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A Systematic Review of CTML Segmenting Principle on Computational Thinking

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ABSTRACT

This paper reviews systematically articles and journals in the past and current studies on Cognitive Theory of Multimedia Learning (CTML) segmenting principle and computational thinking. This paper specifically conducted to (i) identify articles that discussed computational thinking (CT) and segmenting principle, (ii) classify the various research domain and context are discussed in previous studies related to segmenting on CT, (iii) synthesis the results that are reported by relevant studies on CT and segmenting principle. The steps taken for these systematic reviews are adapted from PriSMA (2009). Out of 231 articles retrieved, 22 of them were identified for analytical purposes in tandem with the observed theme under keywords searched "computational thinking AND segmenting" and then, those articles are thoroughly reviewed. Our study revealed that the use of CT is most discussed on the programming and science, technology, engineering, and mathematics (STEM) subjects. Furthermore, this paper pointed out and highlighted that most of the reviewed articles are not related to the segmenting principle even though they are listed as the results of the keywords searched.

Keywords: Systematic Review, Computational Thinking, Segmenting Principle.

1. INTRODUCTION

As broadly discussed in numerous past studies, computational thinking (CT) is considered as a problem-solving skill of a learner. Not only been considered as problem-solving skill, CT are foreseen to ease the learner in developing application using block-based programming without the needs of prior knowledge on programming languages. The well-known definition of CT is popularised by Wing (2006) who stated CT as a fundamental skill for everyone. Since then, lots of definitions and research approaches of CT have been discussed. Most of CT research studies are focusing on STEM and programming subjects especially for K-12 students. Numerous of researchers used unplugged instead of plugged activities in their research experiment design. In this paper, we focused and discussed the various research domain and context of CT as well as investigating whether segmenting principle of CTML is adapted in CT researches. As CT is well-known for K-12 students and are applied in teaching and learning, this research tries to investigate whether segmenting principle is adapted in the learning methods and materials or not. Segmenting principle is claimed that student learns better from a multimedia lesson if it is presented in user-paced segments rather than as a continuous unit. Therefore, this paper reviewed and synthesised the content to investigate the research domain, context, technology intervention and target users of each identified articles and summarised the details in Table 2.

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2. METHODOLOGY

Systematic review is a comprehensive technique to explore, synthesis and analyse specific information of a certain topic of research. The importance of a systematic review is that it could discover the research gaps, further strengthen the research problems and clarify the research question(s) as opposed to the traditional literature review. The past research findings could be categorised and analysed based on the researcher's need. In this case, the categorisation method is crucial to ensure that the researcher is able to make a thorough and comprehensive observations on segmenting principle in computational thinking in the past researches. Researcher adapted the PriSMA (2009) technique and steps for systematic review as summarised in Figure 1. The systematic review was extracted from online articles published in online journal databases. Researcher developed several criteria and attributes for articles' searching keywords through the search engine on online journal databases.

The systematic review approach in this research is further validated using the inclusion and exclusion criteria which have been adapted (Manley et al., 2017; Masnoon et al., 2017; Randolph, 2008) as follow:

i. Issue: What are the research domains, contexts, technology interventions, target users as well as other related research elements on computational thinking and segmenting principle?
ii. Type of research article: concept paper or causal-comparative research or experimental research.
iii. It was a quantitative review of research practices, not a literature review in general or a meta-analysis, which focuses on research outcomes.
iv. The articles were written in English.
v. The number of articles that were reviewed was specified and there is no redundancy of articles.
vi. Identify the group of respondents: (primary/secondary schools' students or tertiary/higher educations' students)
vii. Specific duration of year for search articles: from unspecified year until year 2020
viii. Location of research: Malaysia or outside Malaysia
ix. Journals Online databases: Science Direct, Google Scholar, Springer Link, IEEE Xplore, Wiley Online, Mendeley, ACM, Emerald Insight, EBSCOhost, JSTOR and IOPscience.

Table 1 shows the number of articles being identified through 11 online journal databases which focuses on the advanced search queries as follow:

i. The keywords used to search for the related articles are as follow (title and keywords):
    a. Computational thinking (AND) segmenting

Table 1 Results of number of the articles being identified on the current research date: November 2020

Computational Thinking and Segmenting	
Science direct	n=1
Google scholar	n=192
Springerlink	n=37
IEEE Xplore	n=0
Wiley Online	n=0
Mendeley	n=0
ACM	n=0
Emerald Insight	n=0
EBSCOhost	n=0
JSTOR	n=1

IOPscience	n=0
Total	**N=231**

Table 1 shows the number of identified articles being identified from 11 recognised online search databases. A few steps in conducting systematic literature reviews are adapted from Mohamad, Hamzah, Salleh, & Ahmad (2015) and PriSMA (2009). Figure 1 shows the steps involved for the keywords "computational thinking AND segmenting".

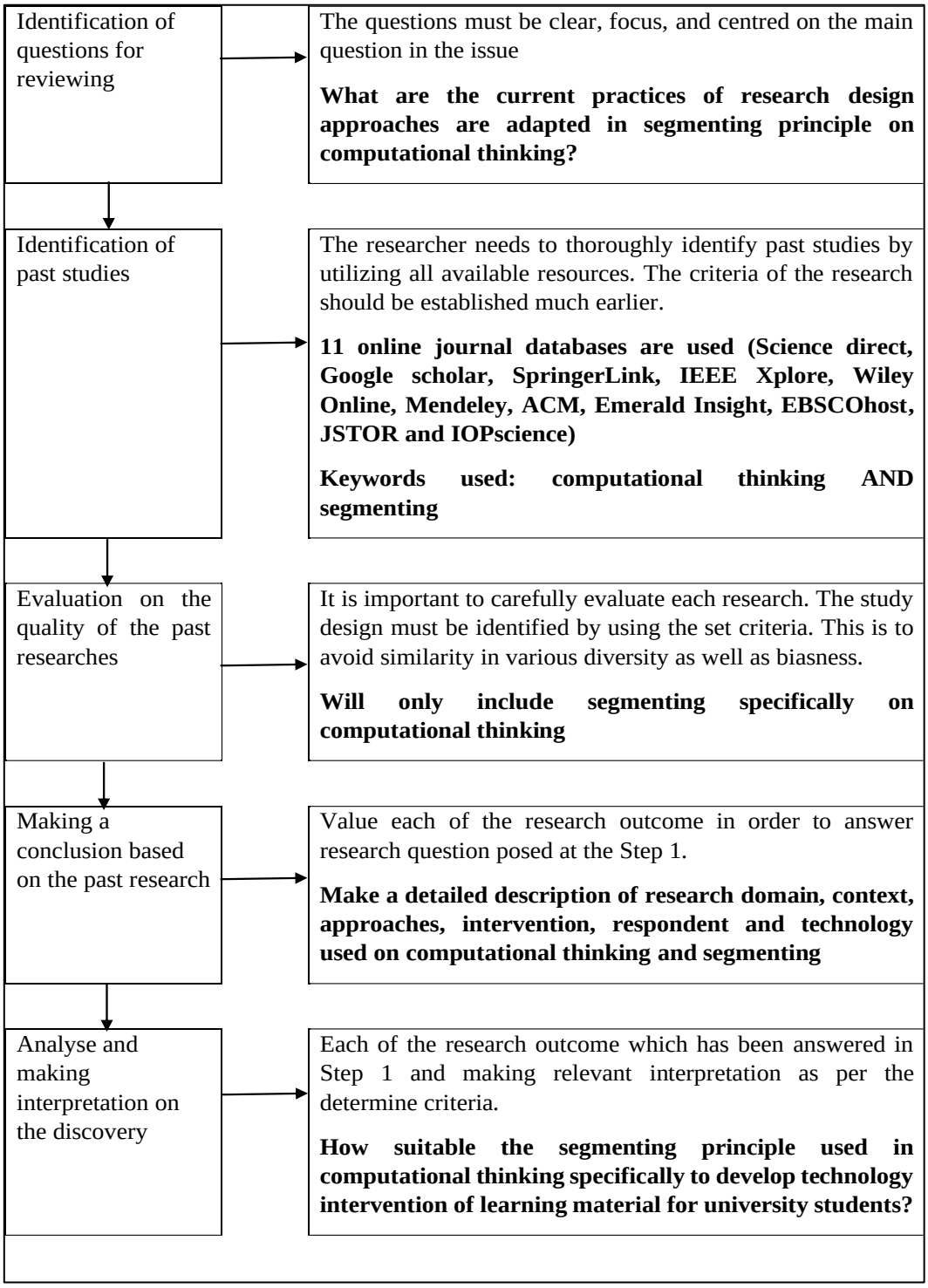

Figure 1. Process of systematic review approach for keywords searched (computational thinking AND segmenting) (adapted from (Mohamad *et al.,* 2015; PriSMA, 2009).

3. FINDINGS AND DISCUSSION

A total of 231 articles were successfully obtained using the keyword search via 11 online journal databases selected from unspecified year until year 2020. This is because, this study aims to obtain as much as possible related studies on the keyword searched. Figure 2 shows the selection process conducted to select related articles in this systematic literature reviews.

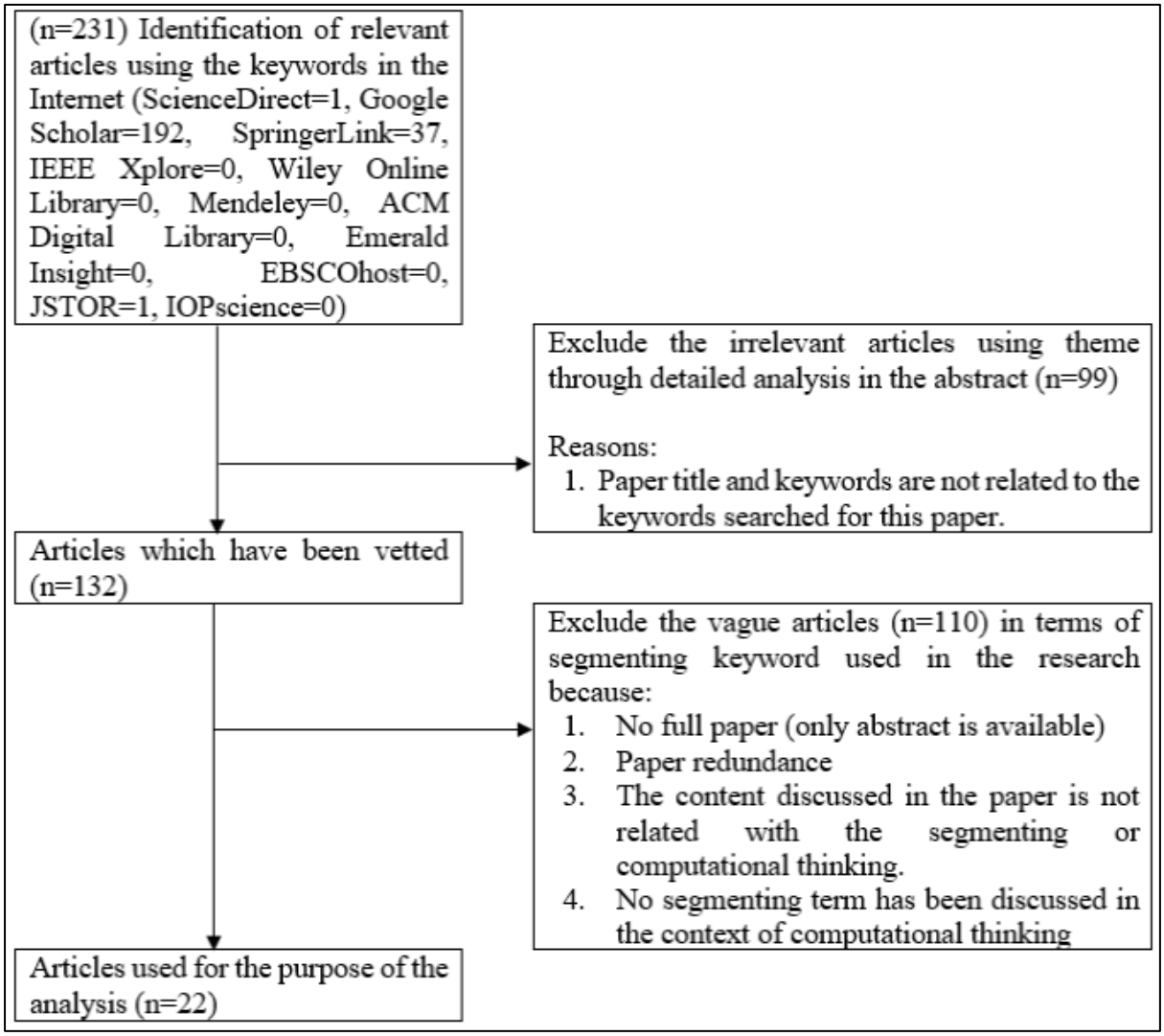

Figure 2. Selection process for studies included and excluded in the analysis for keywords searched (computational thinking AND segmenting).

Figure 2 shows that from 231 identified articles, 99 articles have been excluded because those articles are not matched with the search criteria. Upon vetting the abstracts and screening the content of initial 231 articles, only 132 articles qualified to be categorised in the systematic review theme: computational thinking and segmenting keywords searched. Only 132 articles are related to the search keywords and the abstract of those articles have been vetted thoroughly. Then, 110 articles have been excluded for some reasons where there is no full paper available, paper redundance, the content discussed is not related with the segmenting or computational thinking, no segmenting has been discussed in the domain of computational thinking. Only 22 articles have been thoroughly identified from the keywords "computational thinking AND segmenting".

Researcher has concluded the findings from a thorough review for all of the identified articles as in Table 2. Researcher reviewed and found that there is lack research has been done which focused and discussed in details both computational thinking and segmenting principle. Most of the reviewed articles are focusing on different research domain and context. Researcher on previous studies are more discussing on programming and few of them discussing on STEM subjects. As other CT research studies that have been done, the respondents of experimental research conducted are mostly from primary and secondary school students and there is lack of research being conducted for university students specifically on Technical and Vocational Education and Training (TVET). From previous study, researchers used various kind of educational technology in their experimental research design. The most identified technology being used is Scratch developed by MIT Media Lab, the open-source and free programming application, robotic, eye-tracking and others.

Numerous of identified and reviewed articles focus on programming such as programming debugging, programming language as well as programming plug and play building blocks as the research domains (Ferguson, 2020; Howland & Good, 2015; Li et al., 2020; Papavlasopoulou et al., 2018; Portilla-Meneses et al., 2020). Most of them are referring segmenting term as rule segments in programming, but Ferguson (2020) had mentioned the segmenting principle where he stated that student's programming learning is categorised and fragmented into manageable chunks. Hence, students are able to receive feedback on their programming at the pace they are chosen. They are also capable to visually understand the changes and debugging the errors because segmenting principle lets the student to completely finish each part of the programming before moving on to the next segments.

From lots of identified articles using the keywords searched, only few of articles are focused on CT research domains, however they are not focusing on segmenting principle (Gleasman & Kim, 2020; Long et al., 2018; Rich et al., 2020; Sengupta et al., 2013). The segmenting terms used in those articles are general segment terms which are not related to CTML segmenting principle. A summary of previous studies related on keywords searched (computational thinking AND segmenting) can be referred in Table 2.

Table 2 A summary of previous studies until 2020 (keywords searched: computational thinking AND segmenting)

No.	Author / Country	Research Domain	Research Context	Technology or Intervention Developed / Used	Target user	Research Design/Experiment/Approach	Segmenting Term / Perspective used
1	(Sengupta et al., 2013) / Null	Computational thinking and agent-based computation	K-12 science topic	CTSiM (Computational Thinking in Simulation and Modelling)	6th grade students	Scaffolded and Classroom groups experiment	Segments of students' developed model.
2	(Srihari & Singer, 2014) / United States	i.Human examiners ii.Computational methods	Forensic document examination (FDE)	Null	Null	ASTM document Standard Guide for Examination of Hand-written Items	Word segmentation: process of separating images of words
3	(Howland & Good, 2015) / United Kingdom	Programming language/natural language pairing	Programming language	Flip	12 and 13-year-old students	Pretest and posttest	Rules segment in programming
4	(Brown, 2016) / South Korea	Music educational practices	Music classroom	i.Software including ALSong,	Elementary school students.	i.Experimental program ii.interviews and questionnaires	Musical score is divided

				Tunearound Movie Maker ii.Scratch and music		iii.A matrix-based approach iv.Technology- mediated teaching and learning approached	into component parts or segments and the game engine reassembles them on the fly to match the game state.
5	(Brusegard, 2018) / Minnesota	Technology integration	Staff development	i.SMART Notebook Tutorial ii.SAMR model iii.Schoology	Teachers	Training project	Segmenting Principle
6	(Long et al., 2018) / Null	Computational thinking and methods	Geography and GIScience	Computational movement analysis	Null	Review paper	A new segmentation method for partitioning movement data into stops and moves.
7	(Kelly et al., 2018) / United States	Networked technology design	Students' learning networks	BlockyTalky	Middle school students	Workshops involved teachers and students	Decomposing the video into short time segments
8	(Serholt, 2018) / Sweden	Robotic class	Scripted robotic tutor	Robotic	Primary school students	i.Longitudinal study ii.Interaction analysis and thematic analysis	Video segments that were indicative of breakdowns in robotic interaction
9	(Strimel et al., 2018) / United States	Concurrent think-aloud protocols	Engineering design cognition	Null	i.Kindergarten ii.4th grade students	Multiple exploratory case study approach	Verbal protocol analysis technique involves segmenting the collected design protocol into individual cognitive tasks.
10	(Zhi et al., 2018) / North Carolina	Instructional Support Design (Supports)	Educational programming game	Supports: instructional text (Text), worked examples (Examples) and buggy code (Bugs)	Middle school students	Pilot study	Segmenting the concepts and disabling unnecessary commands
11	(Geldreich et al., 2019) / Germany	Theoretical Foundation and Didactic Implementation	Algorithmics and Programming	Scratch	Primary Schools	In-service professional development workshop	Segmenting Principle
12	(Henriksen, 2019) / Norway	Big data, microtargeting, and governmentality	Facebook-Cambridge Analytica data scandal	Null	Null	myPersonality test	Segmenting of a population

13	(McCoy & Auret, 2019) / South Africa	Machine learning methods	Mineral processing	Machine learning application	Null	Review paper	Descriptive symbols to segments of data using Qualitative Trend Analysis (QTA)
14	(Papavlasopoulou et al., 2019) / Norway	Coding	Coding activities	i.Digital robots, ii.Scratch	8 – 17-year-old students	i.Experiment constructionist approach ii.Eye tracking iii.Attitudinal survey (learning, excitement and intention)	Code segments and nothing related to segmenting principle
15	(Draus, 2020) / United States	Techniques in video development	Python programming	Video tutorial	University students	Survey through online class	Segmenting or chunking of info which reduces overall intrinsic load in CTML
16	(Gleasman & Kim, 2020) / United States	Computational thinking and mathematics concepts	Teacher education program	Scratch	Pre-service teachers (under-graduate students majoring in Elementary Education)	Cross-comparative case study	Use term learning segment to differentiate the central focus for learning module
17	(Ferguson, 2020) / Canada	Visual programming languages (VPL) / block-based programming	Educational computer programming	Sphero Macrolab, Scratch, Code.org, Bubble, Alice	6-9th grade students	Open-ended experiment	Segmenting principle
18	(Jost, 2020) / Austria and Norway	Design science process	Privacy decision-making	Quest-based game-frame (QGF)	i.Educators ii.University students and high-school students	Binational experiment	i.A segmented approach is proposed to address the different areas of privacy issues. ii.Segmenting and limiting an awareness cycle.
19	(Li et al., 2020) / China	Programming debugging	Error Finding Programming Tests	Eye-Tracking	University student	Procedural evaluation scheme	Segmenting the students' programming process in error-finding tasks
20	(Portilla-Meneses et al., 2020) / Colombia	Plug and play building blocks	Training and learning in the field of robotics	Simulator of physical robotic entities (SER)	Null	Preliminary analysis and design of the modules	Segmenting the 3D scanned hand model
21	(Rich et al., 2020) / United States	Computational thinking	Elementary mathematics and	Teacher implementation profiles	Elementary school teachers	Teacher training	Video segments observed

			science instruction				from the training
22	(Strimel et al., 2020) / United States	Students' cognitive processes	Design thinking of primary and secondary students	Null	Primary and secondary schools	i.Design cognition studies ii.Meta-synthesis methodology	Segmentin g and coding of the data dividing the verbal protocol transcripti ons and/or video recordings.

4. CONCLUSION

There are three aims of this paper: to (i) identify articles that discussed computational thinking (CT) and segmenting, (ii) classify the various research domain and context are discussed in previous studies related to segmenting on CT, (iii) synthesis the results that are reported by relevant studies on CT and segmenting principle. Through this process, researcher identified that there are insufficient studies have been conducted to relate the segmenting principle with the computational thinking. There is only a brief discussion on the CT and segmenting being used in the previous studies. Most of the studies only mentioned about the general segmenting term applied which does not related to the CTML segmenting principle.

From the reviews, researcher can conclude that, there is lack of published articles discussed the CT and segmenting principle specifically in designing the learning materials. Researcher had classified SLR findings into several research elements and found out that most of the identified articles from the keywords searched are focused on programming as the research domain that are not discussing the CT concepts directly. The CT and segmenting terms only being briefly mentioned in the articles' content. The segmenting terms are mostly referred as rules segments in programming. Therefore, this paper concludes that there is almost none related past studies on CT as well as CTML segmenting principle has been identified.

The findings from synthesis phase conducted by the researcher foresees that CT and segmenting principle are the best approaches to be adapted in designing a technology intervention in TVET pedagogy. Future research study should focus more on the CT and how CTML segmenting principle could be adapted in designing learning materials for students. By adapting the CTML segmenting principle, the process of developing CT skills among university students can be achieved and it could affect their knowledge and interest in learning processes. By applying both CT and segmenting principle in designing learning material in our future works, we foresee it could assist students in practice learner-centered learning as well as avoiding the cognitive overload among the students.

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