ISSN: 1985-5826 AJTLHE Vol. 14, No. 2, December 2022, 59 - 79

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

BRIDGING MAYER'S COGNITIVE THEORY OF MULTIMEDIA LEARNING AND COMPUTATIONAL THINKING IN TACKLING THE COGNITIVE LOAD ISSUES AMONG YOUNG DIGITAL NATIVES: A CONCEPTUAL FRAMEWORK

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Abstract

In 2020, it is undeniable that the existence of digital natives in tertiary education is undeniable, especially in universities. They are part of a tech-savvy generation that led to technological progress that is always connected and linked based on their wishes and needs without any hesitation of time and place. They are basically using technology without guidance, but how far they can manage to handle the consequences of the technology usage and the problems that occur is always questionable. It is undeniable that a digital native must begin with at least a basic level of computer knowledge in order to manage their education and daily life. Learning about computer science not only helps students to create programs, applications or how to handle devices, but strengthens the practise of Computational Thinking (CT). CT refers to the capacity of learners to systematically tackle unstructured tasks focused on four computing concepts such as decomposition, abstraction, pattern recognition, and algorithmic thinking. The purpose of this paper is to study the relationship between CT and Mayer's Cognitive Theory of Multimedia Learning (CTML) on the cognitive load of the learners. This research focuses on CT concepts that will be integrated with Mayer's CTML in designing the learning material for young digital natives. Therefore, the researcher proposes a conceptual framework that aims to comprehend how to facilitate the cruciality of CT concepts in Mayer's CTML when designing instructional learning. The proposed conceptual framework adds value in tackling the cognitive load among students, particularly in the context of the digital native generation. This paper provides several implications and highlights for further studies through a comprehensive and wide-ranging literature review.

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

Keywords: Cognitive theory, Mayer's Cognitive Theory of Multimedia Learning, Computational Thinking, Cognitive Load Theory

Abstrak

Pada tahun 2020, memang tidak dapat dinafikan bahawa kewujudan digital natif dalam pendidikan tinggi terutamanya di universiti. Digital natif merupakan generasi celik teknologi yang membawa kepada kemajuan teknologi. Digital natif pada asasnya mahir menggunakan teknologi tanpa bimbingan, tetapi sejauh mana mereka boleh menguruskan kesan akibat penyalahgunaan penggunaan teknologi sentiasa dipersoalkan. Memang tidak dinafikan bahawa digital natif bermula dengan tahap asas pengetahuan komputer untuk menguruskan pendidikan dan kehidupan seharian mereka. Mempelajari sains komputer bukan sahaja dapat membantu pelajar mencipta program, aplikasi atau cara mengendalikan peranti, tetapi mengukuhkan amalan Pemikiran Komputasional (CT). CT merujuk kepada kapasiti pelajar untuk menangani tugas tidak berstruktur secara sistematik yang tertumpu pada empat konsep pengkomputeran seperti penguraian, abstraksi, pengecaman corak, dan pemikiran algoritma. Artikel ini adalah untk bertujuan mengkaji hubungan antara CT dan Teori Kognitif Pembelajaran Multimedia (CTML) Mayer terhadap beban kognitif pelajar. Penyelidikan ini memfokuskan kepada konsep CT yang disepadukan dengan CTML Mayer dalam mereka bentuk bahan pembelajaran untuk digital natif. Oleh itu, penyelidik mencadangkan rangka kerja konseptual bertujuan untuk memahami kepentingan konsep CT dalam CTML Mayer dalam mereka bentuk pembelajaran instruksional. Rangka kerja konseptual yang dicadangkan menambah nilai dalam menangani beban kognitif di kalangan pelajar, khususnya dalam konteks generasi digital natif. Kertas kerja ini menyediakan beberapa implikasi dan sorotan kajian lanjutan melalui tinjauan literatur yang komprehensif dan meluas.

Kata kunci: Teori kognitif, Teori Kognitif Pembelajaran Multimedia Mayer, Pemikiran Komputasi, Teori Beban Kognitif

1.0 INTRODUCTION

Learning is the achievement and transferring of new and prior knowledge to be able in solving and explaining problems occur within the educational or daily life contexts. There are numerous of methods and strategies have been discussed to achieve an effective learning performance and outcomes of the learners. The rising awareness and facts of cognitive mechanisms and processes has recently established a solid basis for research and instructional design (Sweller et al., 1998). Cognitive load theory offers fundamental for

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researching and increasing the understanding of cognitive functioning as well as learning behaviours in cognitive psychology. By manipulating human cognitive construction in coping with the design of instruction, cognitive load theory relates to education and learning, assuming limited accessible resources of working memory while data is being handled (Van Merriënboer & Sweller, 2005).

Generally, learners are having high cognitive load when facing with a complex learning content, poor design of learning materials and ineffective delivery systems. Research studies by Sweller always stated the importance of handling the cognitive load of a learner when designing the instructional messages or learning materials. There are lot of studies adapted the Sweller's Cognitive Load Theory when highlighting the importance of their learning materials but there is lack of study investigates the importance of computational thinking and Mayer's CTML in tackling the issues of cognitive load among the young digital native and study the impacts of their thinking styles towards the taken approaches. Therefore, by adapting the CT concepts, Mayer's CTML as well as Sweller's Cognitive Theory as a context, this research aims to increase the awareness of young digital native learners' cognitive structure, which can contribute in encouraging the cognitive achievement of learners in various tasks.

2.0 LITERATURE REVIEWS

2.1 Digital Natives

The ideal methods for teaching and learning activities with university students are still being debated in most studies. The majority of university students come from the millennial generation, which is known as the "digital native" generation (Prensky, 2001). Most of the digital natives are coming from millennial generations which born in 1980s to 2000s (Moran, 2016). Hence, the university students can be considered as the digital natives, which showed that using traditional teaching and learning approaches with students is no longer appropriate. The fact that students from those generations have grown up in the digital age and are eager to integrate technology into every part of their lives must also be taken into account by lecturers. However, because they are unfamiliar with digital systems and computational skills, the majority of them lack the skills necessary to manage technology effectively.

CT is viewed as a cutting-edge method for managing the generation of students who are digital natives rather than as a replacement for existing systems. Instead of employing conventional methods, lecturers must adjust their pedagogies and learning applications by applying the relevant techniques or skills. They also need to stay informed about how

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technology is evolving in education because it will inevitably happen (García-Peñalvo & Mendes, 2018). The next generation, which includes our young digital natives, needs CT skills to build their knowledge and solve problems. These competencies include a variety of skills like algorithm, systematic, and logical thinking (Tsai et al., 2019).

These talents are closely tied to the computer science and programming lessons and abilities, which were fiercely queried as factors in raising CT skill (Jocius et al., 2020; Tsai et al., 2019). Due to the significance of CT skills in boosting problem-solving abilities among young digital natives, this study intends to integrate CT concepts into developing the learning materials. Numerous studies have investigated CT and concluded that it can raise students' self-efficacy in learning as well as their academic achievement.

However, no research has been done to examine the effects of cognitive load on young digital natives or to incorporate CT concepts in the design of learning materials or adapt the CT concepts in their present subject in higher institutions. There are countless CT studies for kids, particularly in K-12 and STEM fields, but few studies have been done for college students. Therefore, this paper focuses on highlighting the integration of CT concepts and Mayer’s CTML principles in designing the learning materials.

2.2 Computational Thinking (CT)

CT is referred as procedural thinking by Papert in 1980s’ before he brought the LOGO educational programming with Piaget’s theory of constructivist to propose constructionism. Then, the first CT term used in 1996 which focusing more on the programming domains. However, in 2006, Wing had reintroduced the CT term and claimed it as an essential ability and skills for every person not only focuses on computer science and programming. The main ideas proposed by Wing is to promote thinking like a computer among public but there is no general definition of CT is defined by Wing. In 2012, Wing started describing CT as a thought process and one of the types of problem-solving skills which adapt the computer-related information processing concepts. These skills are crucial in today’s digital age to nurture the creativity and innovation in problem-solving specifically among the millennials and generation X which indirectly can develop attitudes, self-confidence, and communication.

CT becomes trending issues highlighted in current research studies which most of them are discussing on the STEM and computer science (CS) programming subjects. Due to the importance of this skills in this twenty-first centuries, CT is not only crucial for science, mathematics and computer sciences students, but are for all students in primary or secondary

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schools, as well as in HEIs. Though, the CT concepts are debatably complex because the terms are directly led to the computing or computer itself. Several research studies confirmed that there is still no firm and valid consensus defining the CT, thus making the researchers to explicitly define the CT terms to suit their research domains (García-Peñalvo & Mendes, 2018; Román-González et al., 2018). Frequent research studies had related the CT with the problem-solving skills and the steps involved are related with the computational steps and algorithms. Moreover, relevant researchers have recently argued CT as the conceptual basis needed to find the solutions of any problems effectively and competently. Román-González et al. (2018a) has comprehensively reviewed that CT is related and supported the cognitive theory in several ways such as universal cognitive ability, general abilities as well as the level of cognitive development.

Even though no consensus on the definition of CT has been declared, but the importance of it have been broadly discussed. CT is not intended to replace the other approaches, but is considered a new technique as a head of the game in a new era of education in managing digital native students' generation. Lecturers need modifying their pedagogies and learning materials by adapting appropriate techniques or skills instead of using conventional approaches. They also need to be aware and update with technology emergence in education because it's bound to happen eventually (García-Peñalvo & Mendes, 2018).

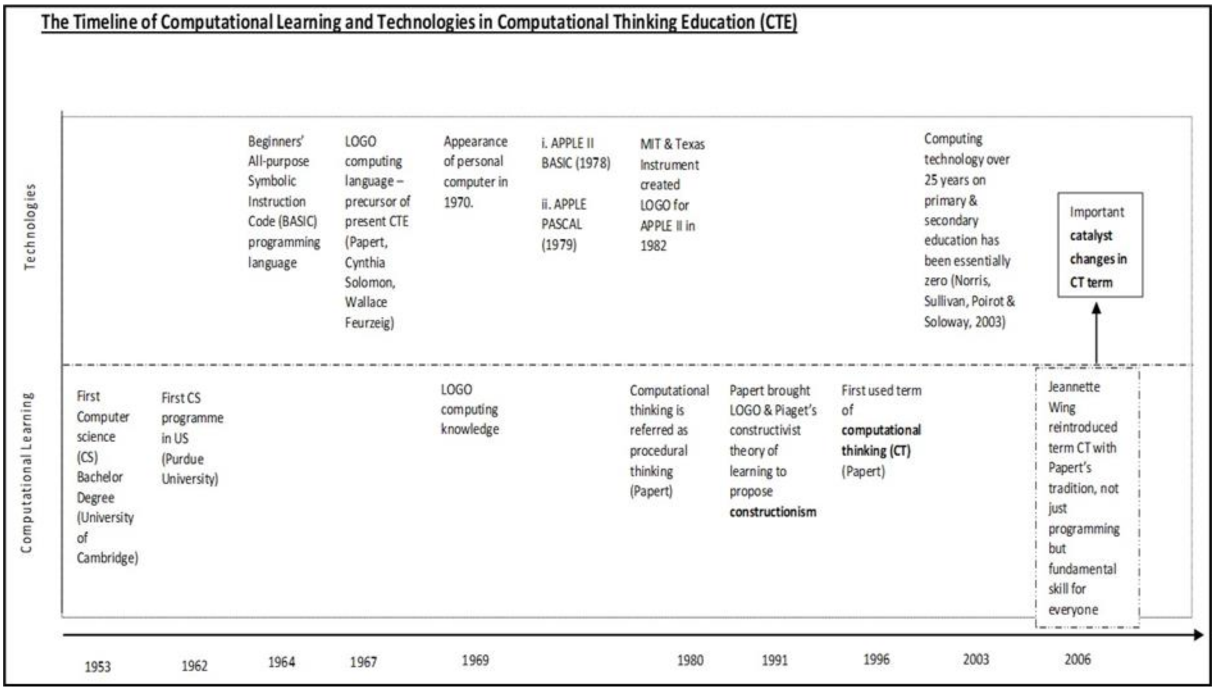

Figure 1: The timeline of computational learning

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Figure 1 shows the timeline of CT history where in 1990s, Papert has brought LOGO programming and working out with Piaget's constructivist theory of learning to propose the constructionism. In 1996, Papert has introduced the Computational Thinking term and from that point, researchers have gradually started revealed the impacts of programming in education. The CT started to become a trending research issues once Wing (2006) reintroduced the CT as a fundamental skill for every person to think like a technologist or computer expert. Starting from that phase, researchers have investigated and discovered how programming lessons can boost and increase learners' CT skills. Generally, programming lessons were considered as a lesson to create computer system and applications, but the CT concepts has extended and expanded such a conception. Basically, learners who are able to solve a complex problem by adapting the CT concepts which naturally will enhance their thinking system to think as a computer scientist. As being highlighted in various studies, CT is unlimited which is it not limited to the computer programming itself but the programming skills and systematically approach are adapted in one's problem-solving skills in tackling various types of challenges.

According to Shute et al. (2017) Shute et al. (2017), CT is a technique to solve a complex problem systematically. They highlighted six (6) concepts in CT such as i) decomposition, ii) abstraction, iii) algorithms, iv) debugging, v) iteration, and vi) generalisation. Decomposition and abstraction can be defined as the method of handling a problem as manageable segments, focus on the main segment of the problem and extracting the structures. Algorithm signifies learners' logical and common-sense of interpretations to systematically design a flow of method for a specified problem. Debugging and iteration are the phases where learner needs to evaluate their whole tasks such as searching, correcting as well as refining errors when they are implementing the solution. Finally, the last phase which is generalization, is applied to seek chances to in transferring the solution to a wider circumstance.

2.3 The core elements of CT

CT can be implemented in education through formal and informal approach that is by integrating it into curriculum as well as in daily life. There are several CT core elements have been discussed in various studies, however the most known elements are decomposition, pattern recognition, abstraction, and algorithms. The decomposition assists learners to break down complicated problem into smaller and manageable issues while recognition guides

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learners to evaluate comparisons between related issues or prior experiences. The abstraction assists learner to recognise valuable information and indirectly ignore unrelated or irrelevant information and algorithm is applied to guide the learner in planning quick and systematic steps to solve issues.

According to Tsai et al. (2019), CT competencies are crucial for the next generation that is our young digital natives in constructing their knowledge and solving issues which are various skills like algorithm, systematic and logical thinking. Those skills are much related to the computing and programming lesson and abilities that were widely debated as contributing factor in enhancing the confidence of CT skills (Jocius et al., 2020; Tsai et al., 2019). The clarification by Wing (2011) stated CT as the processes of thought that involved in formulating problem and the solution can be carried out by the information processing agent was being simplified by Aho (2012). He conceptualised CT as the thought processes in formulation problem and the solution can be represented in the form of algorithm or computational steps. The importance of programming and CT was discussed in work by Wei et al. (2021) that educational researcher has started to explore the pedagogical strategies to teach those subject. One of the pedagogical strategies used in teaching CT is using partial pair programming (PPP)(Lye & Koh, 2014). Kong et al., (2018) discussed that programming empowerment is based on the one's competence as well as perceived autonomy to apply CT successfully. Dong et al. (2019) highlighted that Google also focuses on four CT concepts which are decomposition, pattern recognition, abstraction and algorithm. Those concepts can be applied as a standalone or can be integrated with one another and implement it in any subjects with the existing lesson plans or creating a new one. He also stressed that teachers should be introduced with CT to meet their learning objectives and suitable with their pedagogies rather than to be add on in K-12 curriculums.

Therefore, this research foresees that not only the teachers, but lecturers also can integrate the CT concepts into their pedagogy practices as long as students can achieve the learning objectives. Even though CT is commonly referred as a fundamental part of the computing or programming languages, it can be adapted to facilitate a problem-solving process across any disciplines that is not focuses only in programming and computing related. Referring to the numerous CT research studies, there is still no consensus regarding the CT definition and pedagogies. Countless researchers had stated that there is no strict order in implementing CT and each of the CT concept can be taught independently based on the needs. Therefore, this paper aims to investigate the relationship of algorithm in CT concepts

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with the Mayer's CTML in reducing the cognitive load among the learners.

2.4 Mayer's Cognitive Theory of Multimedia Learning (CTML)

A cognitive theory of multimedia learning (CTML) is proposed by Mayer that focus on human information processing systems. Mayer suggested the CTML based on three cognitive science principles of learning (Mayer, 2014b): (i) there are two distinct channels (auditory and visual) to process information; (ii) the channel has limited volume of capacity to process information; (iii) the active learning is carrying out a set of cognitive processes such as filtering, selecting, organizing, and assimilating information.

Mayer also stressed that there are three concerns on the learner's cognitive capacity which are extraneous processing, essential processing as well as generative processing. Extraneous processing happens when information processing is not related with the instructional objective, essential processing is required to psychologically indicate the important material as demonstrated while generative processing is expected to making sense of the learning material. In 2009, Mayer identified 12 principles in designing instructional multimedia that have been commonly acknowledged and adapted by instructional designers as well as the researchers over the world. The 12 principles of CTML (Mayer, 2014b) are supported the development of the multimedia application for this paper.

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2.5 Sweller's Cognitive Load Theory

Cognitive load theory is an instructional theory that is based on the knowledge of human cognition (Sweller, 2011). It involves on how human's brain processes the information and store it which consist of working memory and long-term memory. Information is processed through the working memory which has limited capacity while it will be store it the long-term memory which has unlimited capacity. Sometimes, the prior knowledge and experiences stored in the long-term memory will be retrieved and integrated to be used in the working memory. Those situations happen in the working memory results in the cognitive load in someone's brain. The processes of new information as well as the cognitive load happen in the working memory will affect the learning outcomes. According to Sweller (2011), the learning activities should be designed carefully to minimise the working memory load since the capacity of working memory is limited and to promote schema achievement in long-term memory. Shannon (2019) found that learner's cognitive becomes better with the use of robotic in teaching the CT among K-12 learners while Weese et al. (2016) highlighted the practice of Scratch which is a program of block-based programming language which has been proven to reduce learner cognitive load. Cognitive load is defined as the volume of information in working memory that was able to grasp at a time. Sweller (1988) stressed that any design or activities that do not contribute in learning should be avoided since working memory has a limited capacity.

According to Kelleher & Pausch (2005), visual programming is able to reduce cognitive load since learner focus and learn the basic of programming where learner focuses on the structure and logic and no need to worry about the language structure of programming. Furthermore, Lye & Koh (2014) stated that programming tools can assist the teacher to teach CT practices that has less cognitive demand. A study conducted by Çakiroğlu et al. (2018) highlighted that the use of Scratch as a programming tool in teaching CT among young learner has the impacts on the perceived cognitive load. They have stated that students generate high perceived cognitive load when they use a lot of programming blocks in Scratch. According to (Sweller, 2011), the capacity for working memory is limited, thus if the intrinsic load is high, the extraneous load must be lower than usual. Meanwhile if the intrinsic load is low and extraneous load is high, it will not hinder the learning processes.

2.6 Computational Thinking and Cognitive Load Theory

According to Moon et al. (2020), they emphasised that the cognitive load in the term of CT where novice learners are likely to encounter high cognitive load when they analyse and

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produce programming codes. Cheng et al. (2022) also argued that many university students having high cognitive load while learning programming and students need to study hard to gain the programming concepts, theories, and skills. However, there are several studies discussed some strategies in reducing the cognitive load in term of CT. According to Winter et al. (2019), the use of visualization and segmenting could lessen the cognitive load associated with the programming. Moore et al. (2020) also discussed that by using the flowchart or any visualization in programming or debugging would help the students manage their cognitive load. They also expressed their views on the CT viewpoint, which holds that students should solve problems algorithmically and could benefit from scaffolding. They believe that using algorithm strategies could assist to reduce the student cognitive load. Moreover, Yadav et al. (2019) highlighted that recently educators are interested with the CT concepts being applied in their lesson since they believe that by applying CT concepts in their lesson could reduce the cognitive load among the students. Weese et al. (2016) also had emphasized that by using scaffolding technique like block-based programming language in nurturing the CT skills, could lessen the cognitive load among the students. Study conducted by Lin et al. (2021) found that there is no significant relationship of cognitive load in CT skills towards students' learning outcome, which means that CT concepts can be applied in any lesson accordingly. However, in Zhong et al. (2021)'s study highlighted the significance of the cognitive load theory in examining the potential educational advantages of multimedia and they stressed that more research studies should be done to investigate the effects of multimedia educational materials on students' cognitive load.

2.7 Mayer's CTML Principles

The development of the multimedia application for this study was supported by the twelve principles of Cognitive Theory in Multimedia Learning (CTML) (Mayer, 2009). Those 12 principles are coherence principle, signalling principle, redundancy principle, spatial continuity principle, temporal continuity principle, segmenting principle, pre-training principle, modality principle, personalization principle, voice principle and image principle.

The multimedia application is designed in accordance with the CTML principles. The CTML principle allows for the integration of many principles into a single module rather than just one module for each principle. When presenting the students with the available fundamental characteristics for a certain subject, the functions of signalling, spatial continuity, and temporal principles are used. Students are exposed to the certain characteristics to make them familiar with the functionality before moving to the content of learning material. The

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highlights of each module are indicated by signals denoted by arrows.

The CTML principles are adapted accordingly in designing the multimedia application. The CTML principle is not only allocated for one module per each principle but one module could have the integration of numerous principles. The functions of signalling, spatial continuity and temporal principles in demonstrating the basic and crucial terms in the subject to the students. Signals that were represented by arrows indicate the highlight of that particular module.

The usage of the spatial continuity concept was proved by the words that described the element that appeared close to the photos. To ensure that students can comprehend the meaning of the visuals, it is preferable to deliver words and graphics at the same time rather than continuously. The CTML temporal principle validates this fact. In this learning material module, the signalling, spatial continuity, and temporal concepts can be used to highlight and illustrate to the students the important parts of the knowledge. According to Mayer (2009) multimedia concept, using words and images combined in a learning application is preferable to using just words. With the use of graphics and words given in multimedia applications, students can learn more effectively.

When creating a module to represent knowledge in a form of short video, the principles of coherence, redundancy, modality, customization, voice, and picture were used. In order to create a better short video for the multimedia application, researchers take into account a number of factors, including the following: I the coherence principle allows for the removal of extraneous words, images, and sounds; ii) in order to support the dual coding theory, images are presented with on-screen text and narration voice; however, in order to avoid violating the redundancy principle, researcher presented a mute function for each module in the application; and iii) (modality principle), iv) use an advanced text-to-speech generator that produces a human-sounding machine voice in the brief video narration (voice principle); v) avoid including the speaker's picture; and vi) words presenting a conversational style are preferable to words presenting a formal style (personalization principle) (image principle). These guidelines are followed to make sure that students may learn more effectively and comprehend the important concepts that the researcher wants to emphasise in the specific modules.

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2.8 Relationship Between Computational Thinking and Mayer's CTML

Algorithm is defined as step by step that involve as the instruction in solving a problem or the similar problems (Aristawat et al., 2018; Dong et al., 2019). Dong et al. (2019), have emphasised a model known as PRADA as a mindset of CT that could assist learner to solve problems systematically. They had stated that coding is important lesson to facilitate PRADA but educators do not need to generate coding or develop any object or application to teach PRADA. Their main objective is to assist the educators to integrate PRADA model in their existing pedagogical practices but the educators need to know how to recognise and adapt the CT concepts in their own subjects or areas. The educators have their own flexibility and creativity to create their learning materials using any available resources. Using PRADA, educators are able to introduce CT to the learners as well as can generalise CT across fields and domains. The study conducted by Dong et al. (2019) proved that PRADA can be adapted to assist the educators to gain more understanding about CT and can integrate CT in creating their own learning materials.

Study conducted by Mihci Türker & Pala (2020) proved that algorithm lessons had the significant and positive effects to the learners algorithmic thinking. Learners are taught the logic of programming with algorithm without any programming languages which demonstrate to the learner on how a computer works in finding a solution to a problem. Learners are able to create their own algorithm based on their own languages by creating flowchart or a pseudocode. According to Mihci Türker & Pala (2020), learners should identify the problem first, then they must define the input, output and possible solutions which will be arrange and connect through step by step systematically in creating their algorithm. These situations demonstrated that algorithm lessons can be considered as an unplugged activity that aim to develop algorithmic thinking to the learners without using computers. Mihci Türker & Pala (2020) added that learners are able to develop games, characters, robots as well as producing a movie by applying the algorithm. Their research results are pointed to be quite similar with the study conducted by Kalelioılu (2015) about the cruciality of CT in high-level thinking skills environment.

There are lot of research studies have been conducted and led to explore the learner's cognitive capacity and instructional goals such as extraneous processing, essential processing as well as generative processing. Those Mayer's CTML have been proved by many studies that instructional goals by Mayer are correlated with the Sweller's Cognitive Load Theory in determining the capacity of learner's working memory. When discussing about

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the working memory, learner-controlled in learning environment playing a key role to reduce the cognitive overload among the learners. It is because learner basically has full or partial control of their own learning pace based on their needs, interests as well as capabilities (Vandewaetere & Clarebout, 2013). There are three cognitive load have been discussed by Sweller (2011) which are extraneous load, intrinsic load and germane load. Extraneous load is generally referring to the poor and bad design of the learning materials while the intrinsic load is measured by the complexity of the content in the learning materials.

Learners are facing with high intrinsic load if there are more elements in the learning materials that need to be interacted and processed by them. The germane load is associated with the scheme acquisition, where learner involves in cognitive processing to organise materials and integrate those information with the prior knowledge. Sweller (2010) associated the germane load with interactivity element and defined it in the terms of intrinsic load. It means that germane load is considered to deal with intrinsic load that represent the working memory. Germane load is occurred when the learners are able to foster their learning by processing the essential information in the learning materials. However, if the cognitive load happens to the learner which do not foster their learning, it is considered as the extraneous load.

DeLeeuw and Mayer (2008) had conducted a study the investigate the relationship of three cognitive load and found out that intrinsic and germane load are significantly related to the learning. They highlighted three different measurements to study those three cognitive loads. The extraneous load was measured by the response time on the secondary task, intrinsic load was reflected by the ratings of mental effort while germane load was based on ratings of the difficulty. The results from those measurement is consistent with the triarchic theory of cognitive load that diverse cognitive load may be selected by diverse measurements. The Mayer's CTML and Sweller's Cognitive Load Theory stressed that a learning material should be carefully design to avoid higher cognitive load more than the learner's working capacity. However, based on the extensive reviews done by DeLeeuw & Mayer (2008), researchers have not yet grasped consensus on measuring the cognitive load in learning.

Therefore, this paper aims to conceptualise the relationship of Mayer's CTML and CT concepts in designing the learning material and supporting the Sweller's Cognitive Load Theory by tackling the extraneous and intrinsic loads while increasing the germane load.

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3.0 PROPOSED CONCEPTUAL FRAMEWORK OF CT AND MAYER'S CTML

Computational Thinking Concept	Description of Computational Thinking Concepts	Mayer's CTML (Instructional goal)	Mayer's CTML (Principle used in instructional design)	Sweller's Cognitive Load Theory
- Decompose - Abstraction	- Breaking down a complex problem into more manageable parts* - Filtering the required data*	Minimise extraneous processing	i. Coherence principle ii. Signaling principle iii. Redundancy principle iv. Spatial continuity principle v. Temporal continuity principle	Extraneous cognitive load
- Decompose - Abstraction - Pattern Recognition - Algorithm	-Decompose* -Abstraction* - Searching the likenesses patterns of existing problems* - Step by step instruction in solving problems or completing tasks*	Manage essential processing	i. Segmenting principle ii. Pre-training principle iii. Modality principle iv. Multimedia principle	Intrinsic cognitive load
- Pattern Recognition - Algorithm	-Pattern recognition* -Algorithm*	Stimulate generative processing	i. Personalisation principle ii. Voice principle	Germane cognitive load

shows the relationship between the CT, Mayer's CTML and Sweller's Cognitive Load Theory. Cognitive load theory was adapted to study various effects of instructional design which basically rely on the Mayer's principles when designing and developing the instructional learning materials. The effects of the cognitive load theory are concerned with the way of learning materials were presented that results in long-term schema acquisition.

Table 1: The relationship between the CT, Mayer's CTML and Sweller's Cognitive Load Theory

Computational Thinking Concept	Description of Computational Thinking Concepts	Mayer's CTML (Instructional goal)	Mayer's CTML (Principle used in instructional design)	Sweller's Cognitive Load Theory

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- Decompose - Abstraction	- Breaking down a complex problem into more manageable parts* - Filtering the required data*	Minimise extraneous processing	vi. Coherence principle vii. Signaling principle viii. Redundancy principle ix. Spatial continuity principle x. Temporal continuity principle	Extraneous cognitive load
- Decompose - Abstraction - Pattern Recognition - Algorithm	-Decompose* -Abstraction* - Searching the likenesses patterns of existing problems* - Step by step instruction in solving problems or completing tasks*	Manage essential processing	v. Segmenting principle vi. Pre-training principle vii. Modality principle viii. Multimedia principle	Intrinsic cognitive load
- Pattern Recognition - Algorithm	-Pattern recognition* -Algorithm*	Stimulate generative processing	iii. Personalisation principle iv. Voice principle	Germane cognitive load

This paper aims to integrate the CT concepts into designing the learning materials due to the importance of CT skills in enhancing the problem-solving skills among young digital natives. Numerous studies have conducted research on CT and found that CT can improve the self-efficacy of students in learning as well as their performance. However, lack of study has been conducted to integrate the CT concepts in designing the learning materials or adapt the CT concepts in their existing subject in tertiary institutions and investigate the impact of cognitive load among the young digital natives. There are uncountable CT researches for children especially in K-12 and STEM subjects but there is lack of studies have been conducted for university students. Several studies have connected the impact of CT concepts in cognitive load but there is no specific Sweller's Cognitive Load Theory has been discussed thoroughly.

Since this paper aims to investigate the relationship of CT concepts with the Mayer's CTML towards the Sweller's Cognitive Load Theory, researcher illustrated the conceptual framework as in **Error! Reference source not found.**. As shown in **Error! Reference source**

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

not found., researcher bridging the CT concepts, Mayer's CTML, Sweller's Cognitive Load Theory, Bloom's Taxonomy and Mental Self-Government Theory.

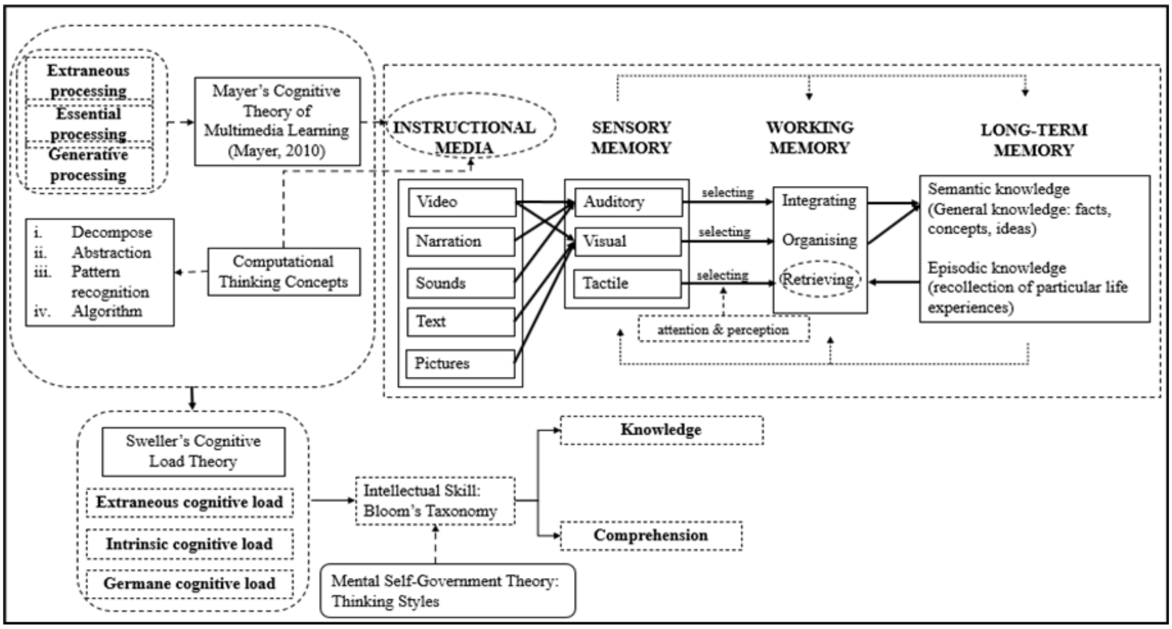

Figure 2: The proposed integrated CT and Mayer's CTML conceptual framework in tackling the cognitive load

Figure 2 shows the relationship of cognitive theory that can enhance the learner's performance in learning. An educator or instructor should create a learning material that can reduce the intrinsic and extraneous load and increase the germane load in order to generate great learning outcomes. This paper aims to highlight those theories in minimising the cognitive load of the learners and this research also focuses to investigate whether the thinking styles of a learner affects the cognitive load when adapting the CT concepts with the Mayer's Cognitive Theory of Multimedia Learning.

4.0 DISCUSSION

The conceptual framework proposed in this paper was designed as a platform to assist the educators in tertiary institutions, instructional designers as well as the educational technologists in designing and developing learning materials for their new or updating their existing lessons. The learning materials that will be designed and created based on the proposed conceptual framework is focuses on reducing the learning material's complexity with respect to elements of interactivity to tackle the issues of cognitive overload of the learners. The outcome of the new updated learning materials based on the proposed conceptual framework would afford learners to generate effective learning experience and achieving

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https://doi.org/10.17576/ajtlhe.1402.2022.05

optimal learning outcomes.

From the previous studies, researcher found the importance of CTML principles to tackle the cognitive load among the students when designing the learning materials. The 12 principles of CTML could help students learn better, specifically the segmenting principle which can be used to tackle the extraneous cognitive load. While studying the importance of CTML principles, researcher found the significance of CT concepts in learning.

The integration of CTML (Mayer, 2014a) and computational thinking (Wing, 2006) will not only benefited in reducing the cognitive load among the students, but researcher believes that it can be applied to enhance the students' achievement as well as nurturing the CT skills as 21st century skills. The emergence of technology and its practices in the educational field has brought a unique, interactive and interesting ways to the learning environment. In achieving the learning outcomes and ensuring learners' intellectual skills are improved, integrating the cognitive learning theories and CT concepts play an important role to tackle the cognitive load among the young digital native learners.

5.0 CONCLUSION

In conclusion, researcher foresees that designing and creating the learning materials and instructional designs based on the proposed conceptual framework can effectively minimise the unnecessary extraneous and intrinsic loads on working memory. Researcher also expects that those situations will create an atmosphere that would aid the young digital native learners to learn and surge their involvement and contribution in the learning process, which afford to lead for a better and outstanding learning outcome. This conceptual framework should be deployed in tertiary educations across various levels such as Diploma, Bachelor degree as well as Master degree of coursework for effective learning outcomes. Educators especially lecturers must be well knowledgeable about the basic information and knowledge of the highlighted principles of the concept (CT concepts, Mayer's CTML and Sweller's Cognitive Load Theory) for extensive acknowledgement and acceptance of the proposed conceptual framework. Future research should be conducted to investigate the effects of the integration of CTML Mayer principles with the CT concepts in term of student's achievement and self-efficacy in programming skills.

6.0 REFERENCES

Aho, A. V. (2012). Computation and computational thinking. *Computer Journal*, *55*(7), 833–835. https://doi.org/10.1093/comjnl/bxs074

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

Aristawat, F. A., Budiyanto, C., & Yuana, R. A. (2018). Adopting educational robotics to enhance undergraduate students' self-efficacy levels of computational thinking. *Journal of Turkish Science Education*, *15* (Special Issue), 42–50. https://doi.org/10.12973/tused.10255a

Çakiroğlu, Ü., Suiçmez, S. S., Kurtoğlu, Y. B., Sari, A., Yildiz, S., & Öztürk, M. (2018). Exploring perceived cognitive load in learning programming via scratch. *Research in Learning Technology*, *26*(1063519), 1–19. https://doi.org/10.25304/rlt.v26.1888

Cheng, Y. P., Shen, P. Di, Hung, M. L., Tsai, C. W., Lin, C. H., & Hsu, L. C. (2022). Applying online content-based knowledge awareness and team learning to develop students' programming skills, reduce their anxiety, and regulate cognitive load in a cloud classroom. *Universal Access in the Information Society*, *21*(2), 557–572. https://doi.org/10.1007/s10209-020-00789-6

DeLeeuw, K. E., & Mayer, R. E. (2008). A comparison of three measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load. *Journal of Educational Psychology*, *100*(1), 223–234. https://doi.org/10.1037/0022-0663.100.1.223

Dong, Y., Cateté, V., Jocius, R., Lytle, N., Barnes, T., Albert, J., Joshi, D., Robinson, R., & Andrews, A. (2019). Prada: A practical model for integrating computational thinking in K-12 education. *SIGCSE 2019 - Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 906–912. https://doi.org/10.1145/3287324.3287431

García-Peñalvo, F. J., & Mendes, A. J. (2018). Exploring the computational thinking effects in pre-university education. *Computers in Human Behavior*, *80*, 407–411. https://doi.org/10.1016/j.chb.2017.12.005

Jocius, R., Joshi, D., Dong, Y., Robinson, R., Catete, V., Barnes, T., Albert, J., Andrews, A., & Lytl, N. (2020). Code, connect, create: The 3c professional development model to support computational thinking infusion. *Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE*, 971–977. https://doi.org/10.1145/3328778.3366797

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

Kalelioǩlu, F. (2015). A new way of teaching programming skills to K-12 students: Code.org. *Computers in Human Behavior*, *52*, 200–210. https://doi.org/10.1016/j.chb.2015.05.047

Kelleher, C., & Pausch, R. (2005). Lowering the barriers to programming: A taxonomy of programming environments and languages for novice programmers. *ACM Computing Surveys*, *37*(2), 83–137. https://doi.org/10.1145/1089733.1089734

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* (June), 178–189. https://doi.org/10.1016/j.compedu.2018.08.026

Lin, Y. S., Chen, S. Y., Tsai, C. W., & Lai, Y. H. (2021). Exploring computational thinking skills training through augmented reality and AIoT learning. *Frontiers in Psychology*, *12*(February), 1–9. https://doi.org/10.3389/fpsyg.2021.640115

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

Mayer, R. E. (2009). Multimedia learning (2nd ed.). In *Psychology of Learning and Motivation - Advances in Research and Theory*. Cambridge University Press. https://doi.org/10.1016/s0079-7421(02)80005-6

Mayer, R. E. (2014a). Cognitive theory of multimedia learning. *The Cambridge Handbook of Multimedia Learning, Second Edition*, 43–71. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E. (2014b). *The cambridge handbook of multimedia learning* (2nd ed.). Cambridge University Press. https://doi.org/https://doi.org/10.1017/CBO9781139547369

Mihci Türker, P., & Pala, F. K. (2020). The effect of algorithm education on students' computer programming self-efficacy perceptions and computational thinking skills. *International*

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

Journal of Computer Science Education in Schools, *3*(3), 19–32. https://doi.org/10.21585/ijcses.v3i3.69

Moon, J., Do, J., Lee, D., & Choi, G. W. (2020). A conceptual framework for teaching computational thinking in personalized OERs. *Smart Learning Environments*, *7*(1). https://doi.org/10.1186/s40561-019-0108-z

Moore, T. J., Brophy, S. P., Tank, K. M., Lopez, R. D., Johnston, A. C., Hynes, M. M., & Gajdzik, E. (2020). Multiple representations in computational thinking tasks: A clinical study of second-grade students. *Journal of Science Education and Technology*, *29*(1), 19–34. https://doi.org/10.1007/s10956-020-09812-0

Moran, K. (2016). *Millennials as digital natives : Myths and realities*. Nielsen Norman Group. https://www.nngroup.com/articles/millennials-digital-natives/

Prensky, M. (2001). Digital natives, digital immigrants. In *On the horizon, 9(5)*. https://doi.org/10.1177/1078390313481999

Shannon Marshall Smith. (2019). A comparison of computer-based and robotic programming instruction: Impact of Scratch versus Cozmo on middle school students' computational thinking, spatial skills, competency beliefs, and engagement. Kent State University.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257–285. http://onlinelibrary.wiley.com/doi/10.1207/s15516709cog1202_4/abstract

Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review*, *22*(2), 123–138. https://doi.org/10.1007/s

Sweller, J. (2011). Cognitive load theory. In *Psychology of Learning and Motivation - Advances in Research and Theory*, 55. Elsevier Inc. https://doi.org/10.1016/B978-0-12-387691-

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

1.00002-8

Tsai, M. J., Wang, C. Y., & Hsu, P. F. (2019). Developing the computer programming self-efficacy scale for computer literacy education. *Journal of Educational Computing Research*, *56* (8), 1345–1360. https://doi.org/10.1177/0735633117746747

Vandewaetere, M., & Clarebout, G. (2013). Cognitive load of learner control: Extraneous or germane load? *Education Research International*, 1–11. https://doi.org/10.1155/2013/902809

Weese, J. L., Feldhausen, R., & Bean, N. H. (2016). The impact of STEM experiences on student self-efficacy in computational thinking. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/p.26179

Wei, X., Lin, L., Meng, N., Tan, W., Kong, S. C., & Kinshuk. (2021). The effectiveness of partial pair programming on elementary school students' Computational Thinking skills and self-efficacy. *Computers and Education*, *160*, 104023. https://doi.org/10.1016/j.compedu.2020.104023

Wing, Jeannete. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 22–24.

Wing, Jeannette. (2011). Research notebook: Computational thinking--What and why? *The LINK*. cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why

Winter, V., Friend, M., Matthews, M., Love, B., & Vasireddy, S. (2019). Using visualization to reduce the cognitive load of threshold concepts in computer programming. *Proceedings - Frontiers in Education Conference, FIE*, 1–9. https://doi.org/10.1109/FIE43999.2019.9028612

Yadav, A., Larimore, R., Rich, K. M., & Schwarz, C. (2019). Integrating computational thinking in elementary classrooms: Introducing a toolkit to support teachers. *Proceedings of the Society for Information Technology & Teacher Education International Conference*, 347 – 350.

Zhong, H. X., Chiu, P. S., & Lai, C. F. (2021). Effects of the use of cdio engineering design in

Received: 17 January 2022, Accepted: 29 September 2022, Published: 20 December 2022
https://doi.org/10.17576/ajtlhe.1402.2022.05

a flipped programming course on flow experience, cognitive load. *Sustainability (Switzerland)*, *13*(3), 1–14. https://doi.org/10.3390/su13031381