Journal of Human Development and Communication
Volume 9, 2020 [11-22]

A Systematic Review of Learning Theory on Computational Thinking

Wan Nor Ashiqin Wan Ali[1,2*] and Wan Ahmad Jaafar Wan Yahaya[1]

[1]*Centre for Instructional Technology and Multimedia, Universiti Sains Malaysia, Penang, Malaysia.*
[2]*Faculty of Applied and Human Sciences, Universiti Malaysia Perlis, Perlis, Malaysia.*

ABSTRACT

This paper reviews systematically theory used in the past studies on computational thinking, learning theory used in past studies on computational thinking and explore how these learning theories on computational thinking can be improved for future studies conducted in Malaysia. Today, computational thinking is not just an ability that only focuses on computer scientist and being adapted by them, but an ability for everyone needs. It is because computational thinking is changing the way we think and become an integral part of our daily life. 18 out of 126 articles were identified for analytical purposes in tandem with the observed theme under keywords searched "theory AND computational thinking, theory on computational thinking" and 2 out of 4 articles were identified under keywords searched "learning theory AND computational thinking, learning theory on computational thinking". This paper aims to study what are the recognised learning theory being studied and focused on computational thinking scope research areas. Further exploration on the type of research theory, type of intervention and respondent as well as technology being used or developed are discussed in details in this paper. The study findings highlight that constructivist learning theory is the well-known learning theory being used in computational thinking research area which focuses on primary and secondary school students in worldwide.

Keywords: Systematic Review, Computational Thinking, Learning Theory.

1. INTRODUCTION

According to previous studies, there are several identified Malaysian graduate's skills challenges which are a lack of relevant skills training, outdated curriculum and poor soft skills, specifically concerning the weaknesses in English proficiency as well as problem-solving skills (Wan Ali, 2018). A comprehensive literature study by Agbo, Oyelere, Suhonen, & Adewumi (2019) revealed that some of researchers practiced visualisation, puzzle, games, as well as Computational Thinking (CT) to develop the student's problem-solving skills and encourage them to learn in Higher Education Institutions (HEIs). Referring to Agbo et al. (2019), Wing (2006) has stated that CT covers the fundamental concept of computer science on how to design system, understanding human behaviours and enhance the problem-solving skills. Furthermore, Agbo et al. (2019) claimed that no organized literature review of CT as a programming training and teaching approach conducted within the HEIs. Therefore, researcher conducted the systematic literature review related to CT and study on what kind of theory, research approaches, intervention or technology have been used on previous studies. This paper also proves that there is deficiency of CT research studies in Malaysia that was categorised under the searched keywords.

2. METHODOLOGY

Systematic review is a comprehensive technique to explore and analyse specific information of a certain topic of research or the investigation of study. The importance of a systematic review is

*Corressponding Author: *ashiqinali@unimap.edu.my*

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 theory and learning theory of computational thinking in past research. 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 from (Manley *et al.,* 2017; Masnoon et al., 2017; Randolph, 2008) as follow:

i. Issue: What are the theories, research approaches, intervention, respondent and technology been used and on computational thinking?
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. Location of research: Malaysia or outside Malaysia
viii. Online journal databases: Science Direct, Google Scholar, Springer Link, IEEE Xplore, Wiley Online, Mendeley, ACM, Emerald Insight, & EBSCOhost.

Table 1 shows the number of articles being identified through 9 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. theory (AND) computational thinking
    b. theory on computational thinking
    c. learning theory (AND) computational thinking
    d. learning theory on computational thinking
ii. Current search articles (year): 2015 - 2020

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

Theory		**Learning Theory**	
Science direct	n=9	Science direct	n=0
Google scholar	n=11	Google scholar	n=1 (paid)
Springerlink	n=18	Springerlink	n=0
IEEE Xplore	n=4	IEEE Xplore	n=1
Wiley Online	n=0	Wiley Online	n=0
Mendeley	n=72	Mendeley	n=1
ACM	n=0	ACM	n=0
Emerald Insight	n=3	Emerald Insight	n=1
EBSCOhost	n=9	EBSCOhost	n=0
Total	**126**	**Total**	**4**

Table 1 shows the number of identified articles being identified from 9 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 (a) shows the steps involved for the keywords "theory AND computational thinking, theory on computational thinking" while Figure 1 (b) shows the steps involved for the keywords "learning theory AND computational thinking, learning theory on computational thinking."

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

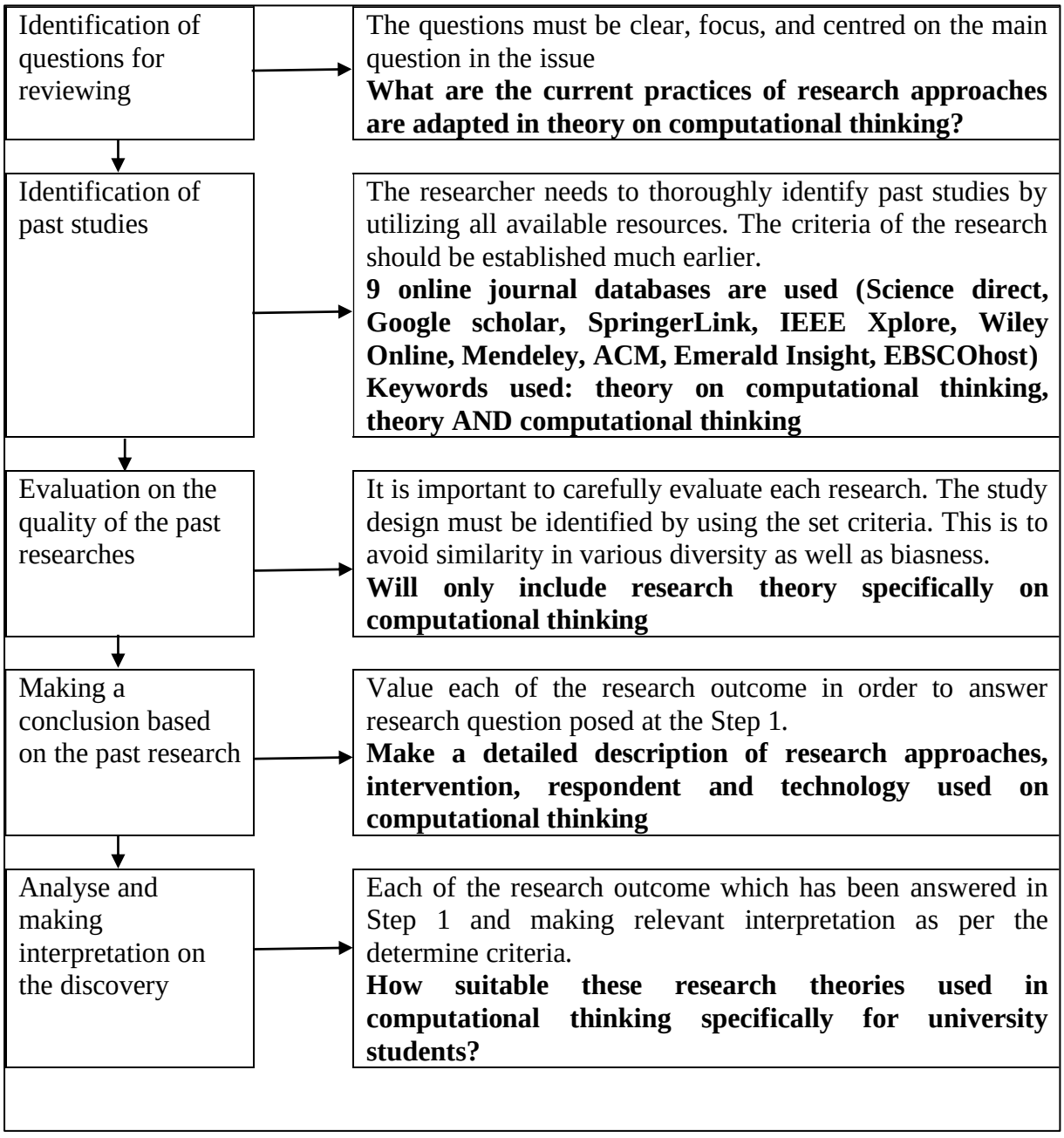

Figure 1(a). Process of systematic review approach for keywords searched (theory AND computational thinking, theory on computational thinking) (adapted from Mohamad et al., 2015; PriSMA, 2009).

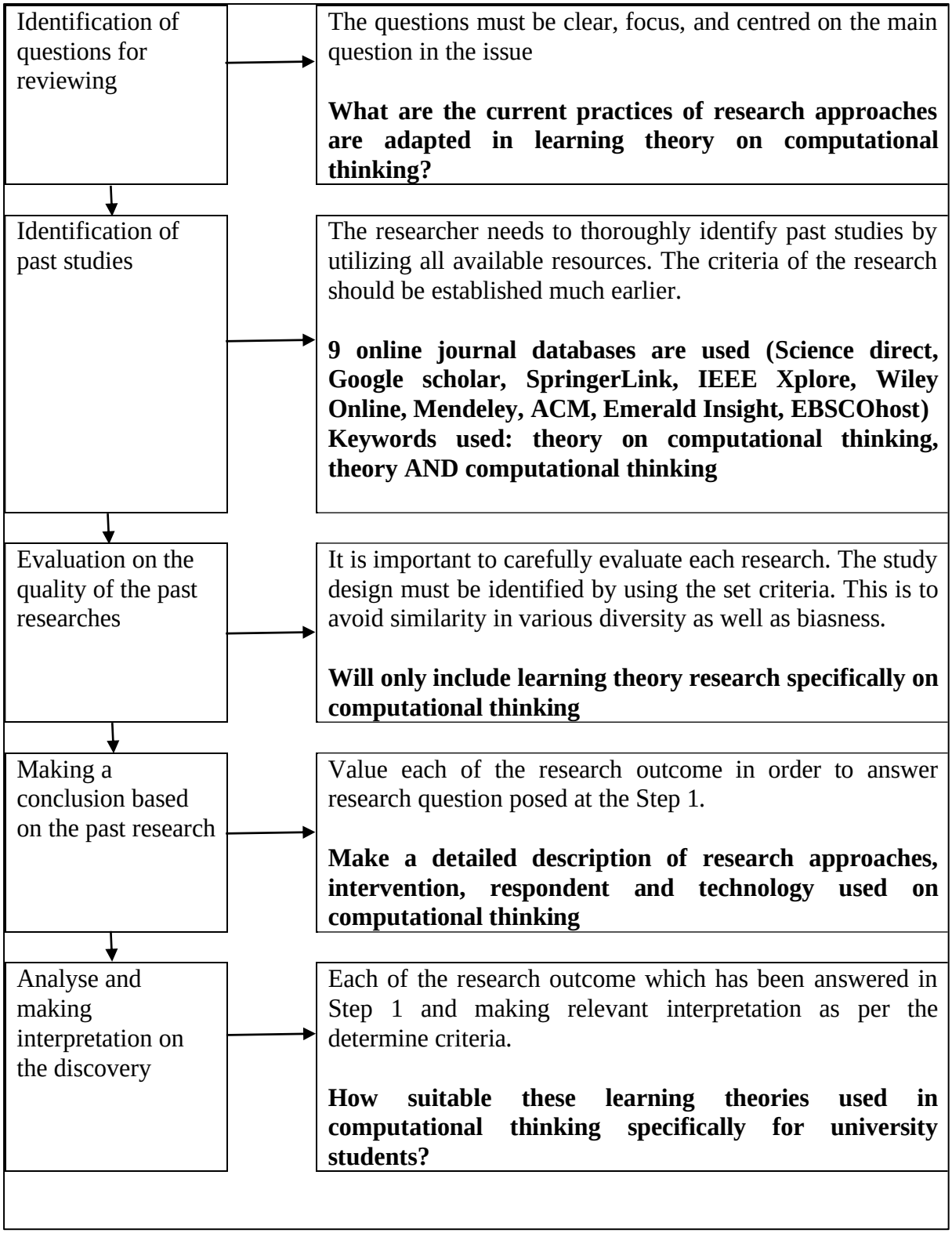

Figure 1(b). Process of systematic review approach for keywords searched (theory AND computational thinking, theory on computational thinking) (adapted from (Mohamad et al., 2015; PriSMA, 2009).

3. FINDINGS AND DISCUSSION

A total of 126 articles were successfully obtained using the keyword search via the nine online databases selected. However, upon vetting the abstracts of the initial 126 articles, only 43 articles qualified as they focused on the systematic review theme: theory on computational thinking research. Figure 2 (a) and Figure 2 (b) show the selection process conducted to select related articles in this systematic literature reviews.

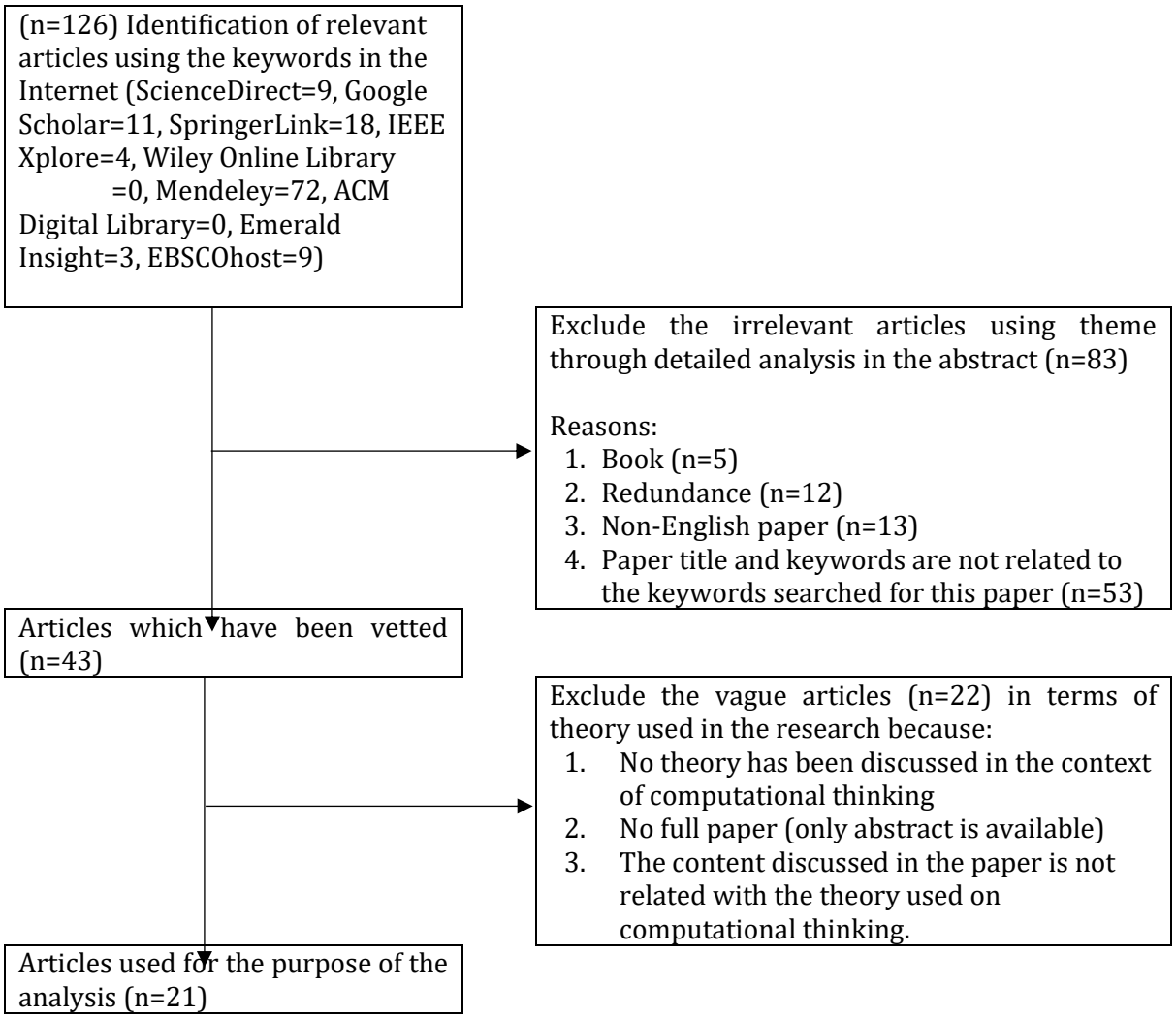

Figure 2 (a). Selection process for studies included and excluded in the analysis for keywords searched (theory AND computational thinking, theory on computational thinking).

Figure 2 (a) shows 83 articles have been excluded because those articles are not matched with the search criteria. Only 43 articles are related to the search keywords and the abstract of those articles have been vetted thoroughly. Then, 25 articles have been excluded for some reasons where there is none of theory has been discussed, no full paper and the content discussed are not related with theory used on CT. Only 18 articles have been thoroughly identified from the keywords "theory AND computational thinking, theory on computational thinking". Figure 2 (b) shows that only 4 articles have been identified under the search keywords "learning theory AND computational thinking, learning theory on computational thinking" from the same recognised online search databases. Only 2 articles have been included which related to the search criteria and one of the articles is also identified in Figure 2 (a).

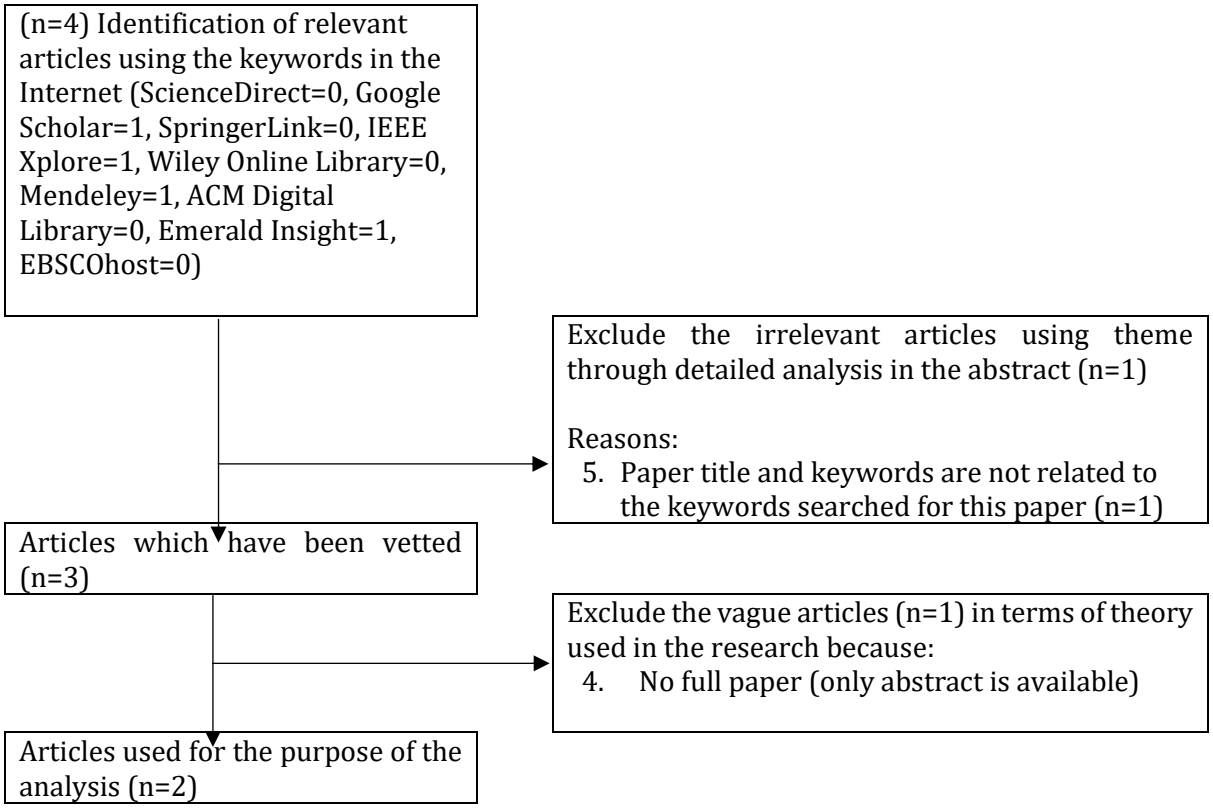

Figure 2 (b). Selection process for studies included and excluded in the analysis for keywords searched (learning theory AND computational thinking, learning theory on computational thinking).

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 deficiency of research has been done in Malaysia context for the related search keywords. Most of the reviewed articles are focusing on constructivist learning theory environment and conducting experimental research design. The respondents of experimental research design conducted in previous studies 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 and online community where everyone is able to create their own interactive stories, animations or even games. A summary of previous studies related on keywords searched (theory AND computational thinking, theory on computational thinking) can be referred in Table 2 (a) and (learning theory AND computational thinking, learning theory on computational thinking) as in Table 2 (b).

Table 2 (a) A summary of previous studies from 2015 until 2020 (theory AND computational thinking, theory on computational thinking)

No.	Author	Theory applied	Research approaches	Type of Intervention	Respondent	Technology used/developed	Country
1	(Flanigan et al., 2017)	Scaffolding theory	Experiment research	Control group: traditional scratch lesson Test group: play "Angry Birds Pigs Out" via platform Code.org "	Undergraduate students (Computer Science)	Null	United State

2	(Papavlasopoulou et al., 2019)	Constructionism theory	Design-based research	Used refined and improved designs that influence practice	Primary school students	Scratch	Norway
3	(Kong & Wang, 2020)	Situated learning theory	Experimental research	Developed a 3-year programming curriculum on Scratch and App	Primary school students	Scratch, App Inventor	Hong Kong
4	(Baratè et al., 2017)	Active learning theory	Experimental research	Experiential learning approach occurring in three phases: 1) definition of the problem, 2) meta-cognitive reflection and construction of a mental model, and 3) hands-on experience. use of LEGO bricks	Primary school students	A multi-touch tabletop application that uses LEGO	Italy
5	(Mindetbay et al., 2019)	item response theory	quantitative research design	Computational thinking performance multipe-choice test (GAT, ALG, INF, CTS)	Secondary school	Null	Kazakhstan
6	(Kush, 2019)	Constructivism learning theory and social-constructivism theories	Concept paper	NULL	Ukrain's students (specifically on higher education)	Null	Ukrain
7	(Denning, 2016)	Remixing theory, Constructionism theory used	Experimental research	using control of blocks in Scratch	Scratch community (young people, children)	Scratch	Washington
8	(Shell et al., 2017)	Epstein's Generativity Theory	Experimental research	Computational Creativity Exercises (CCEs) with T	University students (Computer Science course)	Null	England
9	(Yang & Lin, 2019)	Scaffolding theory	Experiment research	Control group: traditional scratch lesson Test group: play "Angry Birds Pigs Out" via platform Code.org "	Primary school students	Scratch	Taiwan
10	(Lin & Chen, 2020)	Learning theory	Experimental group	AR with deep learning recommendation, and control group: without AR	University students	Augmented Reality	Taiwan
11	(Gao, 2016)	Computer science theory, constructivism, connectivism	Concept paper which discussed causal-	Adapting flipped classroom	University students	Mobile learning	China

		– used in mobile learning	comparative research where one-year practice result.				
12	(Piedade et al., 2020)	Pedagogical theory	Descriptive and exploratory case study design	Design learning scenarios with robotics.	Pre-service teachers	Educational robotic	Portugal
13	(Thompson, 2018)	Variation theory	Experimental research	Unplugged activities	Computer science learners	Null	England
14	(Gadanidis et al., 2018)	Group theory	Experimental research	Mathematical experiences (ME) activities design using Scratch	Primary school students	Scratch	Canada
15	(Wu, 2018)	Situated learning theory	Exploratory case study	Engaged in design activities using three purpose-built game design tools in succession—Gamestar Mechanics, Lego Universe, and Microsoft Kodu.	Secondary school students	Null	United State
16	(Csizmadia, Standl, & Waite, 2019)	Constructionist Learning Theory	Experimental research	Control: Solve task without computer Treatment group: solve the same ask using CodeMonkey	Primary school students	Scratch, Khan Academy, Code.org	England
17	(Buteau et al., 2019)	Constructivist learning theory	Experimental research	programming-based courses	University students	Programming technology (Creating program GUI using Visual Studio)	Canada
18	(Uzumcu & Bay, 2020)	Interest driven Creator IDC theory	Experimental research	Innovative educational intervention/ unplugged activities, plugged, robotic-aided	Teachers	Computer aided and robotic activities	Turkey
19	(Felicia et al., 2017)	Constructionism theory	Quasi-experiments	Control: No intervention Treatment group: Application of robotics and programming module for primary school (RPGsr)	Primary school students	Robotic program	Malaysia
20	(Mensan et al., 2020)	Social cognitive theory	Constructivism teaching	Unplugged activities using ACTS module	Primary school students – Year 5 (11 years old)	Null	Malaysia
21	(Lapawi & Husnin, 2020)	Constructivism theory Constructionism theory	Quasi-experimental research	Control group: conventional instruction	Secondary school students –	Scratch	Malaysia

				Treatment group: Science Module	Form 1 (13 years old)		

Table 2 (b) A summary of previous studies from 2015 until 2020 (learning theory AND computational thinking, learning theory on computational thinking)

No.	Author	Theory applied	Research approaches	Type of Intervention	Respondent	Technology used/developed	Country
1	(Tsortanidou, Daradoumis, & Barberá, 2019)	Constructionism learning theory	Concept paper	Pedagogy-driven approach	Primary and Secondary school students	Null	Spain
2	(Csizmadia, Standl, & Waite, 2019)	Constructionist Learning Theory	Experimental research	Control: Solve task without computer Treatment group: solve the same ask using CodeMonkey	Primary school students	Scratch, Khan Academy, Code.org	England

4. CONCLUSION AND IMPLICATION

There are two aims of this paper: first and foremost is to review systematically the theory used in the context of computational thinking research. The second aim is to review the current studies of learning theory on computational thinking. Through this process, researcher identified that there are insufficient studies have been conducted to relate the theory applied with the computational thinking concepts. There is only a brief discussion on the theory being used in the previous studies. Most of the studies only mentioned about the theory applied and does not discuss it in details because they are focused more on the experiments' results. From the reviews, researcher can conclude that, most of the studies had mentioned about constructivism theory and there is lack of researches done for tertiary education students like TVET students has been identified using the keywords searched.

Researcher try to focus more on the keywords searched by specify the keywords from theory to learning theory. However, the results from the searched related articles are disappointing. There is lack of studies focusing on learning theory on computational thinking. Previous studies might mention about theory being used in their study, but they had not discussed and linked the theory and learning theory with the computational thinking in their studies. However, most of the studies are discussing the same elements in their articles such as current practices on research design, intervention, type of respondent as well as technology being used.

Most of the reviewed articles are highlighting unrelated keywords for the papers and they are not focusing on the main keywords of their research. This situation results in lack of related articles being found due to wrong keywords used in the paper. Researchers should focus in finding a proper and related article's title that reflect their content. Unrelated or wrong choice of research titles might result in lack of keyword search and less of researchers find, refer or cite the article. Hence, it is crucial to choose a better title and keywords before submitting the article to be published. This systematic review is limited to the identified articles from 9 recognised online search databases and there is a lot of possibility that other related articles is not found and cited by other researchers due to the wrong choices of keywords in their papers.

REFERENCES

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Adewumi, S. (2019). A systematic review of computational thinking approach for programming education in higher education institutions. *In Proceedings of the 19th Koli Calling International Conference on Computing Education Research*, 1-10.

Baratè, A., Ludovico, L. A., & Malchiodi, D. (2017). Fostering Computational Thinking in Primary School through a LEGO®-based Music Notation. *Procedia Computer Science*, *112*, 1334–1344.

Buteau, C., Sacristán, A. I., & Muller, E. (2019). Roles and Demands in Constructionist Teaching of Computational Thinking in University Mathematics. *Constructivist Foundations*, *14*(3), 294–309. http://www.ezplib.ukm.my/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=137772573&site=eds-live

Csizmadia, A., Standl, B., & Waite, J. (2019). Integrating the Constructionist Learning Theory with Computational Thinking Classroom Activities. *Informatics in Education*, *18*(1), 41–67.

Denning, W. F. (2016). Remixing as a Pathway to Computational Thinking. *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, 1438–1449.

Felicia, A., Sha'rif, S., Wong, W., & Mariappan, M. (2017). Computational Thinking and Tinkering: Exploration Study of Primary School Students' in Robotic and Graphical Programming. Asian *Journal of Assessment in Teaching and Learning*, *7*(1993), 44–54.

Flanigan, A. E., Peteranetz, M. S., Shell, D. F., & Soh, L. K. (2017). Implicit intelligence beliefs of computer science students: Exploring change across the semester. *Contemporary Educational Psychology*, *48*, 179–196.

Gadanidis, G., Clements, E., & Yiu, C. (2018). Group Theory, Computational Thinking, and Young Mathematicians. *Mathematical Thinking and Learning*, *20*(1), 32–53.

Gao, Q. (2016). *Computational Thinking and MOOC - Oriented Computer Courses Teaching Mode for Non-Computer Major*. Icassr 2015, 419–422.

Kong, S. C., & Wang, Y. Q. (2020). Formation of computational identity through computational thinking perspectives development in programming learning: A mediation analysis among primary school students. *Computers in Human Behavior*, 106(November 2019), 106230.

Kush, J. C. (2019). Computational Thinking as a Pedagogical Tool for Ukrainian Students. *Професіоналізм Педагога: Теоретичні Й Методичні Аспекти*, *0*(9), 21–27.

Lapawi, N., & Husnin, H. (2020). The Effect of Computational Thinking Module on Achievement in Scienceonal Thinking Modules on Achievement in Science. *Science Education International*, *31*(2), 164–171.

Lin, P. H., & Chen, S. Y. (2020). Design and Evaluation of a Deep Learning Recommendation Based Augmented Reality System for Teaching Programming and Computational Thinking. *IEEE Access*, *8*, 45689–45699.

Manley, G., Gardner, A. J., Schneider, K. J., Guskiewicz, K. M., Bailes, J., Cantu, R. C., Castellani, R. J., Turner, M., Jordan, B. D., Randolph, C., Dvořák, J., Alix Hayden, K., Tator, C. H., McCrory, P., & Iverson, G. L. (2017). A systematic review of potential long-term effects of sport-related concussion. *British Journal of Sports Medicine*, *51*(12), 969–977.

Masnoon, N., Shakib, S., Kalisch-Ellett, L., & Caughey, G. E. (2017). What is polypharmacy? A systematic review of definitions. *BMC Geriatrics*, *17*(1), 1–10.

Mensan, T., Osman, K., & Majid, N. A. A. (2020). Development and Validation of Unplugged Activity of Computational Thinking in Science Module to Integrate Computational Thinking in Primary Science Education. *Science Education International*, *31*(2), 142–149.

Mindetbay, Y., Bokhove, C., & Woollard, J. (2019). What is the Relationship between Students' Computational Thinking Performance and School Achievement? *International Journal of Computer Science Education in Schools*, *March*, 3–19.

Mohamad, E., Hamzah, M. R., Mohamed Salleh, S., & Ahmad, A. L. (2015). Diabetes knowledge in health communication research. *Journal of Asian Pacific Communication*, *25*(2), 191–207.

Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2019). Exploring children's learning experience in constructionism-based coding activities through design-based research. *Computers in Human Behavior*, *99*(7491), 415–427.

Piedade, J., Dorotea, N., Pedro, A., & Matos, J. F. (2020). On teaching programming fundamentals and computational thinking with educational robotics: A didactic experience with pre-service teachers. *Education Sciences*, *10*(9), 1–15.

PriSMA. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *The PRISMA Statement*. http://www.prisma-statement.org/

Randolph, J. J. (2008). Multidisciplinary methods in educational technology research and development by Justus J. Randolph. HAMK Press/Justus Randolph.

Shell, D. F., Flanigan, A. E., Peteranetz, M. S., Soh, L. K., & Ingraham, E. (2017). Improving students' learning and achievement in CS classrooms through computational creativity exercises that integrate computational and creative thinking. *Proceedings of the Conference on Integrating Technology into Computer Science Education*, ITiCSE, 543–548.

Thompson, E. (2018). Teaching computational reasoning through construals. *Education and Self Development*, *13*(3), 40–52.

Tsortanidou, X., Daradoumis, T., & Barberá, E. (2019). Connecting Moments of Creativity, Computational Thinking, Collaboration and New Media Literacy Skills. *Information and Learning Science*, *120*(11–12), 704–722.

Uzumcu, O., & Bay, E. (2020). The effect of computational thinking skill program design developed according to interest driven creator theory on prospective teachers. *Education and Information Technologies*.

Wan Ali, W. N. A. (2018). Preliminary Study in Emerging Competence Domain: Synergised Computational Thinking (CT) Skills and Brain-Based Learning (BBL) in TVET Curriculums. *Journal of Human Development and Communication*, *7*, 95–104.

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

Wu, M. L. (2018). Educational Game Design as Gateway for Operationalizing Computational Thinking Skills among Middle School Students. *International Education Studies*, *11*(4), 15.

Yang, K. H., & Lin, H. Y. (2019). Exploring the Effectiveness of Learning Scratch Programming with Code.org. *Proceedings - 2019 8th International Congress on Advanced Applied Informatics*, IIAI-AAI 2019, 1057–1058.