-CoT module, a quasi-experimental study with a pre-test and post-test design was carried out. The treatment group applied the ME-CoT module, while the control group utilized the traditional method. The instruments used are the Respiratory System in Humans and Animal Achievement test, MAI (Metacognitive Awareness Inventory), as well as CT as Problem Solving Questionnaire. Both inferential and descriptive statistics were employed to analyze the data. Wilcoxon T-Test and Mann-Whitney U Test were implemented in inferential statistics because the number of samples used was less than 20 students per group. Although there was an improvement in the control group, the treatment group's inferential test results demonstrated a more significant improvement. Therefore, the study's findings cannot be generalized. Still, the implications of this study suggest that the application of CT as a problem-solving skill may enhance achievement, establish computational thinking, as well as develop metacognitive awareness among Form 4 Biology students.

Keywords

Interdisciplinary Projects, Human-Computer Interface, Pedagogical Issues, Secondary Education, Teaching/Learning Strategies

1. Introduction

When information technology spreads across all industries and has a revolutionary impact on the economy, business, governments, and countries, as well as society and humans, IR 4.0 emerges (Mokhtar et al., 2019). The revolution in technology is rapidly changing, producing new models and methods of education for the future and enhancing the universities' capabilities to prepare graduates for life in the real world (Rahardja et al., 2019). IR 4.0 will advance the establishment of smart robots and replace humans in certain job sectors and industries. However, specific skills, knowledge and emotional intelligence can never be replaced by robots (Alaloul et al., 2018; Rahardja et al., 2019). Because of technological advancement, the education sector is forced to begin its technological revolution, focusing on educational innovation and agility, ultimately changing traditional learning methods (Rahardja et al., 2019).

Malaysia's development horizon in the Science and Technology field holds a crucial role in fostering a culture of excellence in Engineering, Science, as well as Technology (Malik, 2019). However, student enrollment statistics in science streams for all government and government-aided schools (secondary and upper secondary) still do not reach the 60:40 Policy, where MajalahSains.com (2017) recorded the overall achievement of 60:40 Policy till 2017 was only 20:80. The issue of student shortage in STEM education is closely related to the decline in achieving Policy 60:40 (MajalahSains.com, 2017). Meanwhile, the decline in achieving the 60:40 Policy was due to the defects in the application of the national Science curriculum, which changed significantly starting from 1965 to 2017 (KSSM revised curriculum 2017). This shortcoming is due to the lack of sensitivity to changes in learning strategies in the Malaysian education system, which is still examination-oriented and teachers, which also contributed to the deterioration of Policy 60:40. The economic and social development of a country depends on the capabilities of science and technology (MajalahSains.com, 2017). If traced, the development of the country in terms of science and technology is dependent on science education (Lilia et al., 2018) which is now specified as a STEM field (Ah-Nam & Osman, 2017). Science, Technology, Engineering, and Mathematics Education or better known by the acronym STEM, has become a major component in the Malaysian Education Development Plan (PPPM 2013-2025) that is emphasized in the curriculum and co-curricular activities of primary and secondary schools and at higher levels, namely high institutions. At the same time, the National Science Curriculum includes the curriculum of core science subjects and elective science subjects. Biology is an elective science subject available at the upper secondary school level rooted in The Nuffield O Level Pure Science Syllabus. Now, in addition to developing science-literate students, high-level thinking skills, and applying scientific knowledge, the biology subject curriculum is specially designed to empower and strengthen students' knowledge and skills in STEM so that lifelong learning occurs in students (KPM, 2018). Yet one of the consistent issues that are still at an alarming level is the difficulty of students studying Biology. Teaching and learning practices practiced by teachers are often disputed with difficulty in mastering the concepts and content standards of Biology (Çimer, 2012).

Besides that, there is a problem with implementing learning strategies that arise from the variations in the educational environment between western and eastern education in terms of content delivery (Phang & Tahir, 2012). Teachers at secondary schools use innovative instructional strategies such as inquiry- and problem-based learning, which diverge from traditional educational norms. Fully student-centered learning remains a question mark as many teachers still practice traditional learning and are still less sensitive to the Industrial Revolution 4.0 challenges (Anealka, 2018; Mokhtar et al., 2019). This challenge must be overcome to produce active human capital. Students who are active and capable of developing society and the country are students who pursue STEM. Note that students that have a STEM mindset and are critical, inventive, and creative may solve problems and make judgments in their daily lives based on scientific principles. In addition, students are also more dynamic, viable, fair, and responsible to society and the environment. However, critical, creative, innovative, and skilled human capital (KPM, 2018) that cultivates STEM alone is not enough to achieve the Malaysian Digital Policy in the 4.0 educational revolution. An interdisciplinary approach to STEM and computer science is necessary because of the spreading of digital technologies in the digital world. Therefore, using the updated KSSR and KSSM, an initiative to include computational thinking (CT) abilities in teaching and learning started in Malaysia in 2014. CT is closely related to computer science subjects; hence, an interdisciplinary approach to the STEM field, including computer science, is much needed (Burbaite et al., 2018; Rubinstein & Chor, 2014; Tran, 2019).

CT has been integrated since the development of 21st-century abilities through digital literacy (Mohaghegh & McCauley, 2016; Susan & Nurfaradilla, 2019). However, in Malaysia and international education, the efficiency of interdisciplinary methods is a contentious issue (Mohd Tafizam & Ramlee, 2017; Weintrop et al., 2016). CT skills may help students accomplish the computer and digital technology requirements in STEM fields. This is because CT incorporates computer science ideas (conditions, loops, subroutines) as well as methods (debugging and abstraction) that may be implemented in other science fields, for instance, mathematics, physics, biology, social sciences, engineering as well as language arts (Kotsopoulos et al., 2017; Lye & Koh, 2014). Many researchers argue that CT must guide in disciplines other than computer science because of the ability of CT to form powerful cognitive skills, which may possess a positive influence with respect to children's intellectual development. A student's cognitive skills are based on the development that exists in the cognitive domain (HOTS) and the knowledge domain (metacognitive awareness) of the student. Although the integration of CT in KSSM Semakan 2017 exists now, the main issue is implementing CT in schools, and integration in the classroom is still a question mark. CT is still new in the world of education (Lockwood & Mooney, 2018). Teachers still need guidance in the form of professional training, computing tools and support materials, such as modules to guide and practice CT in the classroom (Lockwood & Mooney, 2018; Puganesri & Puteh, 2019; Rich et al., 2020; Tran, 2019; Weintrop et al., 2016), particularly in the STEM field (Khine, 2018; Najibulla et al., 2018; Rich et al., 2020; Tran, 2019; Weintrop et al., 2016). CT skills can be taught in the classroom utilizing appropriate pedagogy strategies to assist students in developing metacognitive awareness and improve students' achievement in STEM subjects.

1.1. Statements of Problems

The emergence of the 4.0 Industrial Revolution presents a great challenge in the Malaysian Industrial Sector (Zafir et al., 2018). Role machines now, during the IR 4.0, carry out duties automatically to suit human demands via various systems, for instance, Internet of Things (IoT), Cyber-Physical System (CPS), IR 4.0, Advanced Management Program, or Industrial Internet (Kamaruddin & Che Aleha, 2016). In line with that, drastic changes in the integration of information technology should be given serious attention as it has a profound impact on the economy, business, government and country, society, and individuals (Mokhtar et al., 2019). If traced, this phenomenon affects the education system not only in the country but also in the world through the transformation of education at the global level in addressing the rapid pace of innovation and technology (Nurulrabihah et al., 2020) which is stated in PPPM (2013-2025) to produce students who are high-minded and competitive at the global level as well as enhance the STEM education quality. However, now the question mark is; 1) Does the human capital of science and technology in Malaysia have the competence to compete in the global economic market, and 2) Can educational issues in the STEM education field be identified and addressed efficiently? Conclusive evidence shows that student participation and achievement in STEM are very worrying.

It is quite concerning how few students pursue STEM fields, as seen by the challenge of reaching 60:40 Policy (Science/technical: Literature). Based on that, the Malaysian government's intention to produce more STEM-skilled manpower was also stalled when the government's intention to achieve the 60:40 (Science/technical: literature) Policy in education has not been fully achieved. The 60:40 Policy is also emphasized in the National Education Policy by providing more science and technology packages for students to choose from. The Malaysian government's decline in achieving the 60:40 Policy was due to more students opting for the literary stream, which created a shortage of assets in order to satisfy the requirements of the labor force in the period of the 4.0 IR. Majalah-Sains.com (2017) claims that the overall achievement of the 60:40 Policy up to 2017 was only 20:80.

Various initiatives have been taken, including the upgrading of the educational system, the formulation of the Primary and Secondary School Standard Curriculum, which includes various elements across the curriculum, as well as the integration of higher-order thinking skills and computational thinking. However, the government's efforts fell short of the desired requirements, and the international assessment's outcomes are dismal. The problem of Malaysian students' deteriorating performance in international Science and Mathematics assessments, for instance, the Program of International Science Assessment (PISA), as well as the Trends in International Mathematics and Science Study (TIMSS) (KPM, 2016, 2017), is a cause for concern.

The issue of deterioration in the achievement of international assessments, especially in the subject of Biology, is also influenced by the issue of difficulty in mastering the subject of Biology or the lesson's content. An extensive comprehension of the anatomical and physiological parts of the body is necessary for The Respiratory Systems in Humans and Animals study. As is well known, the majority of students who select STEM biology courses go for careers in medicine. Core courses like physiology and anatomy are required in health and medical science degrees, which are frequently more difficult than those in other areas (Periya & Moro, 2019). Furthermore, issues related to the pedagogy approaches used by teachers in delivering content to students are often major issues in education (Çimer, 2007; Çimer, 2012; Tan et al., 2019). Learning with construction in terms of student structuring and assimilation of knowledge from existing knowledge possessed by students is entirely dependent on the planning and implementation of pedagogy practices that take place in the classroom (Lilia et al., 2018). It is the duty of teachers to contextualize science knowledge, modifying it to meet the demands and requirements of the curriculum and students in order to ensure that significant learning takes place (Piaget, 1972; Reinoso Tapia et al., 2019). Nevertheless, rote learning in schools (Fazilah et al., 2016) prevents using active learning. Additionally, in order to encourage passive learning, abstract and difficult information is typically delivered to students through lectures (Çimer, 2012; Fazilah et al., 2016; Kamisah et al., 2013; Ah-Nam & Osman, 2017). The simplicity of controlling the class and the ease with which the syllabus could be completed led to the selection of this approach (Fazilah et al., 2016). Memorization learning methods enhanced the effects of deteriorating accomplishment in Biology subjects as a result of students lacking exposure to problem-based learning, which led to troubles in answering HOTS questions. This was in conjunction with the ongoing issues of interest and motivation lacking (Ah-Nam & Osman, 2017). The memorization effect also contributed to a decline in test scores on problem-solving tasks for the TIMSS (KPM, 2018) as well as the PISA

2012 (Fazilah et al., 2016).

The integration of CT is intimately tied to pedagogical issues related to problem- and inquiry-based learning. Particularly among Malaysian teachers, CT is a rather recent idea in the realm of education. The unconsciousness that exists in Malaysian education today, particularly in the field of technology, limits the capacity of pupils who utilize technology to think, learn, and create (Ling et al., 2017). Malaysian teachers' attitudes and intentions in integrating CT through programming and teaching, as well as Malaysian teachers' awareness of CT, all have a substantial impact with respect to CT integration inside the classroom (Ling et al., 2017; Najibulla et al., 2018). Meanwhile, computational thinking's ability to promote the development of various skills (Najibulla et al., 2018; Weintrop et al., 2016) proves that CT can guide students to think creatively and critically and indirectly elicit metacognitive awareness (Çakiroğlu & Er, 2020; Cansu & Cansu, 2019). The importance of CT is seen in the proposal to integrate CT into each child's thinking skills for reading, writing, and arithmetic (Wing, 2006; Yağcı, 2019). Meanwhile, metacognitive awareness also has a significant impact on problem-solving and self-control, which is one of the strategies recommended in the Standard Based Curriculum for Secondary School through inquiry learning. A student's awareness of what they know and do not know is known as metacognitive. When awareness exists in students, students can control their minds as cognitive strategies are utilized to plan, monitor, and evaluate what has been learned (Koc & Kuvac, 2016). Metacognitive strategies or ways to raise awareness of the thinking and learning process occurring are very important and can be enhanced through knowledge of thinking. So, it is clear that students themselves are the main human capital in determining their success in a subject (Cardinale & Johnson 2017), whose role is to practice metacognitive processes integrating new ideas with existing knowledge to create deeper learning (Cardinale & Johnson, 2017; Gómez-Veiga et al., 2018; Pratama et al., 2015) Hence, CT represents a set of metacognitive and cognitive strategies in designing a form of problem-solving creatively using digital technology.

1.2. Computational Thinking in Education

Although it is challenging to integrate CT in the field of STEM (Csizmadia et al., 2019; Kong et al., 2018; Swanson et al., 2019) yet various initiatives have begun to be undertaken around the world. It is crucial to ensure that the application of CT takes place as planned (Burbaite et al., 2018; Weintrop & Wilensky, 2017). The application of CT in the classroom starts from the study of Brennan and Resnick (2012), who provide an extensive study of CT starting with computational thinking's definition. The three main elements that make up the definition of CT are 1) computational concepts, 2) computational practices, as well as 3) computational perspectives (Brennan & Resnick, 2012). The three domains all have a significant impact on the technological world. Nevertheless, computational concepts (for example, conditions, loops, as well as subroutines) and practices (such as debugging and abstraction) are fundamental necessities in computing and computer science (Lye & Koh, 2014; Sengupta et al., 2013). Both domains open opportunities for the integration of programming into the STEM curriculum. The importance of the application of CT in the classroom received the attention of various parties. Thereby, a taxonomy with four categories was formed by David Weindrop and his research colleagues in 2016. The practice of CT in STEM can be categorized into four main groups such as 1) data practices, 2) modeling and simulation practices, 3) computational problem-solving practices, as well as 4) systems thinking practices.

The theme of "practice" or "practical" is used in defining the "skills" and "concepts" of CT within the framework of the Taxonomy of CT in Mathematics and Science because the practice of scientific investigation is not limited to skills but includes specific knowledge for each practice. Although the Taxonomy of CT in Mathematics and Science encompasses four different sets of categories, the practice of the four categories is interrelated and dependent on each other (Weintrop et al., 2016). To achieve scientific goals, these practices are often used together. Following these findings, this study uses a combination of practices such as; 1) modeling and simulation practices, as well as 2) computational problem-solving practices. Practice is often associated with pedagogy activities that take place in the classroom, where this study involves a combination of the four practices of the Taxonomy of CT in Mathematics and Science (Weintrop et al., 2016). Although among these four practices, Modeling and Simulation Practices are among the most frequently used practices in the study of Biology. Kong et al. (2019) express that developing the practice of CT in the STEM field context is a productive endeavor and have identified key activities related to CT-STEM practice. Meanwhile, programming has been focused on in this study showing computational problem-solving practices have been focused on directly.

Programming is inseparable from the practice of CT (João et al., 2019; Romero et al., 2017; Rubinstein & Chor, 2014; Scherer & Siddiq, 2020). Programming not only helps students improve their computational skills, but it can also help them think more systematically (João et al., 2019; Scherer & Siddiq, 2020). To achieve optimum comprehension of course content among students, programming must be accompanied by guidance in the form of support materials, assistance from teachers, or more skilled (Rehmat et al., 2020; Scherer & Siddiq, 2020). As a result, programming techniques using the modeling and stimulating practices included in the construction of ME-CoT modules are projected to help secondary school students acquire CT abilities.

The world is rapidly evolving toward a digital era, necessitating a greater requirement for programming expertise among students (Stripeikaitė, 2017). Now programming education has become a fashion (Hermans & Aivaloglou, 2017), and programming has become one of the universal languages in the digital world (Jancheski, 2017). The importance of creating a skilled workforce in programming has urged the world of education globally to teach programming starting from the school realm (Stripeikaitė, 2017). In addition, there are various methods, tools, books, and applications for teaching programming (Hermans & Aivaloglou, 2017) gradually and easily for children on the market. Programming learning also benefits students in terms of cognitive or thinking construction, information processing, and communication. These benefits can help foster 21st-century skills among students (Basu et al., 2017; Jancheski, 2017; Scherer & Siddiq, 2020).

In Malaysia, research and initiatives have been taken by the MOE in introducing and teaching students to master the programming language with scratch and robotics activities. Furthermore, various studies involving scratch and robotics have gained the attention of researchers to guide CT in students (Cheah, 2016; Saad, 2020; Sharifah Maryam et al., 2017). Meanwhile, in the analysis of long-term effects, the importance of programming puts pressure on students when students majoring in computer science after graduation often end up with desperate results or switch to other subjects (Becker, 2019). However, the very bright job opportunities are only focused on students who are capable of handling digital technology in the IR 4.0 era. Furthermore, students who are high-minded and globally competitive should master problem-solving skills more explicitly. According to Cheah (2016), Wing (2011) and Wing & Stanzione (2016), CT possesses the ability to build problem-solving skills. Simultaneously, problem-solving skills are regarded as part of programming learning because they make a difference in a student's cognitive ability (Qian & Lehman, 2017). Programming is a valuable teaching tool that allows students to form a diverse set of problem-solving skills within themselves (Malik et al., 2019). CT skills, for example, problem-solving suggested by Kalelioglu et al. (2016), are applied through programming activities using programming language to guide students to improve their level of cognitive thinking in acquiring content knowledge, build computational thinking, and also foster students' metacognitive awareness.

Numerous studies on improving CT skills among school students have been conducted in Malaysia and abroad using various methods such as scratch, robotics, and other block programs. Yet scratch has disadvantages compared to the use of programming languages for programming activities. The most notable disadvantage of the use of scratch is that it has no procedures. Therefore the use of Scratch cannot produce an impressive phenomenon, which is one of the main ideas in computer science. In addition, using natural language in block naming in Scratch applications can minimize and limit students' exposure to programming terminology that should be known, such as loops and functions (Li et al., 2019). While Scratch builders accept this opinion, their reason is not to want to threaten children with programming languages (Harvey & Mönig, 2010). Thus, various initiatives were taken by Scratch to further strengthen the Scratch programming system by dividing it into kids users and advanced users (Harvey & Mönig, 2010). This clearly shows that the founders of scratch developed the scratch system for advanced users but still adopted the concept of block-based programming instead of text-based programming, which is a form of programming that can be integrated among high school students (Krpan et al., 2017).

Although the teaching of programming language is favored by students, the difficulty of students in understanding and applying the programming language is a question mark due to the complexity of the programming language itself. Meanwhile, (Vygotsky, 1979) criticized Piaget's opinion to introduce programming languages such as Java through Smalltalk teaching (Angeli & Jaipal-Jamani, 2018; Khine, 2018) to school students with his justification that this effort lies outside a student's proximal zone development. Nevertheless, support and assistance from adults or teachers (Angeli & Jaipal-Jamani, 2018; Basu et al., 2017; Scherer & Siddiq, 2020) can guide students in mastering programming languages, for instance, C++, C, C# as well as Java. Despite the general criticism of programming languages, researchers began to explore an alternative method to introduce programming to high school students more interesting and effective, namely a form of programming, "Text-based Programming," that utilizes the C# programming language.

In this study, the choice of programming language also mattered. Researchers make sure that the usage of programming languages is consistent with Vygotsky's Social Theory of Constructivism, which holds that new ideas are created in the Proximal Development Zone to establish that students do not incur cognitive burdens. Because of this, Stripeikaitė (2017) compared students using Scratch and C-Syntax in terms of their programming skills and discovered that C-Syntax users had a deeper understanding of programming. Additionally, students that learn C-Syntax programming (for instance, Java, C++, and C#) are better able to master the language than those who learn block-based programming, like Scratch (Stripeikaitė, 2017). The use of Python and C# has been widely adopted by students in secondary and primary schools in the nation of Croatia. Both programming languages are extremely well-liked and benefit from being translated or extended to other languages (Krpan et al., 2017). Thus, it can be concluded that the weakness of Scratch, which acts as the most basic programming that is only suitable and can be introduced to kindergarten children and primary school students (Jancheski, 2017; Stripeikaitė, 2017), has opened up opportunities for researchers to find a suitable form of programming and easy in terms of use to high school students to study the Respiratory Systems in Humans and Animals which accumulate full of images. Compared to Python, the researcher chose C# programming for this study because of the Visual Studio Community 2019 software that had been selected. Furthermore, programming involving programming languages also plays a role in guiding students to master metacognitive awareness more efficiently (Basu et al., 2017; Scherer & Siddiq, 2020). Therefore, the researcher chose C# programming used in WPF (Window Presentation Foundation) with Visual Studio software. Meanwhile, researchers also agree with João et al. (2019) that when students are showered with pleasant experiences in the use of programming languages in building interesting programming products starting in the school world, then, obviously, students' fears of learning programming will disappear (Becker, 2019). Students are becoming interested in learning the subjects taught and gaining new knowledge through programming activities. Therefore, the researcher took the initiative to give a touch of text-based programming to STEM students, especially Biology students, so that their job opportunities are not only focused on medicine but more broadly on Biology and technology.

1.3. Metacognitive Awareness

At the secondary and primary school levels, pedagogy approaches are based on a teaching system that emphasizes the content knowledge and skills of the subjects taught. The ability to read and comprehend scientific content is known as scientific literacy. Scientific reading is essential in the realm of research since it entails not only the retrieval of scientific data but also an active approach that includes techniques of analysis, data interpretation, and data processing (Dori et al., 2018). Most instructors overlook where learning strategies should be cultivated in students rather than independently throughout the delivery of established subject requirements while adopting content learning. Meanwhile, students should be given a conducive learning environment to acquire and use metacognitive awareness (Çakiroğlu & Er, 2020).

In this context, combining metacognitive strategies while delivering content knowledge is critical to effective learning outcomes. The success of a student depends on the student's capability to use learning strategies in learning a subject and subsequently build a deep understanding of the topic studied (Sun, 2013). Metacognitive learning strategies possess a significant impact on knowledge acquisition and the outcome of learning. Moreover, researchers in this research emphasize the fact that problem-based learning approaches are closely related to metacognitive awareness (Çakiroğlu & Er, 2020) in addressing such problems by finding procedural solutions using CT involving computer programming. The concept of "thinking about thinking" refers to metacognitive awareness, as we already know (Astuti et al., 2017; Koc & Kuvac, 2016; Mazli Sham & Saemah, 2014; Sun, 2013). Metacognitive comprises two main elements, which are cognition knowledge as well as cognition regulation (Caviola et al., 2009; Koc & Kuvac, 2016; Rahimi & Katal, 2012). The ability to understand and manage one's own thinking and learning processes is known as metacognitive (Astuti et al., 2017; Chou, 2017). A person's awareness with respect to what they know and do not know is also referred to as metacognitive. Students employ metacognitive strategies as a way to become more conscious of their own internal processes of thought and learning. Planning, observing, and assessing the knowledge taught can help students better manage their thoughts (Koc & Kuvac, 2016; Hasan et al., 2017). Building metacognitive in students is the existence of awareness of learning processes and strategies that lead to success. When awareness exists in students, then students have high self-confidence and high motivation to plan ways to achieve success.

The success of a student depends on the student's learning style, which can guide the student to form metacognitive awareness (Crowe et al., 2008). In addition, a high level of metacognitive students can improve student achievement

(Mohamad Masrizan, 2019) and teachers should be prepared to present an interactive teaching style to meet the needs of the diversity of learning styles available to students (Fraenkel et al., 2012). The importance of metacognitive awareness is even more evident in the field of computing. The ability of students to solve a problem using or accessing technological tools can often enhance metacognitive awareness (Basu et al., 2017; Scherer & Siddiq, 2020). Furthermore, computer-based learning often focuses on the domain of students 'knowledge in terms of their ability to implement cognitive and metacognitive processes during the problem-solving process. Symbiosis with this, several studies of metacognitive enhancement through the practice or fostering of CT among students have caught the attention of researchers (Basu et al., 2017; Scherer & Siddiq, 2020).

Metacognitive awareness is already available in the experience of problem-solving computational thinking. Debugging or troubleshooting skills can help students correct their errors (Lai et al., 2015; Schraw & Dennison, 1994) and complete assignments more accurately and transparently. Increased metacognitive awareness and self-organization of the students are often associated with students' strengths in identifying and correcting misconceptions and errors as well as developing efficient and effective problem-solving strategies (Basu et al., 2017). From a metacognitive perspective, complex problems require students to develop strategies for elaborating learning as well as problem-solving tasks. Nevertheless, students have choices in the process of decomposing, planning, sequencing, and completing a given task. Furthermore, it is the responsibility to coordinate, manage, evaluate, monitor, and reflect on suitable metacognitive strategies and cognitive processes as they interpret, seek, and apply information to build and assess the possibility of problem-solving occurring in students. Viewed from another angle, this process is a major challenge for students when students do not have the skills to use computing system tools (Scherer & Siddiq, 2020) or the experience and understanding to organize learning and problem-solving explicitly (Basu et al., 2017).

In addition to traditional distractions, guiding students in solving a problem in a complex and intricate environment requires a more systematic framework of tasks that lead to the evolution of problem-solving (Basu et al., 2017; Rehmat et al., 2020; Scherer & Siddiq, 2020) that is practiced in computational thinking. Furthermore, Hadad et al. (2020) in their study have stated that formative training provided while applying computational thinking-based activities can foster metacognitive awareness in students. However, Hadad et al. (2020) suggested within the limitations of the study that this practice should be developed in other fields and subjects to see metacognitive development broadly with a variety of formative activities. Meanwhile, Romero et al. (2017) have interpreted cognitive skills and metacognitive awareness to be under the umbrella of computational thinking. The study of Romero et al. (2017) also suggested that programming other than Scratch should be applied not only to students at the university level, but the study should involve various ages or at the school level again. Allsop (2019) suggested that the assessment of CT skills includes the metacognitive assessment. Metacognitive awareness plays an important role in computational thinking. Metacognitive awareness is inseparable from computational thinking. In conclusion, this study also serves to prove the existence of increased metacognitive awareness of students through programming activities. The increase in metacognitive awareness among students in this study can be seen from the overall beginning of metacognitive awareness, cognitive strategies, planning, as well as self-assessment of students (Allsop, 2019).

Furthermore, CT represents a form of problem-solving framework that can guide metacognitive awareness in each student in mastering the content of the lesson and can improve student achievement in the field. The ability of students to apply metacognitive awareness indicates that students can act on their knowledge. Metacognitive awareness can improve students academic achievement across ages, cognitive abilities, and learning domains (Mohamad Masrizan, 2019). The increase in achievement is closely related to the metacognitive awareness of students' levels (Çakiroğlu & Er, 2020). In his research on matriculation biology students, Mohamad Masrizan (2019) discovered that "metacognitive awareness has a vital influence on students' academic improvement." Thus, the researcher clearly shows that metacognitive awareness can be built by applying CT skills via the integration of CT skills from the CT Framework as a Problem-Solving Process (Kalelioglu et al., 2016). At the same time, Farah Aida and Che Nidzam (2016), who stated a very weak relationship between metacognitive awareness and KBAT, are at odds with the findings of Burbaite et al. (2018). The latter stated that the cognitive domain plays a role in building students' metacognitive awareness. Students with high metacognitive awareness can help students improve student achievement (Mohamad Masrizan, 2019). The decline in terms of students' ability to self-learning can be identified through the study by Cardinale and Johnson (2017), which stems from teachers' teaching that is less effective in developing metacognitive awareness. This study states that teaching and learning that guides students to improve metacognitive awareness rests on the shoulders of teachers (Cardinale & Johnson 2017), who should design a creative and efficient form of pedagogy approaches (Mohamad Masrizan, 2019). Training students to master metacognitive awareness can help them change their behavior based on understanding biology's function and its application in learning and positively influencing achievement. The learning strategy used by teachers to communicate subject material has a direct impact on how metacognitive awareness and CT develop. In this research, problem-based and inquiry-based learning were selected and implemented to ensure maximum mastery in the integration of CT to foster metacognitive awareness in students and directly impact students' achievement in Biology education.

1.4. ME-CoT Teaching Module

Considering the issues discussed, the need for improvement and innovative teaching pedagogy approaches need to be implemented in the Biology classroom. ME-CoT module is designed with plugged-in activities that immediately develop students' computational skills through programming activities that directly empower students' metacognitive awareness, even though several upgrowing modules concentrate on delivering Biology content knowledge. In this study, the ME-CoT module is an interaction of three key learning theories, specifically a combination of constructivist, social, and cognitive learning theories. These three theories of learning are Vygotsky's Social Constructivist Theory, Robert Gagne's Information Processing Theory, Constructivist Theory, as well as Metacognitive Theory. Through CT activities, the combination of learning theories can promote metacognitive awareness and student accomplishment in problem-based and inquiry-based learning. Using CT as a problem-solving skill is recommended in the Framm. The skills were organized based on the Model Revised by Bloom's Taxonomy and CT (Burbaite et al., 2018). To optimize the impact on developing metacognitive awareness while employing the ME-CoT module, the CT skills as problem-solving were incorporated from the Framework of CT as Problem-Solving (Kalelioglu et al., 2016), while the skills were organized based on the Model Revised by Bloom Taxonomy and CT (Burbaite et al., 2018). Furthermore, there exist six CT problem-solving skills selected in this study: 1) Abstraction, 2) Decomposition, 3) Pattern recognition, 4) Algorithm, 5) Modeling and Simulation, and 6) Debugging. Thus, metacognitive awareness can be built-in for students at every level. Still, at the debugging and troubleshooting level (Weintrop et al., 2016), students try to identify their mistakes and begin to recorrect them, where the achievement learning process can be seen. Therefore, each selected skill plays an essential role in enhancing the cognitive domain and helping to stimulate students' domains of knowledge to achieve high metacognitive awareness.

1.5. Study's Purpose

This research is designed to create the ME-CoT module for the topic of Respiratory Systems in Humans and Animals and to evaluate its effectiveness in raising students' achievement in biology, cultivating computational thinking, and promoting metacognitive awareness.

2. Method

2.1. Research Design

The unbalanced control group underwent pre- and post-tests as part of this study's experimental design, which is a quasi-experimental design. The study recruited 31 students from two separate schools in the Jempol District of Negeri Sembilan, Malaysia. Furthermore, 15 and 16 students, correspondingly, comprised the treatment and control groups. Students who are enrolled in the biology classes that the school has designated as electives make up the study's respondents. In this study, Campbell et al. (1963) and Fraenkel et al. (2012) suggested a convenience sampling method from the existing group (intact group), which is the existing population. In order to avoid issues or disruptions at the school, respondents will not be randomly assigned to treatment and control groups. Since the ME-CoT module is a teaching and learning module built based on the Form 4 Biology Curriculum Standard document, it can be implemented during school hours during teaching and learning Biology by students who are available in the classroom. This study uses a factorial design, i.e., it involves one independent variable. Groups (treatment and control) were independent variables, so the study design was represented as a 1 × 2 factorial.

Groups A and B underwent Pre-test (O), where Group (A) received intervention with ME-CoT module (X). In contrast, Group (B) did not receive an intervention. It will undergo traditional learning and facilitation for a period set by the researcher according to the annual plan of Biology subjects set by the MOE. Next, Groups A and B will undergo a post-test (O). The research framework is displayed in **Table 1**.

According to Campbell et al. (1963), the best time for the post-test is one month after the pre-test. The post-test was implemented one month following the treatment. A test paper on the topic of Respiratory Systems in Humans and Animals, a questionnaire on computational thinking (CT) as a problem-solving skill (Yağcı, 2019), as well as the Metacognitive Awareness Inventory (MAI), were the instruments utilized for the pre and post-tests (Harrison & Vallin, 2018; Schraw & Dennison, 1994). Before the study, the Biology teacher in the treatment group was trained by the researcher. Note that the teacher underwent training for two weeks.

Population and Sample

Thirty (30) biology students from two schools in the Jempol District of Negeri Sembilan, Malaysia, participated in the project. There were 15 students in each of the treatment and control groups, correspondingly. As per the convenience sample approach, students from both groups were chosen from the current groups (intact group) as stated by (Campbell et al., 1963). Due to the set classroom arrangements in Malaysia, the convenience sampling method was adopted.

2.2. Research Instruments

2.2.1. Exam Paper

The level of students' mastery of the content of a subject in terms of facts, concepts, principles, and skills is measured using the Achievement Test. In this study, the same Achievement Test will be tested twice as the pre-test and post-test. Here, the pre-test was tested to identify students' existing knowledge and homogeneity of both treatment and control groups. In contrast, the post-test was

Table 1. Non-equivalent control group design.

Group	Pre Test	Intervention	Post Test
A	O	X	O
B	O		O

tested after treatment to test the ME-CoT module's effectiveness. In addition, the items in the Achievement Test were constructed by the researcher concerning the Curriculum and Assessment Standard Document (KPM, 2018), last year's SPM questions, Form Four Biology Textbook, and Form Four Biology reference books. The items in the Achievement Test are constructed based on the Test Specification Table (TDS) to ensure that the Test questions are distributed in various difficulty levels, referring to the Revised Bloom's Taxonomy (Krathwohl, 2002). In addition, questions constructed based on the Test Specification Table (JSU) can improve the validity of Test content (McMillan & Schumacher, 2014). The questions were created using six key categories: understanding, remembering, analyzing, applying, evaluating, as well as creating (Krathwohl, 2002). The Achievement Test is carefully constructed to meet the criteria and measure content mastery based on the Respiratory System Learning Area in the Human Body. Moreover, this process can avoid repeating the same question without any modification.

At the beginning of this study, the researcher constructed 40 objective questions, five structural questions, and four essay questions. This is for the process of selecting appropriate and accurate questions to assess the mastery of the content of learning standards. After discussing with two experts, namely the Biology teacher and the head of the SPM Biology paper marker, the objective and subjective questions were carefully selected so that they could be answered once in the allocated time of 1 hour and 15 minutes. This is to ensure the assessment of content mastery at the maximum rate with the number of questions given and the time allocated to answer the Achievement Test. **Table 2** shows the Total questions and marks in the provisions of the Assessment Test that have been recommended by the expert to the researcher.

2.2.2. Computational Thinking as Problem-Solving

The CT questionnaire is Yağcı's (2019) CT problem-solving which includes problem-solving (Kalelioglu et al., 2016; Yağcı, 2019). Programming is an activity

Table 2. Total questions and marks for the achievement test set.

Section	Question	Marks	Total marks	Explanation
A	1 - 15	15	15	Section A contains 15 objective questions with a difficulty ratio of 5:3:2
B	16	6	15	Section B includes two structural questions. Students are required to answer both structural questions.
	17	9		
C	18	20	20	Section C is an essay question where students are required to choose one question
	19	20		
Total marks			50	This total score will be multiplied by 2 to get the % score

that can build CT from the aspects of concept (CT concept), practical (CT Practices), perspective (CT Perspectives) (Allsop, 2019; Angeli & Giannakos, 2020; Hadad et al., 2020) and problem-solving. Because this study focuses on problem-solving employing CT skills, the CT problem-solving skills instrument constructed by Yağcı (2019) is used to identify CT skills as student problem-solving with regards to problem-solving and its impact on the formation of metacognitive awareness among students. CT skills as students' problem-solving were measured using an instrument constructed by Yağcı (2019). The five-point Likert scale comprises 20 items under the factor of CT as problem-solving. This questionnaire was selected to specifically define CT skills as problem solvers built-in students after using the ME-CoT module.

A pilot study of the CFA was conducted on 20 items of the CT as a Problem-Solving questionnaire, which was translated by an expert translator and language teacher. The constructs were assessed by expert construct validity. After identifying the differences and similarities in the terms and language, the researcher discussed with the supervisor and obtained explanations and opinions before the questionnaire instrument was distributed to 157 students of Biology Form 4. A total of 153 questionnaire instruments were received, and 150 questionnaires were used to conduct the CFA test in this study. Internal reliability is measured based on the correlation between the items in a questionnaire item construct. The Cronbach's Alpha statistical value showed a reading above 0.7, which is 0.981. Then, it meets the set level. Overall, the validation factor analysis met the set criteria.

2.2.3. Metacognitive Awareness

The research instrument utilized in this study is the "Metacognitive Awareness Instrument (MAI)," which contains 52 items. This questionnaire has been translated and used locally by researchers in the country to test the metacognitive awareness of school students (Farah Aida & Che Nidzam, 2016) and institutes of higher learning (Cheng & Eng, 2009; Chong & Sungap, 2021) have been consulted and is used by the researcher in this study. The order of items in each construct is according to the order of items stated by Harrison & Vallin (2018). This instrument has the advantage of alternative assessment in that it can measure higher-level thinking skills or metacognitive awareness, covering cognitive regulation as well as cognitive knowledge. Cognitive knowledge may direct declarative knowledge, procedural knowledge, as well as conditional knowledge. In contrast, cognitive regulation can guide students to plan, monitor, evaluate, debug, and information management to solve a problem (Schraw & Dennison, 1994). Thus, this study touches on the metacognitive component covered by the Metacognitive Awareness Instrument (MAI) assessment instrument (Harrison & Vallin, 2018; Koc & Kuvac, 2016; Schraw & Dennison, 1994). Metacognitive awareness can be explicitly measured by the measurement of assessment instruments (Allsop, 2019; O'Neil & Abedi, 1996). The MAI construct proposed by Schraw and Dennison (1994) contains cognitive knowledge factors and cognitive regulatory factors.

Table 3 shows the number of items in MAI. The inventory has a scale of 52 items in which all items are valued with a 5-point Likert scale having eight sub-components, namely 1) Planning, 2) Monitoring, 3) evaluation, 4) Information management strategy, 5) Debugging, 6) Declarative Knowledge, 7) Procedural Knowledge as well as 8) Conditional Knowledge (Harrison & Vallin 2018). Thus, this research uses the Metacognitive Awareness Instrument (MAI), which covers all aspects of the metacognitive component. The table shows eight constructs containing 52 items. This inventory is well suited to assess the effectiveness with respect to the usage of ME-CoT modules.

Determine the Cronbach's Alpha coefficients were analyzed using 30 Biology form 4 students excluded from the actual study. Correspondingly, the findings of the analysis recorded a Cronbach's Alpha multiplier reading of 0.953, which showed that all items showed high consistency.

3. Results

3.1. Data Analysis

The study of the effectiveness of the ME-CoT module is a study of quantitative data. Thus, IBM SPSS 23.0 software was used to evaluate the study's data. Descriptive analysis, for instance, the mean and standard deviation for Achievement Test (pre and post), metacognitive awareness questionnaire data, and computational thinking (CT) skills data, will be used to describe and compare the findings based on group type (Treatment and control group). The research questions raised by the researcher in Chapter one were addressed using inferential analysis. **Table 4** shows the relationship between the research questions, research instruments, research respondents, and the determination of appropriate data analysis.

The quantitative data of the study were analyzed using non-parametric statistical tests because the study involved a sample size of fewer than 30 students.

Table 3. The number of items in MAI.

Factors	Constructs	Number of items
The factor of cognitive knowledge	declarative knowledge	8
	procedural knowledge	4
	conditional knowledge	5
Factors of cognitive regulation	Planning	7
	Monitoring	7
	Evaluation	6
	Information strategy management	10
	Debugging Strategy	5

Table 4. Research questions, instruments and data analysis.

Research questions	Instrument	Data Analysis
Are there differences in pre- and post-achievement test scores for the field of Respiratory Systems in Humans and Animals in the experimental group?	Achievement test for the field of Respiratory Systems in Humans and Animals (Set 1)	Wilcoxon signed Rank Test
Are there differences in post-achievement test scores for the field of Respiratory Systems in Humans and Animals between the control group and the treatment group?	Achievement test for the field of Respiratory Systems in Humans and Animals (Set 2)	Mann Whitney U
Are there differences in pre and post-test scores of CT skills in the experimental group	Questionnaire CT as Problem Solving	Wilcoxon signed Rank Test
Are there differences in post-test scores of CT skills between the control group and the treatment group?	Questionnaire CT as Problem Solving	Mann Whitney U
Are there differences in pre and post-test scores of metacognitive awareness in the experimental group?	Metacognitive awareness questionnaire	Wilcoxon signed Rank Test
Are there differences in post-test scores of metacognitive awareness between the control group and the treatment group?	Metacognitive awareness questionnaire	Mann Whitney U

3.2. Findings

3.2.1. Findings of the Students' Achievements

For the treatment group's Respiratory Systems in Humans and Animals test, a study evaluating the ME-CoT module's effectiveness was carried out to see if there were any variations between pre and post-achievement test scores. Fifteen individuals from the Form 4 Biology class made up the study sample for the treatment group. They were chosen from the available groups. Prior to and during the usage of the ME-CoT module, the Wilcoxon Signed Ranks Test statistical findings revealed that there exist differences in achievement test scores for the Respiratory Systems in Humans and Animals ($p = 0.001$, $p < 0.05$). Table 5 listed the Wilcoxon Signed Ranks Test for pre and post-achievement test scores in the treatment group. Apart from that, the analysis's findings made it abundantly evident that the mean rank for a positive rank (mean rank = 8.00) was greater than the mean rank for a negative rank (mean rank = 0).

Meanwhile, Figure 1 clearly shows that the median values for both pre- and post-groups differ. The median value of the post-test (M = 66), which is higher compared to the pre-test (M = 24) on the Boxplot Graph, clearly exhibits that the ME-CoT module integration may aid students in understanding the Respiratory Systems in Humans and Animals content more effectively because there is improved student achievement before and after treatment. This indicates that the null hypothesis (H_{01}) is rejected.

In addition, the Mann-Whitney U test was employed to answer research question 2, which is to compare the post-achievement test scores between the independent variables of the control group and the treatment group. The findings of the Mann-Whitney test analysis for the Post-Achievement Test between the control and treatment groups are displayed in Table 6 in more detail.

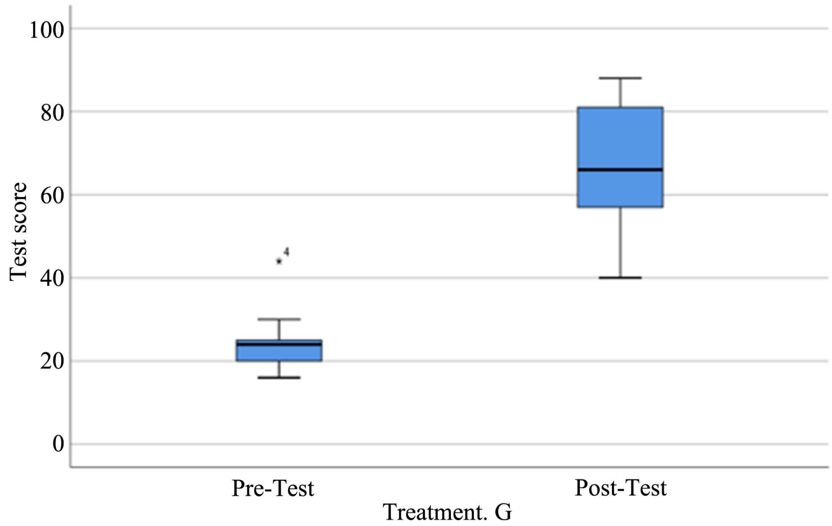

Figure 1. Median values for both pre- and post-achievement tests in the treatment group.

Table 5. Wilcoxon signed rank test for pre- and post-achievement test scores in the treatment group.

Achievement Test	*N*	*M*	*SD*	Median	Z	Mean Rank	Sig
Pre-test	15	24.00	6.676	24	−3.412	8.00	0.001
Post-test	15	67.73	14.655	66			

Table 6. Mann-Whitney U Post Achievement Test score between control and treatment group.

Group	N	MR	SR	Z	Mann-Whitney U	Sig
Control	15	9.37	140.50	−3.826	20.500	0.000
Treatment	15	21.63	324.50			

To test the research hypothesis, the Mann-Whitney U test was implemented to establish if there exists a variation in test scores between the post-test of the control group (N = 15) as well as the post-test of the treatment group (N = 15) with respect to the field of learning Respiratory Systems in Humans and Animals. Moreover, the results of the study were noteworthy; Mann-Whitney U = 20.500, $p = 0.00$ ($p < 0.05$). Apart from that, the null hypothesis (H_{02}) was rejected because the mean post-test rating for the treatment group was greater than the mean post-test rating for the control group (mean of the post-test for the control group = 9.37, whereas the mean of the post-test for the treatment group = 21.63). The Mann-Whitney U test results also exposed that there exists a major difference between the post-test achievement scores for the control group and the treatment group in this research.

A boxplot graph was made to compare the median values of the post-test scores of the treatment and control groups in order to further support the Mann-Whitney U test's conclusions. Figure 2 is a boxplot graph showing the

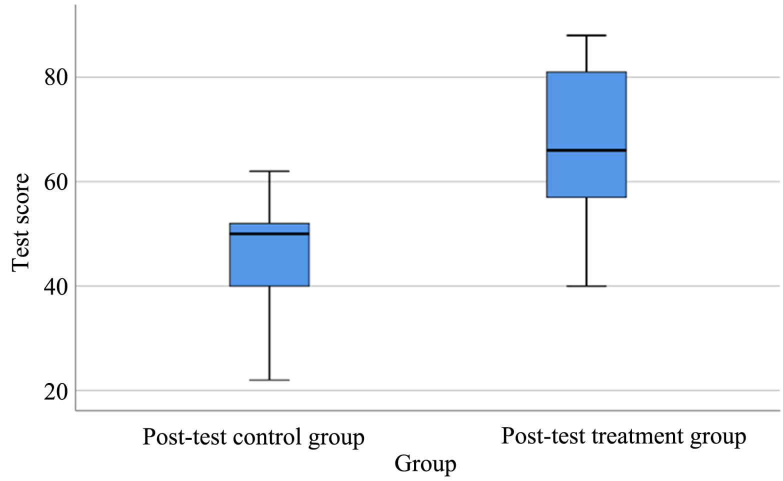

Figure 2. Comparison of median values between the post-achievement test scores of the control and treatment groups.

differences between the two groups. The treatment group's median post-treatment achievement test score (M = 66) was greater than the control group's median score (M = 50) on the test. These results show that the incorporation of the ME-CoT module has an impact on students' performance in the Field of Respiratory Systems in Humans and Animals.

3.2.2. Findings of Computational Thinking as Problem-Solving

To establish whether there exists a difference between the pre-and post-CT ordinal scores in the treatment group, a study evaluating the effectiveness of the ME-CoT module was carried out. A total of 15 study samples from the treatment groups in this study were drawn from Form 4 Biology student groups. Before and after using the ME-CoT module, there was a variation in the ordinal scores for computational thinking, according to statistical findings from the Wilcoxon Signed Ranks Test ($p = 0.001$, $p < 0.05$). The analysis's findings made it abundantly evident that the mean rank for a positive rank (mean rank = 8.00) was greater than the mean rank for a negative rank (mean rank = 0). **Table 7** displays the Wilcoxon Signed Rank Test between Pre- and Post-computational thinking Tests in the treatment group.

Meanwhile, the Boxplot graph in **Figure 3** clearly shows that the median values for both the pre- and post-treatment groups differ. The median value of the post-CT score (M = 98) is higher than the pre-CT score (M = 61) in Boxplot, showing that the ME-CoT module integration may aid students in advancing CT skills along with the improvement of the ordinal score of CT before and after treatment. This indicates that the null hypothesis (H_{03}) is rejected.

Meanwhile, the Mann-Whitney U test was employed to answer study question 4, which is to compare the ordinal score of CT between the independent variables of the control group and the treatment group. The findings of the Mann-Whitney test analysis for the post-test of the control and treatment groups are illustrated in **Table 8**.

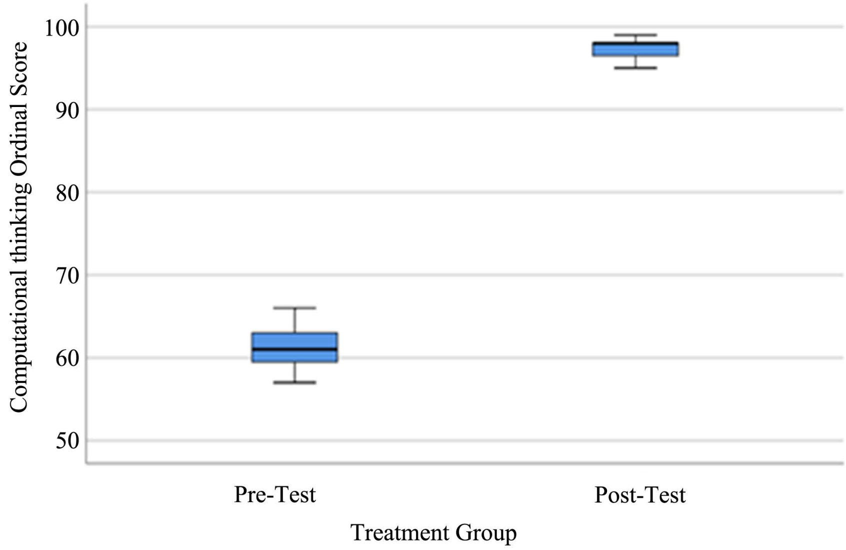

Figure 3. Comparison of median values for both pre- and post-computational thinking scores in the treatment group.

Table 7. Wilcoxon Signed Rank Test of computational thinking in the treatment group.

Computational Thinking	*N*	*M*	*SD*	Median	Z	Mean Rank	Sig
Pre	15	61.20	2.513	61	−3.418	8.00	0.001
Post	15	97.27	1.438	98			

Table 8. Mann Whitney U test of post computational thinking score in control and treatment group.

Group	N	MR	SR	Z	Mann-Whitney U	Sig
Control	15	8.00	120.00	−4.692	0.000	0.000
Treatment	15	23.00	345.00			

The Mann-Whitney U test was employed to establish whether there exists a difference in CT scores between the post-tests of the control group (N = 15) and the treatment group (N = 15) in order to assess the study's main hypothesis. Study findings were significant, Mann-Whitney U = 0.000, $p = 0.00$ ($p < 0.05$). Furthermore, the mean rank post-test with respect to the treatment group was greater in comparison to the mean rank post-test of the control group (mean of the post-test of the control group = 8.00; mean of the post-test of the treatment group = 23). This means that the null hypothesis (H04) is disproved, and the outcomes of the Mann-Whitney U test reveal that there exists a major variation between the control group and the treatment group in this research.

A Grof boxplot was made to compare the Median values between the CT scores of the treatment and control groups in order to support the results of the Mann-Whitney U test. Figure 4 is a Boxplot Graph showing variations between the two groups. The median value with respect to the post-CT score of the

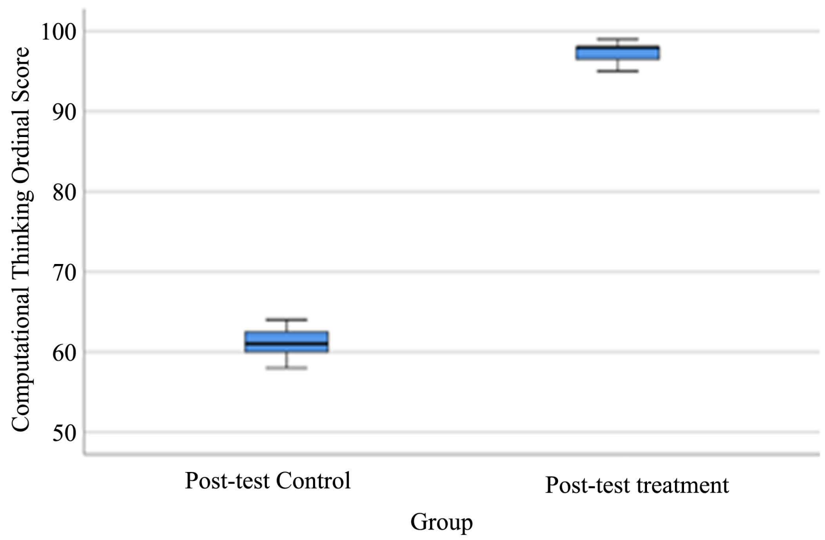

Figure 4. Boxplot of post-test scores of computational thinking scores between the treatment group and the control group.

treatment group (M = 98) was greater compared to the median value of the test score of the control group (M = 61). These findings indicate an effect of the integration of the ME-CoT module on the CT of Form 4 Biology students in the treatment group.

3.2.3. Findings of the Level of Metacognitive Awareness

A study of the ME-CoT module's effectiveness in enhancing Metacognitive awareness was conducted to identify whether there exist variations in metacognitive pre-awareness scores as well as metacognitive post-awareness scores in the treatment group. A total of 15 study samples of the treatment groups involved in this study were from groups available in the Form 4 Biology class. Prior to and following the usage of the ME-CoT module, there was a difference in the ordinal scores with respect to metacognitive awareness ($p = 0.001$, $p < 0.05$), according to the statistical findings of the Wilcoxon Signed Ranks Test in Table 9. The analysis's findings made it abundantly evident that the positive rank's mean rank value (mean rank = 8.00) was higher than the negative rank's mean rank value (mean rank = 0).

Meanwhile, the median values with respect to the pre- and post-metacognitive awareness ordinal scores in treatment groups are different. The median value of the metacognitive post-awareness score (Median = 254) is higher than the metacognitive pre-awareness score (Median = 133). Figure 5 shows a Boxplot Graph of Pre- and Post-Test of Metacognitive Awareness ordinal scores in the Treatment Group. Apart from that, the sketched diagram in the Boxplot Graph clearly shows that the integration of the ME-CoT module can help students cultivate metacognitive awareness with the improvement of ordinal scores in metacognitive awareness before and after treatment. This indicates that the null hypothesis (H_{05}) is rejected.

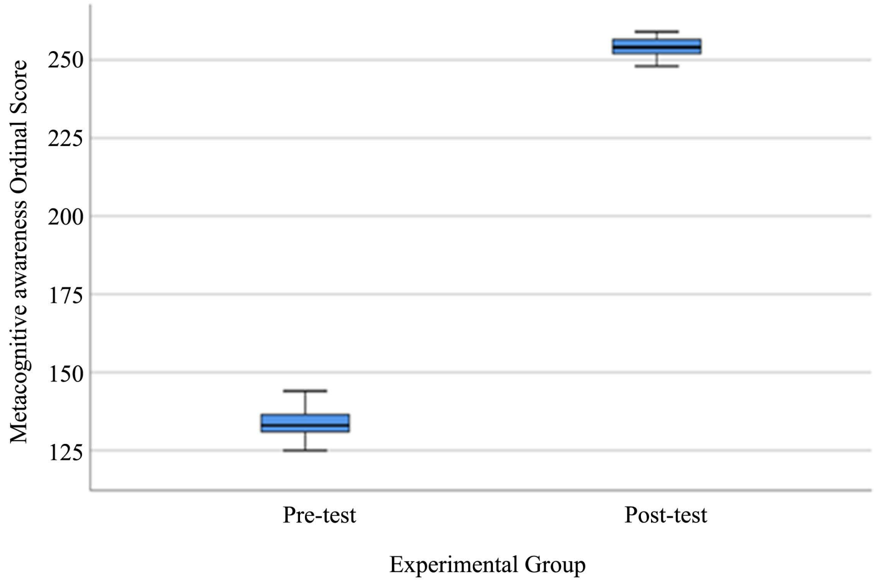

Figure 5. Boxplot graph of pre- and post-test of metacognitive awareness ordinal scores in the treatment group.

Table 9. Wilcoxon Test signed rank metacognitive awareness scores in the treatment group.

Metacognitive awareness	*N*	*M*	*SD*	Median	Z	Mean Rank	Sig
Pre	15	133.47	4.912	133	−3.413	8.00	0.001
Post	15	254.07	3.369	254			

Meanwhile, to answer research question 6, which is to compare the ordinal scores of the metacognitive post-awareness test between the independent variables of the control group as well as the treatment group, the Mann-Whitney U test was implemented. The Mann-Whitney U test findings analysis for the post-metacognitive awareness test ordinal scores for the treatment and control groups are outlined in **Table 10**.

To test the study hypothesis (H_{06}), the Mann-Whitney U test was employed. This is to establish whether there exists a difference between the ordinal score of the metacognitive post-awareness test of the control group (N = 15) and the ordinal score of the metacognitive post-awareness test of the treatment group (N = 15). Study findings were significant, Mann-Whitney U = 0.000, p = 0.00 ($p < 0.05$). Note that the null hypothesis (H_{06}) is rejected because the mean rank of the post-test with respect to the treatment group was higher in comparison to the mean rank of the post-test for the control group (mean rank of the ordinal score with respect to the metacognitive post-awareness test for the control group = 8.50, whereas the mean of the ordinal score of the metacognitive awareness test for the treatment group = 24.00). A substantial difference exists between the control group and the treatment group in this study, referring to the Mann-Whitney U test findings.

Table 10. Mann-Whitney U Test of metacognitive awareness between the control and treatment group.

Group	N	MR	SR	Z	Mann-Whitney U	Sig
Control	15	8.00	120.00	−4.673	0.000	0.000
Treatment	15	23.00	345.00			

Boxplot graphs were created to compare Median values of the ordinal scores of the metacognitive post-awareness test between the treatment and control groups, further supporting the results of the Mann-Whitney U test. **Figure 6** is a Boxplot Graph of ordinal scores of post-metacognitive awareness tests between the control and treatment groups. Furthermore, the median value of the ordinal score of the metacognitive post-awareness test of the treatment group (M = 254) was higher as opposed to the median value of the ordinal score of the metacognitive post-awareness test of the control group (M = 155). These findings indicate an effect of the integration of the ME-CoT module on the metacognitive awareness of Biology Form 4 students in the treatment group.

4. Discussion

The ME-CoT module's effectiveness in this study can be shown with regards to raising students' levels of computational thinking (CT) and metacognitive awareness while also enhancing their performance in the Respiratory Systems of Humans and Animals topic. Therefore, this study uses a quasi-experimental method. Two groups of Form 4 Biology students from two schools in Jempol participated in this study. Moreover, the treatment group comprised 15 students who underwent PdPc sessions based on the ME-CoT module. In comparison, the control group consisted of 16 students who underwent traditional PdPc sessions, which are often applied by teachers while delivering lesson content in the classroom. Both groups were given pre-test and post-test with respect to the three study variables, namely, a set of achievement test questions (Respiratory Systems in Humans and Animals), a set of CT problem-solving questionnaires as well as a set of metacognitive awareness questionnaires. The sampling of the study involved students available in Form Four Science (Biology) classes. The results of a significant Mann-Whitney U test study showed that the treatment group's mean rank post-test grade was significantly greater than the control group. This might be seen as showing that the ME-CoT module had a very significant impact on student achievement, developing a level of CT and encouraging students to be aware of their metacognitive processes. But in order to support the study's conclusions, even more, the relationship and interrelationship between the three dependent variables have been discussed in more detail.

Evaluation in terms of the effectiveness of the module starts from the ME-CoT module establishment. If explored more precisely, the development of the ME-COT module is an integration of four learning theories as Theory of

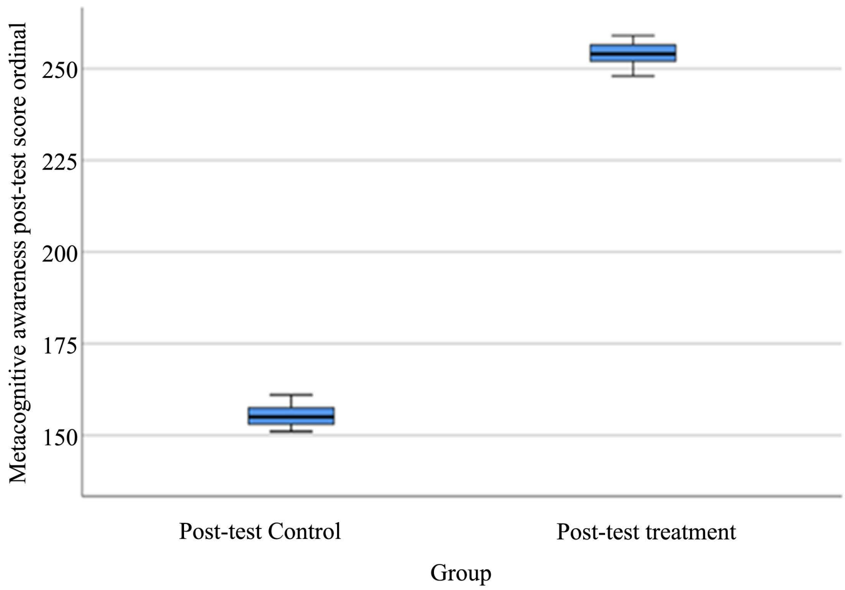

Figure 6. Boxplot graph of ordinal scores metacognitive post-awareness tests between the treatment group and the control group.

Constructivism, Metacognitive Theory, Vygotsky's Social Theory of Constructivism, as well as Robert Gagne's Information Processing Theory. The laws and fundamentals found in each theory are utilized to enhance the ME-CoT module for the mastery of knowledge and information required in this study. Meanwhile, to further strengthen this research, the combination of CT skills as a solution from The Framework of CT as Problem Solving (Kalelioglu et al., 2016) as well as its compilation based on the Revised Bloom Taxonomy Model and CT (Burbaite et al., 2018) have helped in fostering metacognitive awareness in students.

The ME-CoT module is a content-rich module based on four units on the topic of Respiratory Systems in Humans and Animals. Each unit is developed based on the lesson objectives found in the Biology content standard Form 4, which was crafted by the Malaysian Education Ministry. Meanwhile, the ME-CoT module contains 20 worksheets that meet the requirements for the mastery of each piece of information related to the Respiratory Systems in Humans and Animals. In the meantime, the application of CT skills through various activities that include content standards as well as programming activities allows students to train CT in solving a problem. Meanwhile, the arrangement of CT skills is one of the strengths of the ME-CoT module. Referring to the *Revised Bloom's Taxonomy and CT* (Burbaite et al., 2018), this design automatically aids in promoting metacognitive awareness among students. Furthermore, the sequencing of tasks based on inquiry-based and problem-based learning enhances students' motivation to master the subject matter as well as their ability to grasp the lesson's material.

Active learning that exists through the application of ME-CoT modules in the classroom is seen not only from student involvement and formative assessment but also through the production of learning products. Learning products help students understand the content of the lesson. At the same time, each step presented through the arrangement of CT skills like problem-solving also contributes to the CT construction, including fostering metacognitive awareness of students in stages. Furthermore, solving a problem based on the content of Biology lessons computationally (Kalelioglu et al., 2016) can foster metacognitive awareness in students in stages starting with planning, monitoring, evaluation, information management strategies, debugging, declarative knowledge, procedural knowledge, and lastly conditional knowledge (Schraw & Dennison, 1994). This gradual involvement of students triggers an active form of learning and is directly responsible for the construction of CT and the construction of metacognitive awareness in students, as well as contributing to students' achievement in Biology education.

The ME-CoT module's worksheets and activities all adhere to the concept of understanding the course material. Based on the four units of the Respiratory Systems in Humans and Animals, each worksheet was created, where the delivery of lessons ranges from simple to more complex. Programming activities begin with the construction of algorithms, which is among the CT skills of problem-solving. The algorithm provided by the students is the essence of the lesson content to be included in the Visual Studio Software Module to prepare the activity product. With this, it can be clarified that the learning process will occur simultaneously with the construction of CT and the fostering of metacognitive awareness takes place. Although the programming activities applied in the ME-CoT module are the foundation of Computer Science, each CT skill, for instance, problem-solving, is compiled and developed, attributing to the essence of lesson content and can help students improve not only achievement but also build CT as well as foster metacognitive awareness.

Provided that the three variables in the research problem are traced in this case, it has an impact on the achievement of the Biology subject at the school and international levels. Student achievement has a less encouraging impact, especially in the subject of Biology. Student achievement in Biology also contributes to student achievement in STEM. The achievement of Malaysian students in PISA in the subject of Science, as well as the achievement of Malaysian students in TIMSS, specifically in the subject of Biology, gave a great blow to Malaysia at the international level. The decline in achievement, as well as the lackluster scores of Malaysian students, has profoundly impacted the issue of achieving the 60:40 Policy. This issue also contributes to the issue of unemployment (Kamaruddin & Che Aleha, 2016) among male and female students after graduating from the tertiary level due to a lack of capability to be competitive in the global world (Shamsudin et al., 2014). Student engagement in Science and Mathematics declined because of the practice of lecture-type learning (Çimer, 2012; Fazilah et al., 2016; Kamisah et al., 2013; Ah-Nam & Osman, 2017) as well as memorization methods (Fazilah et al., 2016) applied in schools. Here, students begin to feel bored and not interested in actively engaging in learning as well as creating a lack of motivation in learning subjects. This, in particular, concerns STEM and ends up having a negative impact on student achievement in STEM. The ME-CoT module was developed by considering each consequence and problem.

The integration of the ME-CoT module provides a clear explanation of how to discard memorization techniques and the application of the techniques of understanding the content of the lesson in stages, starting from the basic or simple to the more complex without stressing memorization. The thinking skills that are focused on in this study consist of six CT skills as problem-solving, namely; 1) abstraction, 2) decomposition, 3) pattern recognition, 4) algorithm construction, 5) modeling and simulation and 6) debugging recommended by Kalelioglu et al. (2016). Besides, each problem-solving CT skill used in the ME-CoT module was constructed based on the Revised Bloom Taxonomy and CT Model in order to maximize the promotion of metacognitive awareness (Burbaite et al., 2018). The ME-CoT module's uniqueness in building CT is also evident through the application of three Visual Studio Software Modules known as 1) See, Pause and Answer Module, 2) Drag and Drop Module, and 3) Speak Out Module. These three modules include modeling and simulation. The fifth skill in the organization of CT skills is problem-solving. The Visual Studio Software module covers programming activities that use the C# programming language. The ME-CoT module emphasizes programming training because it is a thinking exercise (Oluk & Korkmaz, 2016). In addition, the programming activity is not only a mechanical process but also a discipline of thinking. There exists a very high relationship between students' programming skills and CT skills (Oluk & Korkmaz, 2016), proving the ME-CoT module may enhance students' achievement, establish CT, and develop metacognitive awareness among students.

The development of a student not only involves the achievement and level of thinking skills in students but also the type of activity that students are participating in through the teaching and learning activities is also a contributor. Only the future-oriented and adaptable to the new methods of teaching and learning among educators can bring some changes happening in the digital age of wisdom, not the educator who is still acquiring the traditional methods. Meanwhile, the students or the learners who are thrown out of cybergogy and peeragogy will always be dependent and not independent (Anealka, 2018; Mokhtar et al., 2019). Besides that, transformation in teaching and learning will structure the education market structure when the students are exposed to the new teaching strategies emphasized in IR 4.0 (Nor Samsinar et al., 2019). The exerting to enhance STEM education showed that humans and technology are aligned (Anealka, 2018).

Assessing the information when the memorization method (Dani Asmadi & Kamisah, 2011; Fazilah et al., 2016; Végh et al., 2017) is still applied in the classroom, especially in fact-rich Biology subjects, then the existence of passive learning situations will be more pronounced (Allen & Tanner, 2005). Thereby, active learning must be triggered in a pedagogical approach that enables students to apply cognitive skills and strategies at a higher level by creating meaning from their experiences and environment and therefore building their knowledge and understanding will be created. The ME-CoT module emphasizes PBM and PBI, and these pedagogical approaches have included using CT to solve problems. Solving problems is a CT skill that can aid in developing CT. The need for students to master CT is to help students solve complex problems simply and systematically, such as a computer (Khine, 2018; Lee & Malyn-Smith, 2020; Wing, 2008), to form the workforce needed in IR 4.0. Furthermore, the ME-CoT module is particularly interested in the benefits of integrating CT skills with problem-solving when presenting lesson content, which helps in fostering metacognitive awareness. While using the ME-CoT module, students will carefully plan the time and information required to monitor activity procedures, problems, and information required. Students make evaluations of constructed activity products and products presentation, identify information strategies, debug by identifying errors to be corrected, cultivate declarative knowledge, and implement procedural knowledge, as well as conditional knowledge.

This study result promotes that CT is very important in shaping students so that they are prepared to deal with issues in the actual world. Metacognitive awareness also plays a crucial role in enhancing student achievement and helping students achieve academic excellence at the globalization level. To improve achievement, build computational thinking, as well as foster metacognitive awareness, CT skills, as problem-solving plays an essential role, have been crafted through 20 types of activities, starting from the basics to the more complex ones, as emphasized in the arrangement of CT skills as problem-solving indicated the ME-CoT modules' effectiveness. To further develop the ME-CoT module's effectiveness, the researcher also presented advanced research involving active learning as a research variable, applying the ME-CoT module in other learning areas or other STEM subjects, diversifying the set of CT skills, as well as increasing the number of study respondents. Therefore, the ME-CoT module has become an important tool in taking proactive steps toward elevating the quality of education to world standards.

5. Conclusion

This study effectively demonstrates how the ME-CoT Learning module improves biology education outcomes for students by developing computational thinking (CT) as well as metacognitive awareness. This work proposes an interdisciplinary approach, integrating computer science into Biology education through the ME-CoT module. It is proven to be another method for improving students' achievement in Biology education, developing computational thinking, and nurturing metacognitive awareness among secondary school students. Additionally, teachers are urged to incorporate problem-based learning and inquiry-based learning into their teaching and learning process to promote active learning through the use of this teaching module. This module is also able to increase the students' interest in acquiring Biology content by focusing on the Module independently. The project-based learning emphasized in the Biology curriculum had been a plus point in order to integrate the ME-CoT Learning module in the classroom.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Ah-Nam, L., & Osman, K. (2017). Developing 21st Century Skills through a Constructivist-Constructionist Learning Environment. *K-12 STEM Education, 3,* 205-216.

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Mohammed, B. S. (2018). Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry. *MATEC Web of Conferences, 203,* Article No. 02010. https://doi.org/10.1051/matecconf/201820302010

Allen, D., & Tanner, K. (2005). Infusing Active Learning into the Large-Enrollment Biology Class: Seven Strategies, from the Simple to Complex. *Cell Biology Education, 4,* 262-268. https://doi.org/10.1187/cbe.05-08-0113

Allsop, Y. (2019). Assessing Computational Thinking Process Using a Multiple Evaluation Approach. *International Journal of Child-Computer Interaction, 19,* 30-55. https://doi.org/10.1016/j.ijcci.2018.10.004

Anealka, A. H. (2018). Education 4.0 Made Simple: Ideas for Teaching. *International Journal of Education and Literacy Studies, 6,* 92-98. https://doi.org/10.7575/aiac.ijels.v.6n.3p.92

Angeli, C., & Giannakos, M. (2020). Computational Thinking Education: Issues and Challenges. *Computers in Human Behavior, 105,* 106185. https://doi.org/10.1016/j.chb.2019.106185

Angeli, C., & Jaipal-Jamani, K. (2018). Preparing Pre-Service Teachers to Promote Computational Thinking in School Classrooms. In M. Khine (Ed.), *Computational Thinking in the Stem Disciplines* (pp. 127-150). Springer. https://doi.org/10.1007/978-3-319-93566-9_7

Astuti, D., Khasanah, U., & Romadon, S. (2017). The Effect of Thinking Empowerment by Questioning (TEQ) through Team-Assisted Individualization (TAI) Learning Model to Metacognitive and Learning Achievement. In *Ahmad Dahlan International Conference on Mathematics and Mathematics Education* (pp. 182-186).

Basu, S., Biswas, G., & Kinnebrew, J. S. (2017). Learner Modeling for Adaptive Scaffolding in a Computational Thinking-Based Science Learning Environment. *User Modeling and User-Adapted Interaction, 27,* 5-53. https://doi.org/10.1007/s11257-017-9187-0

Becker, B. A. (2019). A Survey of Introductory Programming Courses in Ireland. In *Annual Conference on Innovation and Technology in Computer Science Education* (pp. 58-64). Association for Computing Machinery. https://doi.org/10.1145/3304221.3319752

Brennan, K., & Resnick, M. (2012). New Frameworks for Studying and Assessing the Development of Computational Thinking. In *Proceedings of the 2012 Annual Meeting of* *the American Educational Research Association* (pp. 1-25).

Burbaite, R., Drasute, V., & Stuikys, V. V. (2018). Integration of Computational Thinking Skills in STEM-Driven Computer Science Education. *Global Engineering Education Conference (EDUCON), 2,* 1824-1832. https://doi.org/10.1109/EDUCON.2018.8363456

Çakiroğlu, Ü., & Er, B. (2020). Effect of Using Metacognitive Strategies to Enhance Programming Performances. *Informatics in Education, 19,* 181-200. https://doi.org/10.15388/infedu.2020.09

Campbell, D. T., Stanley, J. C., & Gage, N. L. (1963). *Experimental and Quasi-Experimental Designs for Research.* Houghton Mifflin.

Cansu, F. K., & Cansu, S. K. (2019). An Overview of Computational Thinking. *International Journal of Computer Science Education in Schools, 3,* 17-30. https://doi.org/10.21585/ijcses.v3i1.53

Cardinale, J. A., & Johnson, B. C. (2017). Metacognition Modules: A Scaffolded Series of Online Assignments Designed to Improve Students' Study Skills. *Journal of Microbiology & Biology Education, 18.* https://doi.org/10.1128/jmbe.v18i1.1212

Caviola, S., Mammarella, I. C., Cornoldi, C., & Lucangeli, D. (2009). A Metacognitive Visuospatial Working Memory Training for Children. *International Electronic Journal of Elementary Education, 2,* 122-136.

Cheah, H. M. (2016). Enhancing Creative Teaching using Computational Thinking. In *International Conference on Teaching and Learning 2016* (pp. 26-42).

Cheng, P., & Eng, P. (2009). Penentuan Kesahan Dan Kebolehpercayaan Alat Ukur Metakognitif Dengan Analisis Model Rasch. In *Conference on Scientific and Social Research CSSR.*

Chong, F. Y., & Sungap, L. (2021). Hubungan dan Pengaruh Kesedaran Metakognitif Terhadap Pencapaian Matematik Pengurusan dalam kalangan Pelajar Diploma Pemasaran Politeknik Malaysia. *Asian Pendidikan, 2,* 1-8.

Chou, M. H. (2017). A Task-Based Language Teaching Approach to Developing Metacognitive Strategies for Listening Comprehension. *International Journal of Listening, 31,* 51-70. https://doi.org/10.1080/10904018.2015.1098542

Çimer, A. (2007). Effective Teaching in Science : A Review of Literature. *Journal of Turkish Science Education, 4,* 20-44.

Çimer, A. (2012). What Makes Biology Learning Difficult and Effective: Students' Views. *Educational Research and Reviews, 7,* 61-71.

Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in Bloom: Implementing Bloom's Taxonomy to Enhance Student Learning in Biology. *CBE Life Sciences Education, 7,* 368-381. https://doi.org/10.1187/cbe.08-05-0024

Csizmadia, A., Standl, B., & Waite, J. (2019). Integrating the Constructionist Learning Theory with Computational Thinking Classroom Activities. *Informatics in Education, 18,* 41-67. https://doi.org/10.15388/infedu.2019.03

Dani Asmadi, I., & Kamisah, O. (2011). Kemahiran Berfikir Aras Tinggi, Pengajaran Tajuk Model Atom Dan Pencapaian Objektif Kursus Kimia. In *Seminar Majlis Dekan-Dekan Pendidikan IPTA September 2011.*

Dori, Y. J., Avargil, S., Kohen, Z., & Saar, L. (2018). Context-Based Learning and Metacognitive Prompts for Enhancing Scientific Text Comprehension. *International Journal of Science Education, 40,* 1198-1220. https://doi.org/10.1080/09500693.2018.1470351

Farah Aida, S., & Che Nidzam, C. A. (2016). Kesedaran strategi metakognitif dan kemahiran berfikir aras tinggi dalam kalangan pelajar biologi. *Jurnal Penyelidikan Pendidi-*

kan (KPM), 15, 1-18.

Fazilah, R., Othman, T., & Azraai, O. (2016). Aplikasi Kemahiran Proses Sains dalam Pembelajaran Berasaskan Masalah untuk Matapelajaran Biologi. *Jurnal Kurikulum & Pengajaran Asia Pasifik, 4,* 38-46.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education* (8th ed.). McGraw Hill Companies.

Gómez-Veiga, I., Vila Chaves, J. O., Duque, G., & García Madruga, J. A. (2018). A New Look to a Classic Issue: Reasoning and Academic Achievement at Secondary School. *Frontiers in Psychology, 9,* Article 400. https://doi.org/10.3389/fpsyg.2018.00400

Hadad, R., Thomas, K., Kachovska, M., & Yin, Y. (2020). Practicing Formative Assessment for Computational Thinking in Making Environments. *Journal of Science Education and Technology, 29,* 162-173. https://doi.org/10.1007/s10956-019-09796-6

Harrison, G. M., & Vallin, L. M. (2018). Evaluating the Metacognitive Awareness Inventory Using Empirical Factor-Structure Evidence. *Metacognition and Learning, 13,* 15-38. https://doi.org/10.1007/s11409-017-9176-z

Harvey, B., & Mönig, J. (2010). Bringing "No Ceiling" to Scratch: Can One Language Serve Kids and Computer Scientists? In *Constructionism 2010* (pp. 1-10).

Hasan, K. A., Hamzah, M. I., & Lubis, M. A. (2017). Tahap metakognitif murid sekolah menengah di kawasan Felda dalam pembelajaran Pendidikan Islam. *ASEAN Comparative Education Research Journal on Islam and Civilization, 1,* 96-106.

Hermans, F., & Aivaloglou, E. (2017). A Controlled Experiment Comparing Plugged First and Unplugged First Programming Lessons. In *ACM International Conference Proceeding Series* (pp. 49–56).

Jancheski, M. (2017). Improving Teaching and Learning Computer Programming in Schools through Educational Software. *Olympiads in Informatics, 11,* 55-75. https://doi.org/10.15388/ioi.2017.05

João, P., Nuno, D., Fábio, S. F., & Ana, P. (2019). A Cross-Analysis of Block-Based and Visual Programming Apps with Computer Science Student-Teachers. *Education Sciences, 9,* Article 181. https://doi.org/10.3390/educsci9030181

Kalelioglu, F., Gulbahar, Y., & Kukul, V. (2016). A Framework for Computational Thinking Based on a Systematic Research Review. *Baltic Journal of Modern Computing, 4,* 583-596.

Kamaruddin, I., & Che Aleha, L. (2016). Pengetahuan Dan Kesediaan Revolusi Industri 4.0 Dalam Kalangan Pelajar Institut Pendidikan Guru Kampus Ipoh. *The Online Journal of Islamic Education, 4,* 18-26.

Kamisah, O., Lee, C. H., & Vebrianto, R. (2013). 21st Century Biology: An Interdisciplinary Approach of Biology, Technology, Engineering and Mathematics Education. *Procedia—Social and Behavioral Sciences, 102,* 188-194. https://doi.org/10.1016/j.sbspro.2013.10.732

Khine, M. S. (Ed.) (2018). *Computational Thinking in the STEM Disciplines: Foundations and Research highlights*. Springer US. https://doi.org/10.1007/978-3-319-93566-9

Koc, I., & Kuvac, M. (2016). Preservice Science Teachers' Metacognitive Awareness Levels. *European Journal of Education Studies, 2,* 43-63.

Kong, S. C., Chiu, M. M., & Lai, M. (2018). A Study of Primary School Students' Interest, Collaboration Attitude, and Programming Empowerment in Computational Thinking Education. *Computers and Education, 127,* 178-189. https://doi.org/10.1016/j.compedu.2018.08.026

Kong, S., Abelson, H., Swanson, H., Anton, G., Bain, C., Horn, M., & Wilensky, U. (2019). Computational Thinking Education. In S.-C. Kong, & H. Abelson (Eds.), *Computational Thinking Education* (pp. 1-10). Springer. https://doi.org/10.1007/978-981-13-6528-7_1

Kotsopoulos, D., Floyd, L., Khan, S., Namukasa, I. K., Somanath, S., Weber, J., & Yiu, C. (2017). A Pedagogical Framework for Computational Thinking. *Digital Experiences in Mathematics Education, 3,* 154-171. https://doi.org/10.1007/s40751-017-0031-2

KPM (2016). Laporan Kebangsaan PISA 2015. Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, Malaysia.

KPM (2017). Laporan Kebangsaan TIMSS 2015. Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, Malaysia.

KPM (2018). *Dokumen Standard Kurikulum dan Pentaksiran* (Bahagian Pembangunan Kurikulum). Malaysia.

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *American Journal of Psychology, 41,* 219-225. https://doi.org/10.1207/s15430421tip4104_2

Krpan, D., Mladenovic, S., & Zaharija, G. (2017). Mediated Transfer from Visual to High-Level Programming Language. In *2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics* (pp. 800-805). IEEE. https://doi.org/10.23919/MIPRO.2017.7973531

Lai, Y., Zhu, X., Chen, Y., & Li, Y. (2015). Effects of Mathematics Anxiety and Mathematical Metacognition on Word Problem Solving in Children with and without Mathematical Learning Difficulties. *Journal of Chemical Information and Modeling, 53,* 1689-1699.

Lee, I., & Malyn-Smith, J. (2020). Computational Thinking Integration Patterns along the Framework Defining Computational Thinking from a Disciplinary Perspective. *Journal of Science Education and Technology, 29,* 9-18. https://doi.org/10.1007/s10956-019-09802-x

Li, X., Liu, D., & Zhang, X. (2019). A System Integrated with C# Programing and Real-Time 3D Observation for Learning Virtual Reality Technology. *Open Journal of Social Sciences, 7,* 127-135. https://doi.org/10.4236/jss.2019.73009

Lilia, H., Norshariani, A. R., Ria, Z., & Lilia, M. (2018). The Roles of Parents in Cultivating Children's Interest towards Science Learning and Careers. *Kasetsart Journal of Social Sciences, 39,* 190-196. https://doi.org/10.1016/j.kjss.2017.05.001

Ling, U. L., Saibin, T. C., Labadin, J., & Aziz, N. A. (2017). Preliminary Investigation: Teachers Perception on Computational Thinking Concepts. *Journal of Telecommunication, Electronic and Computer Engineering, 9,* 23-29.

Lockwood, J., & Mooney, A. (2018). Computational Thinking in Secondary Education: Where Does It Fit? A Systematic Literary Review. *International Journal of Computer Science Education in Schools, 2,* 41-60. https://doi.org/10.21585/ijcses.v2i1.26

Lye, S. Y., & Koh, J. H. L. (2014). Review on Teaching and Learning of Computational Thinking through Programming: What Is Next for K-12? *Computers in Human Behavior, 41,* 51-61. https://doi.org/10.1016/j.chb.2014.09.012

Malik, M. (2019). Jumlah Pelajar Mengambil Kejuruteraan dan Matematik (STEM) Semakin Merosot. *Info Media: BPPDP BIL.*(*02*) *2019*, *Edisi Mac-April*, *02*, 1-12.

Malik, S. I., Mathew, R., & Hammood, M. (2019). PROBSOL: A Web-Based Application to Develop Problem-Solving Skills in Introductory Programming Sohail. In A. Al-Masri, & K. Curran (Eds.), *Smart Technologies and Innovation for a Sustainable Future. Advances in Science, Technology & Innovation* (pp. 295-302). Springer.

https://doi.org/10.1007/978-3-030-01659-3_34

Mazli Sham, A., & Saemah, R. (2014). Gaya pembelajaran dan kesedaran metakognitif dalam kalangan pelajar aliran sains. In *Proceeding of the Social Sciences Research ICSSR* (pp. 712-719).

McMillan, J., & Schumacher, S. (2014). *Research in Education Evidence-Based Inquiry.* Pearson.

Mohaghegh, D. M., & McCauley, M. (2016). Computational Thinking: The Skill Set of the 21st Century. *International Journal of Computer Science and Information Technologies (IJCSIT), 7,* 1524-1530.

Mohamad Masrizan, A. P. (2019). Exploring Metacognition Regulation among Biology Student at Labuan Matriculation College Mohamad. *Jurnal Kurikulum, 53,* 1-16.

Mohd Tafizam, M. T., & Ramlee, M. (2017). Kemudahan Prasarana Dalam Pelaksanaan Mata Pelajaran Teknologi Kejuruteraan, Lukisan Kejuruteraan dan Reka Cipta di Sekolah Menengah Harian Malaysia. *Sains Humanika, 9,* 11-17. https://doi.org/10.11113/sh.v9n1-5.1171

Mokhtar, S., Alshboul, J. A. Q., & Shahin, G. O. A. (2019). Towards Data-driven Education with Learning Analytics for Educator 4.0. *Journal of Physics: Conference Series, 1339,* Article ID: 012079. https://doi.org/10.1088/1742-6596/1339/1/012079

Najibulla, R., Corrienna, A. T., & Nur Wahidah, A. H. (2018). The Necessity of Computational Thinking in STEM Education: An Analysis with Recommended Research. *Learning Science and Mathematics, No. 13,* 1-12.

Nor Samsinar, K., Radin Firdaus, R. B., Farrah Dina, A. R., & Ridha Siregar, M. (2019). Realizing Industry 4.0 through STEM Education: But Why STEM Is Not Preferred? *IOP Conference Series: Materials Science and Engineering, 506,* Article ID: 012005. https://doi.org/10.1088/1757-899X/506/1/012005

Nurulrabihah, M. N., Siti Hajar, H., & Saedah, S. (2020). Analisis Faktor Kekangan Pembelajaran Berasaskan Reka Bentuk Dalam Kalangan Guru Berdasarkan Fuzzy Delphi Method. *Jurnal Kurikulum & Pengajaran Asia Pasifik, 8,* 33-42.

O'Neil, H. F., & Abedi, J. (1996). Reliability and Validity of a State Metacognitive Inventory: Potential for Alternative Assessment. *Journal of Educational Research, 89,* 234-245. https://doi.org/10.1080/00220671.1996.9941208

Oluk, A., & Korkmaz, Ö. (2016). Comparing Students' Scratch Skills with Their Computational Thinking Skills in Terms of Different Variables. *International Journal of Modern Education and Computer Science, 8,* 1-7. https://doi.org/10.5815/ijmecs.2016.11.01

Periya, S. N., & Moro, C. (2019). Applied Learning of Anatomy and Physiology: Virtual Dissectiontables Within Medical and Health Sciences Education. *The Bangkok Medical Journal, 15,* 121-127. https://doi.org/10.31524/bkkmedj.2019.02.021

Phang, F. A., & Tahir, N. A. (2012). Scientific Skills among Pre-Service Science Teachers at Universiti Teknologi Malaysia. *Procedia-Social and Behavioral Sciences, 56,* 307-313. https://doi.org/10.1016/j.sbspro.2012.09.659

Piaget, J. (1972). The Role of Imitation in the Development of Representational Thought. *International Journal of Mental Health, 1,* 67-74. https://doi.org/10.1080/00207411.1972.11448598

Pratama, H., Azman, M. N. A., Mustapha, R., Ab Rahman, A., & Rus, R. C. (2015). Keberkesanan kaedah pembelajaran berasaskan DD/CT terhadap kecerdasan emosi pelajar sekolah menengah di Banda Aceh. *Sains Humanika, 7,* 19-29.

Puganesri, K., & Puteh, S. (2019). Computer Science Education in Malaysia Schools: The Challenges of Enhancing Computational Thinking Skills. *International Journal of En-*

gineering and Advanced Technology, 8, 441-444. https://doi.org/10.35940/ijeat.F1080.0986S319

Qian, Y., & Lehman, J. (2017). Students' Misconceptions and Other Difficulties in Introductory Programming: A Literature Review. *ACM Transactions on Computing Education, 18,* 1-24. https://doi.org/10.1145/3077618

Rahardja, U., Aini, Q., Graha, Y. I., & Tangkaw, M. R. (2019). Gamification Framework Design of Management Education and Development in Industrial Revolution 4.0. *Journal of Physics: Conference Series, 1364,* Article ID: 012035. https://doi.org/10.1088/1742-6596/1364/1/012035

Rahimi, M., & Katal, M. (2012). Metacognitive Strategies Awareness and Success in Learning English as a Foreign Language: An Overview. *Procedia-Social and Behavioral Sciences, 31,* 73-81. https://doi.org/10.1016/j.sbspro.2011.12.019

Rehmat, A. P., Ehsan, H., & Cardella, M. E. (2020). Instructional Strategies to Promote Computational Thinking for Young Learners. *Journal of Digital Learning in Teacher Education, 36,* 46-62. https://doi.org/10.1080/21532974.2019.1693942

Reinoso Tapia, R., Delgado-Iglesias, J., & Fernández, I. (2019). Learning Difficulties, Alternative Conceptions and Misconceptions of Student Teachers about Respiratory Physiology. *International Journal of Science Education, 41,* 2602-2625.

Rich, K. M., Yadav, A., & Larimore, R. A. (2020). Teacher Implementation Profiles for Integrating Computational Thinking into Elementary Mathematics and Science Instruction. *Education and Information Technologies, 25,* 3161-3188. https://doi.org/10.1007/s10639-020-10115-5

Romero, M., Lepage, A., & Lille, B. (2017). Computational Thinking Development through Creative Programming in Higher Education. *International Journal of Educational Technology in Higher Education, 14,* Article No. 42. https://doi.org/10.1186/s41239-017-0080-z

Rubinstein, A., & Chor, B. (2014). Computational Thinking in Life Science Education. *PLOS Computational Biology, 10,* e1003897. https://doi.org/10.1371/journal.pcbi.1003897

Saad, A. (2020). Students' Computational Thinking Skill through Cooperative Learning Based on Hands-On, Inquiry-Based, and Student-Centric Learning Approaches. *Universal Journal of Educational Research, 8,* 290-296. https://doi.org/10.13189/ujer.2020.080135

Scherer, R., & Siddiq, F. (2020). Computers in Human Behavior: A Meta-Analysis of Teaching and Learning Computer Programming: Effective Instructional Approaches and Conditions. *Computers in Human Behavior, 109,* Article ID: 106349. https://doi.org/10.1016/j.chb.2020.106349

Schraw, G., & Dennison, R. S. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology, 19,* 460-475. https://doi.org/10.1006/ceps.1994.1033

Sengupta, P., Kinnebrew, J. S., Basu, S., Biswas, G., & Clark, D. (2013). Integrating Computational Thinking with K-12 Science Education Using Agent-Based Computation: A Theoretical Framework. *Education and Information Technologies, 18,* 351-380. https://doi.org/10.1007/s10639-012-9240-x

Shamsudin, S., Tek, O. E., & Desa, S. (2014). Kesan Penggunaan Pembelajaran Berasaskan Masalah Terhadap Pencapaian Biologi. *Jurnal Pendidikan Sains & Matematik Malaysia, 2,* 49-61.

Sharifah Maryam, S. A., Mahyuddin, A., & Hasnah, M. (2017). The Framework for the Integration of Computational Thinking in Ideation Process. In *2017 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp.

61-65). IEEE.

Stripeikaitė, I. (2017). “Skipping the Baby Steps”: The Importance of Teaching Practical Programming before Programming Theory. In M. Alcañiz, S. Göbel, M. Ma, M. Fradinho Oliveira, J. Baalsrud Hauge, & T. Marsh (Eds.), *Serious Games. JCSG 2017. Lecture Notes in Computer Science, Vol. 10622* (pp. 319-330). Springer. https://doi.org/10.1007/978-3-319-70111-0_30

Sun, L. (2013). The Effect of Meta-Cognitive Learning Strategies on English Learning. *Theory and Practice in Language Studies, 3,* 2004-2009. https://doi.org/10.4304/tpls.3.11.2004-2009

Susan, S., & Nurfaradilla, M. N. (2019). Teachers’ Concern towards Applying Computational Thinking Skills in Teaching and Learning. *International Journal of Academic Research in Business and Social Sciences, 9,* 296-310. https://doi.org/10.6007/IJARBSS/v9-i1/5398

Swanson, H., Anton, G., Bain, C., Horn, M., & Wilensky, U. (2019). Introducing and Assessing Computational Thinking in the Secondary Science Classroom. In S. C. Kong, & H. Abelson (Eds.), *Computational Thinking Education* (pp. 99-117). Springer Singapore.

Tan, Y. S. M., Amiel, J. J., & Yaro, K. (2019). Developing Theoretical Coherence in Teaching and Learning: Case of Neuroscience-Framed Learning Study. *International Journal for Lesson and Learning Studies, 8,* 229-243. https://doi.org/10.1108/IJLLS-10-2018-0072

Tran, Y. (2019). Computational Thinking Equity in Elementary Classrooms: What Third-Grade Students Know and Can Do. *Journal of Educational Computing Research, 57,* 3-31. https://doi.org/10.1177/0735633117743918

Végh, V., Nagy, Z. B., Zsigmond, C., & Elbert, G. (2017). The Effects of Using Edmodo in Biology Education on Students’ Attitudes towards Biology and ICT. *Problems of Education in the 21st Century, 75,* 483-495. https://doi.org/10.33225/pec/17.75.483

Vygotsky, L. S. (1979). Consciousness as a Problem in the Psychology of Behavior. *Soviet Psychology, 17,* 3-35. https://doi.org/10.2753/RPO1061-040517043

Weintrop, D., & Wilensky, U. (2017). Comparing Block-Based and Text-Based Programming in High School Computer Science Classrooms. *ACM Transactions on Computing Education, 18,* 1-25. https://doi.org/10.1145/3089799

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology, 25,* 127-147. https://doi.org/10.1007/s10956-015-9581-5

Wing, J. (2011). Research Notebook: Computational Thinking—What and Why? *The Link Magazine*, 23 June 2015. http://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why

Wing, J. M. (2006). Computational Thinking. *Concurrences, 49,* 33-35. https://doi.org/10.1145/1118178.1118215

Wing, J. M. (2008). Computational Thinking and Thinking about Computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 366,* 3717-3725. https://doi.org/10.1098/rsta.2008.0118

Wing, J. M., & Stanzione, D. (2016). Progress in Computational Thinking, and Expanding the HPC Community. *Communications of the ACM, 59,* 10-11. https://doi.org/10.1145/2933410

Yağcı, M. (2019). A Valid and Reliable Tool for Examining Computational Thinking Skills. *Education and Information Technologies, 24,* 929-951. https://doi.org/10.1007/s10639-018-9801-8

Zafir, M. M., Fazilah, M. H., & Mohd Nazmy, A. L. (2018). Pengurusan Sumber Manusia Hijau Mendepani Industri 4.0. In *Proceeding of the 5th International Conference on Management and Muamalah 2018 (ICoMM 2018)* (pp. 159-172). http://conference.kuis.edu.my/icomm/5th/images/e-proceeding/IC-016.pdf