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Computational Thinking Skills of Middle School Students: Confirmatory Factor Analysis

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The objective of this research was to examine the congruence model for computational thinking skills among middle school students. Data was collected from 1,011 technology teachers at middle schools using a 5-point Likert scale questionnaire that had an Index of Item-Objective Congruence (IOC) of 1.0 and a reliability of 0.97. The obtained data was analysed using second-order confirmatory factor analysis. The results showed that the middle school students' computational thinking skills were comprised of four factors: applying computational concepts for problem-solving; applying computational concepts for mathematical problems; applying computational concepts to solve problems with a computer program; and digital design and creation. The model's goodness of fit was good and consistent with the empirical data. The factor loading was 0.82-0.90.

Key words: *Computational Thinking, Problem Analysis, Problem-Solving with a Computer Language Program.*

Introduction

Scientific computing is included in the national curriculums of many countries in order for students to use the computational concept in problem solving and has become the core of all fields (Science, Technology, Engineering and Mathematic) in UK and other European countries (ISTE, 2018; NRC, 2012). The Singapore National Curriculum focusses on the development of student in Computer Application (MOE, 2019) reflecting the increasing acceptance of computational thinking, which has come to be considered to be a more necessary skill than using technology (Brennan & Resnick, 2012).

Microsoft Thailand News Center (2015) viewed that computational thinking is a key skill that should be taught in all schools, regardless of age and gender, since it is a problem solving method that uses computer language programming and the computational thinking concept is fundamental to creating interest and developing the imagination of students.

Thailand aims to develop into Thailand 4.0, as determined in The Twelfth National Economic and Social Plan (2017) which has the following five policy areas: 1) Food, agriculture and biotechnology; 2) Public health, health and medical technology; 3) Smart devices, robots and mechanical system controlled by electronics; 4) Digital, internet that connects and control the devices, artificial intelligence and embedded systems; and 5) Creative industries, cultural capital and high value services. All these areas rely upon digital technology. Therefore, Thailand has emphasised human development to develop knowledge in science, technology and thinking processes to develop advanced skills and create innovations and technologies. For this reason, human development begins by developing learners at the basic education level. The core curriculum of basic education (2008) was revised in 2017, particularly in terms of the technology section which had the computer course revised to focus on the development of computational thinking to allow students to generate thinking processes similar to the operation of computers and how to control or command computers using computer language. Thus, the technology section of the core curriculum of basic education (Ministry of Education, 2017) focused on producing thinkers and technology inventors among middle schoolers who were digitally proficient and can utilise information technology wisely, while emphasising on instructional management of program design and coding to practice solving mathematical and scientific problems and develop problem analysis processes to digest problems, apply steps appropriately, rationally resolve problems, and have an awareness of the correct methods, simulations, logical processes and calculating technology to problem solve.

It is therefore clear that computational thinking skills is very significant for the development of middle school students in Thailand. Consequently, the researcher sought to study the development of computational thinking skills of teachers after implementing the new curriculum for a period of one year and analyse the confirmatory factors to analyse the construct validity of their computational thinking skills to determine whether the model was congruent with the empirical data and that the observed variables were consistent with the factors (Angsuchoti et al., 2014).

Research objective

To examine the goodness of fit of the confirmatory factor model for the computational thinking skills of middle school students.

Research hypothesis

This study hypothesised that the confirmatory factor model for computational thinking skills of middle school students would be congruent and consistent with the empirical data.

Research methodology

This quantitative research applied secondary confirmatory factor analysis to examine the developed confirmatory factor model for the computational thinking skills of middle school students in Thailand to determine the goodness of fit. The methodology was as follows.

Population and sample group

The population included technology teachers at middle schools in 77 provinces and six regions of Thailand. The study was conducted in the academic year 2019. A total of 2,361 schools were included in the study. Sample group size was determined based on the analytical concept using the structural equation, maximum likelihood. Boomsma and Hoogland (2001) suggested that the sample size for the maximum likelihood should be over 200. Meanwhile, Costello & Osborne (2006) suggested that 20 per observed variable are appropriate. Furthermore, Schumacker & Lomax (2010) advised 10 or 20 per observed variable. The present study included four factors and 18 observed variables. Thus, the sample size should be no less than 360. To ensure statistical accuracy, the researcher assigned 1,042 participants for this study and applied multistage random sampling, as follows.

1) Sample was randomised from six regions of Thailand using cluster random sampling by drawing method to obtain 50% of provinces from each region (Leekitchwatana, 2015: p. 163).

2) School samples from each province were randomised using simple random sampling by drawing method to obtain 50% of schools in each province.

3) Two technology teachers were randomly selected from each middle school using simple random sampling.

The population and sample details are shown in Table 1.

Table 1: Population and sample group

Region	Population (pax.)	Sample group (pax.)
Northern Thailand	317	140
Central Thailand	526	232
Western Thailand	159	70
Eastern Thailand	208	92
Northeastern Thailand	825	364
Southern Thailand	326	144
Total	2,361	1,042

Research tool

An 18 question 5-point Likert questionnaire was developed by the researcher and informed by previous studies (Aumgri & Petsangsri, 2019; Barr & Stephenson, 2001; Brennan & Resnick, 2012; Chokchai & Pimdee, 2019; Grover & Pea, 2013; Ministry of Education, 2017; ISTE, 2018; Kalelioglu & Gulbahar, 2014; Lye & Koh, 2014; NRC, 2012; Selby & Woollard, 2013; Wing, 2006). The questionnaire was used to survey the opinions of technology teachers on the computational thinking skills level of their middle school students in four aspects: applying computational concepts for problem solving; applying computational concepts for mathematical problems; applying computational concepts to solve problems with computer programs; and digital design and creation. Content validity was calculated using the item objective congruence (IOC) and scored 0.50 - 1.00 while the reliability score was 0.97.

Data collection

Data was collected from teachers from the sample group who taught technology at middle schools in Thailand. The participants were contacted to get permission to compile data from the online questionnaire, which was also sent by post and email. Data was collected during December 2019. Data was compiled from 1,011 participants which accounted for 97% of the sample group, which complied with the analysis concept, the maximum likelihood that the sample should be over 200 (Boomsma & Hoogland, 2001) and there were 20 samples per observed variable (Costello & Osborne, 2006).

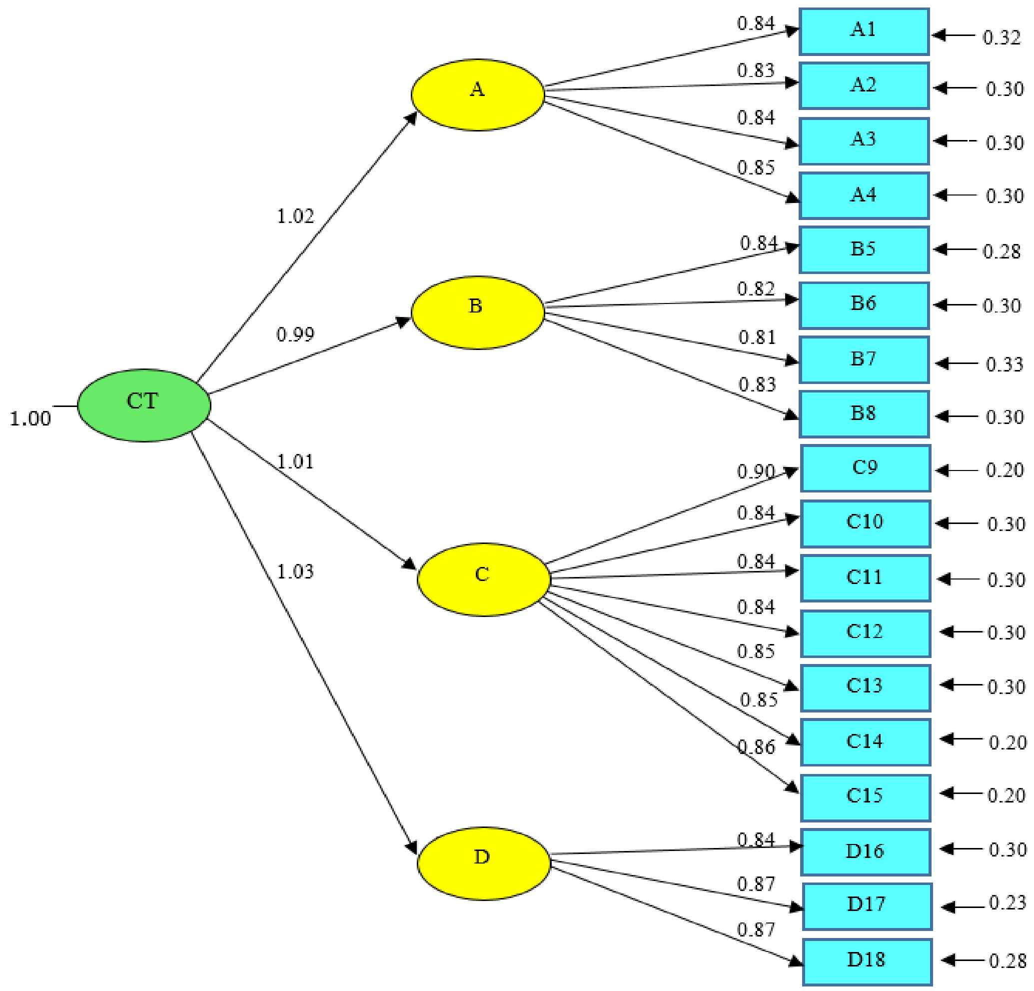
Research results

Table 2: Skewness and Kurtosis of latent and observed variables

Factors and Variables	α	Mean	SD	Skew	Kurt
1. Applying computational concepts for problem-solving (A) 1.1 Analyse problems by digesting them into sub-problems (Decomposition) (A1).	0.98	3.69	0.84	-0.29	-0.44
1.2 Consider each sub-problem (Pattern) (A2).	0.97	3.72	0.92	-0.37	-0.47
1.3 Classify the necessary details for problem solving from other unnecessary details (Abstraction) (A3).	0.97	3.64	0.94	-0.34	-0.71
1.4 Plan and process problem solving (Algorithm) (A4).	0.98	3.72	0.94	-0.31	-0.76
2. Applying computational concepts for mathematical problems (B) 2 .1 Analyse the factors of mathematical problems which include area composition, capacity, shape capacity and prism using the decomposition concept (B5).	0.97	3.74	0.91	-0.22	-0.76
2. 2 Consider the data pattern in the sub-composition of polygonal area, capacity, shape capacity and prism (B6).	0.98	3.72	0.94	-0.28	-0.74
2.3 Analyse the details of necessary data for problem solving or operations connecting the use of mathematical equations, such as the number and operation, measurement units, capacity, shape and prism (B7).	0.98	3.72	0.89	-0.29	-0.54
2.4 Planning for problem solving and processing the solution to mathematical problems. Verifying the accuracy of the outcome (B8).	0.98	3.74	0.93	-0.36	-0.61
3. Applying computational concept to solve problems with computer programs (C) 3.1 Skills to use fundamental computer language (C9).	0.97	3.68	1.00	-0.26	-1.22
3.2 Analyse and design program coding for polygonal drawing, such as coding programs for drawing triangles, squares, hexagons, octagons, circles and heart shapes (C10).	0.98	3.68	0.86	-0.26	-0.53
3 .3 Analyse and design program coding to calculate the mean, percentage, discount and net price (C11).	0.98	3.69	0.88	-0.24	-0.61
3.4 Analyse and design program coding to calculate the area of a square, rectangle, parallelogram, irregular quadrilaterals, triangle and circle (C12).	0.98	3.70	0.92	-0.33	-0.53
3 .5 Analyse and design program coding to calculate the capacity and shape capacity of cubic, rectangular shape, circle, cylinder shape and cone shape (C13).	0.98	3.64	0.96	-0.29	-0.82
3.6 Analy0e and design program coding to calculate prism which include a square-based prism, triangular-based prism	0.98	3.72	0.95	-0.30	-0.81

Factors and Variables	α	Mean	SD	Skew	Kurt
and hexagonal prism (C14).					
3.7 Verify the accuracy of outcomes and correct (testing and debugging) (C15).	0.98	3.74	0.91	-0.20	-0.80
4. Digital design and creation (D) 4.1 Analyse and design a program that receives data from users and displays problem solving results (D16).	0.97	3.73	0.93	-0.27	-0.75
4.2 Analyse and design a program that creates and uses functions with parameters (D17).	0.98	3.74	0.97	-0.33	-0.75
4.3 Develop digitally creative work using the computational thinking concept with interaction between the user and the object (D18).	0.98	3.78	1.0	-0.40	-0.87

Figure 1 shows the analytical results of the secondary confirmatory factor of computational thinking skills of the middle school students in Thailand.



Chi-Square = 9.13, *df* = 47, P-value = 1.00, RMSEA = 0.00

Figure 1: Secondary confirmatory factor model of computational thinking skills of middle school students in Thailand

The researcher proposed the goodness of fit measurement by analysing the confirmatory factor and the empirical data, as detailed in Table 2.

Table 3: Goodness of fit measurement of the confirmatory factor model and the empirical data of computational thinking skills of middle school students in Thailand

Goodness of Fit Index (GFI)	Criteria	After model revision		Conclusion
		Value	Result	
1. Chi-Square				
χ^2-test or χ^2-Sig (p)	p>0.05	1.00	Pass	Good
χ^2/df	<2.00	0.19	Pass	Good
(After adjusting $\chi^2 = 9.13$, $df = 47$)				
2. Absolut Goodness of Fit **index**				
GFI	≥ 0.95	0.99	Pass	Good
AGFI	≥ 0.95	0.99	Pass	Good
PGFI	≤ 0.50	0.28	Pass	Good
3. Relative Goodness of Fit **index**				
NFI	≥ 0.95	1.00	Pass	Good
NNFI	≥ 0.95	1.00	Pass	Good
PNFI	≤ 0.50	0.31	Pass	Good
CFI	≥ 0.95	1.00	Pass	Good
IFI	≥ 0.95	1.00	Pass	Good
4. Square Root of Mean Square Error				
RMSEA	≤ 0.05	0.00	Pass	Good
SRMR	≤ 0.05	0.00	Pass	Good
5. Root mean square error of approximation				
RMR	≤ 0.05	0.00	Pass	Good
6. Largest Standardized Residual and Smallest Standardized Residual Index				
Largest Standardized Residual	$\leq \pm\|2.00\|$	1.35	Pass	Good
Smallest Standardized Residual	$\leq \pm\|2.00\|$	-1.20	Pass	Good
7. Q-Plot and Diagonal line				
Q-Plot	Slope>1	>1	Pass	Good

Goodness of Fit Index (GFI)	Criteria	After model revision		Conclusion
		Value	Result	
Summary		Congruent with empirical data		

Table 4: Factor loading, validity of observed variables and score coefficient of factors of computational thinking skills of middle school students in Thailand

Variables \ Factors	Factor Loading b	Factor Loading β	SE	t	R^2
1. Applying computational concepts for problem-solving in daily life (A)					
1.1 Analyse problems by digesting them into sub-problems (Decomposition) (A1).	0.84	0.83	0.03	32.57*	0.68
1.2 Consider each sub-problem (Pattern) (A2).	0.83	0.82	0.03	32.43*	0.67
1.3 Classify the necessary details for problem solving from other unnecessary details (Abstraction) (A3).	0.84	0.83	0.03	32.89*	0.69
1.4 Plan and process problem solving (Algorithm) (A4).	0.85	0.84	0.03	33.14*	0.70
2. Applying computational concepts for mathematical problems (B)					
2.1 Analyse the factors of mathematical problems which include area composition, capacity, shape capacity and prism using the decomposition concept (B5).	0.84	0.85	0.03	32.79*	0.72
2.2 Consider the data pattern in the sub-composition of polygonal area, capacity, shape capacity and prism (B6).	0.82	0.83	0.03	31.63*	0.68
2.3 Analyse the details of necessary data for problem solving or operations connecting the use of mathematical equations, such as the number and operation, measurement units, capacity, shape and prism (B7).	0.81	0.82	0.03	31.11*	0.67
2.4 Planning for problem solving and processing the solution to mathematical problems. Verifying the accuracy of the outcome (B8).	0.83	0.83	0.03	31.96*	0.70
3. Applying computational concept to solve problems with computer programs (C)					
3.1 Skills to use fundamental computer language (C9).	0.90	0.90	0.03	36.70*	0.80
3.2 Analyse and design program coding for polygonal drawing, such as coding programs for drawing triangles, squares, hexagons, octagons, circles and heart shapes (C10).	0.84	0.83	0.03	32.45*	0.70
3.3 Analyse and design program coding to calculate the mean, percentage, discount and net price (C11).	0.84	0.84	0.03	32.61*	0.70
3.4 Analyse and design program coding to calculate the area of a square, rectangle, parallelogram, irregular quadrilaterals, triangle and circle (C12).	0.84	0.83	0.03	32.37*	0.69
3.5 Analyse and design program coding to calculate the capacity and shape capacity of cubic, rectangular shape, circle, cylinder shape and cone shape (C13).	0.85	0.85	0.03	33.34*	0.72
3.6 Analyse and design program coding to calculate prism which include a square-based prism, triangular-based prism	0.85	0.84	0.03	32.82*	0.71

Variables \ Factors	Factor Loading b	Factor Loading β	SE	t	R^2
and hexagonal prism (C14).					
3.7 Verify the accuracy of outcomes and correct (testing and debugging) (C15).	0.86	0.85	0.03	33.73*	0.73
4. Digital design and creation (D)					
4.1 Analyse and design a program that receives data from users and displays problem solving results (D16).	0.84	0.82	0.03	33.04*	0.67
4.2 Analyse and design a program that creates and uses functions with parameters (D17).	0.87	0.84	0.03	34.44*	0.71
4.3 Develop digitally creative work using the computational thinking concept with interaction between the user and the object (D18).	0.87	0.85	0.03	34.91*	0.72

* $p < .01$

The computational thinking skills model for middle school students included 18 variables and was comprised of four factors, including: applying computational concepts for problem-solving in daily life; applying computational concepts for mathematical problems; applying computational concepts to solve problems with computer programs; and digital design and creation. The model goodness of fit and consistency with the empirical data was at a good level. Ordered by highest factor loading they were: digital design and creation (1.03); followed by applying computational concepts for problem-solving in daily life (1.02); applying computational concepts to solve problems with computer programs (1.01); and applying computational concepts for mathematical problems (0.99).

Discussion

Upon analysing the results of the confirmatory factor model for computational thinking skills among middle school students in Thailand, four factors or latent variables were found. Factor 1 was applying computational concepts for problem-solving in daily life, consistent with Wing's (2006) concept that computational thinking skills can be applied to problem solving processes, decomposition system design and put it in order, as well as understanding about human thinking behavior. This is related to logic, analysis and problem solving which are useful for living. Moreover, it was consistent with the standard of indicator in the core curriculum of the basic education, revision 2017, regarding Technology - Design an algorithm used in the computational thinking concept to resolve problem or apply to routine tasks. Likewise, Manovich (2013) stated that humans are digital citizens living in a digital ecology system filled with objects steered by software. Computer language management skills are new skills which help people to fully participate and be efficient in the digital world. The new skills were code literacy skills.

Factor 2 was applying computational concepts for mathematical problems. Factor 3 was applying computational concepts to solve problem with computer programs and Factor 4 was digital design and creation. These are in line with the Computer Science Standard: CSTA (2017) which set the standard for instructional activities that students should develop, including data analysis, abstraction, algorithm programming, computational problem, testing, computing system program development and creating. This is in line with the indicator of middle school students' development in the core curriculum of basic education, revision 2017, Technology. These were: 1) program design and coding using logic and problem solving function; and 2) fundamental program design and coding to resolve simple mathematical or science problems. This is consistent with the indicator for learners in the national curriculum for educational management of basic education in Singapore, in which students learn about computational thinking to be applied with computer application solutions and routine life.

The four factors of the confirmatory factor model for computational thinking skills among middle school students in Thailand were in line with Yadav et al., (2011) who found out that arranging computer concept activities with kindergarten students through to grade 12 by using the computers to resolve problems and applying computational thinking was appropriate to their development. Meanwhile, Youngseok & Jungwon (2019) studied the factors of computational thinking by organising leaning activities for learners to be able to code Python programs using an abstraction, pattern, condition and algorithm design concept.

The above mentioned computational thinking and relevant research are consistent with the analysis results of the confirmatory factor of computational thinking skills among middle school students in Thailand. These are comprised of four factors or latent variables and 18 observed variables. Moreover, the model was congruent with the empirical data, in which χ^2/df was 0.19, which was less than 2.0, reflecting that the structural model was consistent with the empirical data (Mclver & Carmines, 1981). As GFI was 0.99, AGFI was 0.99 and CFI was 1.00, this qualified the criteria because they were more than 0.95. This implied that the model was consistent with the empirical data. Moreover, RMR was 0.00 and RMSEA was 0.00. Such values show that the confirmatory factor model for computational thinking skills was consistent with the empirical data, which included: applying computational concepts for problem-solving in daily life (A); applying computational concepts for mathematical problems (B); applying computational concepts to solve problems with computer programs (C); and digital design and creation (D). The results confirm the construct validity since the confirmatory factor analysis was the optimal technique to validate it. Wiratchai (1997) stated that the important step in confirmatory factor analysis is the model validity test or the goodness fit of the model and the empirical data. The above results illustrate that the analysis of confirmatory factor of the development of computational thinking skills had a suitable goodness of fit with the empirical data and can be applied to measure the development of computational thinking skills among middle school students in Thailand.

From the analysis of factor reliability to evaluate the computational thinking skills of middle school students, the factor loading or significance of the observed variables was 0.81-.90 which implies the consistency of the variables between the observed and latent variables. An acceptable factor loading of ±.5 or above reflects that the questions or the observed variables related to the factors of latent variables and which implied the validity of question of each factor (Hair et al., 2010).

Analysis results of the reliability showed that the prediction coefficient (R^2) or the reliability was 0.69-0.80, higher than 0.5. This implies that all the variables of each factor and all the questions were reliable.

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