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Reliability and Construct Validity of Computational Thinking Scale for Junior High School Students: Thai Adaptation

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Abstract. Computational thinking (CT) is defined as a broad spectrum of cognitive abilities including creativity, algorithmic reasoning, critical analysis, problem-solving, collaborative thinking, and communication. There are currently not many self-rated CT skill measurements available. One of these tools for measurement is the Korkmaz Computational Thinking Scale (CTS). The purposes of this present study are to adapt the Korkmaz CTS into Thai and to assess its reliability and validity. Employing a convenience sampling method, data from 3,241 junior high school students in Thailand were collected using Thai translated Korkmaz CTS. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were used for data analysis. According to the findings, Thai version of Korkmaz CTS exhibited reliable psychometric properties. However, one item from the Thai CTS was eliminated during the EFA process whereas six items were removed during the CFA. Thus, the Thai CTS can be used as a self-rating instrument to assess the CT of junior high school students in addition to high school and undergraduate students. Schools can measure students' CT faster and with cost-saving.

Keywords: Computational Thinking, Computational Thinking Scale, Psychometric Properties, Junior High Students

1. Introduction

The world is evolving rapidly in nearly every industry, likewise in the field of education. The development of each student's unique skills is given more weight in the 21st century global educational system. The International Society for Technology in Education (ISTE) identifies high-level abilities, e.g., problem-solving, collaboration, creativity, and critical thinking as "21st century student standards." According to several surveys, students in the 21st century need to be proficient in technology as well as other abilities including teamwork, research, social interaction, learning, communication, and self-management (Gunuc et al., 2013). It seems critical thinking, analytical thinking, and problem-solving have

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become important in the 21st century (Yilmaz et al., 2018). Notably, computational thinking (CT) is incorporated among these skills. According to Wing (2006), CT is a mental skill that each person possesses not only computer scientists. It is indeed a fundamental skill related to logic, analysis, and problem-solving. It is considered useful for learning, working, and daily living (Cuny et al., 2010; Wing, 2006). The main goal of CT is to solve problems using concepts that are fundamental to computer science (Wing, 2006).

All students should possess and develop their CT skills as technology advances because they are crucial to their professional success in the modern digital age (Vallance & Towndrow, 2016). The ability to distinguish and extrapolate important information from larger sources is one of the "digital literacy" sub-skills that are crucial for the 21st century. It is connected to other 21st century empowerment skills, e.g., problem-solving, critical thinking, job effectiveness, and creativity. Wing (2006) propounded the view that this empowerment needs to be incorporated into all children's' analytical capability which is the crucial backbone in their science, technology, engineering, and math learning. Advocating CT in the educational system will add a new ability to the student skill list they need in the not-too-distant future and which many institutes have initiated (Grover & Pea, 2013). For example, promoting CT was infused into the US Next Generation Science Standards (NGSS) and STEM courses in the level of K-12. CT was integrated into various educational programs in many countries, e.g., Finland, Norway, South Korea, Israel, Poland, New Zealand, and Estonia (Tikva & Tambouris, 2021). CT was also incorporated into the elementary school curricula in 52 countries according to the surveys of studies published between 2006 and 2018 (Tang et al., 2020). In Thailand, CT was introduced as part of the National Standards Curriculum in 2017.

The development of students' technological and learning-style-specific skills has become a top priority in Thailand. The Institute for the Promotion of Teaching Science and Technology (IPST) has revised its technology curricula with a focus on material that supports the key CT skills of thinking, analysing, and problem-solving. Due to the significance of CT performing in a technology role, IPST places a high priority on CT development among students. CT is important in concepts and planning frameworks, design, imagination, creativity, systematic thinking, and societal coexistence with the digital ecosystem. It is a thought process that requires skills and techniques or a kind of style or method that allows students to analyse and find answers (Janpilom et al., 2019). Students use CT to solve their problems in learning. CT not only offers a new perspective to K-12 children but also enhances their capabilities in terms of observing and perceiving the surrounding world. It reckons to be a novel comprehension that allows students to solve issues utilising computational techniques and approaches. It is a practical skill that is crucial for them to handle upcoming challenges and competitions.

Computational thinking is currently receiving more attention from researchers, notably from professionals in the field of educational technology who have underlined that CT is crucial for developing 21st century skills (Voogt et al., 2015). According to the literature mentioned above, CT is seen as being very important for students, with numerous institutions all over the world working very hard to develop it. However, there are some viewpoints catching their interest that are predicated on the idea that it is critical to establish methods for developing and evaluating students' computational abilities. This means that, before they design and develop some practical intervention in order to enhance CT skills, all educational institutes should try to discover what the current CT skill level of their students is. This has led to the matter of CT assessment, which is quick and cost-saving. A self-report questionnaire is one feasible option and has been widely used in educational psychology.

Currently, there are only a few self-rated CT skill measurements (e.g., Ertuğrul-Akyol, 2019; Kukul, 2019; Tsai et al., 2021; Yağcı, 2019). The Computational Thinking Scale (CTS) is among these assessment scales and was developed by Korkmaz et al. (2017). This scale is created in English and consists of 29 items from five dimensions, e.g., creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving.

Presently, CTS has been adapted into only two languages: Turkish (Srakaya et al., 2020) and Chinese (Korkmaz and Bai, 2019). Korkmaz and Bai (2019) collected data from 1,015 grade 10 and grade 11 students and results showed that there remained 20 items measuring CT under the five dimensions. Adapting CTS into the Turkish language, Sırakaya et al. (2020) collected data from 703 secondary school students. The results showed that there were 22 items under five constructs as well with a valid and reliable CTS measurement scale. In light of this evidence, there were only two researches concerned with this issue (see Table 1). More research should be required to demonstrate the reliability and validity of CTS, especially with different educational levels, i.e., junior high school students and larger number of participants. There is also no scale available to test CT proficiency in Thai that has been proven to measure validity and reliability. The purposes of this study are to adapt the 29 items of CTS into Thai and to assess its reliability and validity.

Table 1: CTS assessment in different languages

Study	Language	Location	Participants	Data analysis	Result
Korkmaz et al. (2017)	English	Turkey	726 Undergraduate Students	EFA, CFA	five-factor construct 29 items
Korkmaz and Bai (2019)	Chinese	China	1,015 K10 and K11 students	EFA, CFA	five-factor construct 20 items
Sırakaya et al. (2020)	Turkey	Turkey	703 Secondary school	EFA, CFA	five-factor construct 22 items
Current study	Thai	Thailand	3,241 Junior high school students	EFA, CFA	-

2. Literature Review

2.1 Computational Thinking

Over time, the concept of CT has gained in popularity. Papert and Wing were the pioneers in this field. Using the fundamental ideas of computer science, Wing (2006) described CT as an approach for problem-solving, system design, and comprehending human behaviour., while the article by Papert (1996) contains one of the earliest mentions of CT. According to Papert (1996), it is beneficial to observe relationships between the many parts of complex systems and to apply fundamental human cognition to object-oriented problems. It is a technique to problem-solving, system design, and human behaviour understanding that is founded in computer science (Korkmaz et al., 2017; Wing, 2006). It is a type of mental process that entails articulating issues and outlining options in a way that enables a computer to function properly (Wing, 2014).

Similarly, Curzon (2015) defined CT as a fundamental skill meant to solve problems for humans and indicated that problem comprehension is considered crucial due to the consequence regarding producing practical solutions. CT is a general reflection of creativity, algorithmic thinking, critical thinking, problem-solving, collaborative thinking, and communication skills (ISTE, 2015). These are skills that are mostly mentioned in the literature. The Computer Science Teacher Association (CSTA) revised its definition of a problem-solving mechanism in 2016. This strategy can be applied to all fields of study in the field of computer science, allowing for analysis and the creation of solutions to issues that can be resolved by computational means (CSTA, 2017).

Alternatively, CT is a combination of comprehensive thinking abilities, e.g., mathematical, engineering, and scientific thinking (Mannila et al., 2014; Riley & Hunt, 2014; Syslo & Kwiatkowska, 2013). It contributes a remarkable capacity for original thought (Korkmaz & Bai, 2019). Although CT is not specifically defined as one, its importance is clear given that everyone is expected to utilise it as one of the fundamental skills, along with reading, writing, logic, and math (Wing, 2006, 2010). Every child's critical thinking ability for reading, writing, and mathematics should be integrated with it (ISTE, 2015; Wing, 2008). The dimensions of the computational thinking abilities determined by Korkmaz et al. (2017) are shown below and include creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving.

2.2 CT Dimensions

2.2.1 Creativity

Creative thinking is one of the dimensions of CT (Grover & Pea, 2013). It is a cognitive process that entails the generation of fresh concepts or ideas as well as fresh connections between old concepts or ideas (Agogi et al., 2014; Jackson et al., 2012). The "capacity for creation" or "ability to create" is creativity. Making something out of nothing is another meaning of creation. Therefore, fresh notions or ideas are meant when one talks about creativity. It has to do with creativity, originality, and imagination. The ability to recognise novel challenges and propose a solution requires the use of creative thinking. It is not a standalone skill but is intimately tied to analytical and problem-solving abilities (Korkmaz et al., 2017).

2.2.2 Algorithmic Thinking
Algorithmic thinking is the basis of CT (Aho, 2012; Denning, 2009). An algorithm is a process that uses stages that are clearly specified to solve a problem (Futschek, 2006). The capacity to comprehend, act upon, assess, and create an algorithm is known as algorithmic thinking (Brown, 2015). It derives from the idea of an algorithm, which is the process of designing a sequence of sequential steps to solve a problem and produce the intended outcome (Katai, 2015). Algorithmic thinking relates to the notion of developing and comprehending algorithms (Futschek, 2006; Katai, 2015). The primary CT feature is algorithmic reasoning used to solve problems automatically (Barr & Stephenson, 2011). It is a meticulous ability that calls for a capacity for conceptual thinking and problem-solving. It entails creating a flowchart of steps leading to suitable solutions, refining the flowchart, and coming up with other processes to make sure that supported alternative solutions to the problem are found (Futschek, 2006). The capacity to define abstraction, which is the core of computational thinking, is also strongly tied to it (Wing, 2008; Wong & Jiang, 2018). One of the fundamental competencies in CT is algorithmic thinking (Yadav et al., 2017).

2.2.3 Cooperativity
Cooperativity is also deemed to be a part of CT dimension (Farris & Sengupta, 2014; Grover & Pea, 2017). According to Missiroli et al. (2017), cooperative thinking is the ability to explain, recognise, dissect issues and computationally solve them in teams in a socially sustainable fashion. Cooperative thinking and the concept of CT are blended in this definition. Essentially, it is a procedure for solving problems. Corporation and collaboration between people leads to effective problem-solving because when issues grow more complicated, it becomes challenging for one person to arrive at a solution. Students should be able to describe and dissect large problems into their component parts. In CT, wherein students employ higher level reasoning (National Research Council, 2011), social collaboration plays a major role (Farris & Sengupta, 2014; Standl, 2016). Interoperability is essential when the problem's complexity rises, while cooperativity is superior among learning methods because of the participation in which individuals can share information and build social relationships (Korkmaz, 2012; Nam, 2014).

2.2.4 Critical Thinking
Having numerous definitions for it, a crucial component of CT is critical thinking, one of the higher order thinking abilities, which helps students solve problems by assessing them at a deeper level of thought (Doleck et al., 2017). Individual attitudes, information, and abilities which are utilised to reason and evaluate the situation of a problem are all part of the critical thinking process. According to Csizmadia et al. (2015), critical thinking refers to the process of thoughts assessment and evaluation in an attempt to seek room for improvement. It entails asking "how" and "why" inquiries (Seferolu & Akbyk, 2006). Kules (2016) identified parallels between the eight-dimensional critical

thinking framework and the Computer Science Standards suggested by CSTA (2017) and figured out several akin concepts, e.g., "concepts and abstraction, formulation and question-at-issue, information/data, confidence and persistence, and logic" (p. 508). Many approaches can be used to tackle problems; however, it requires critical thinking. Therefore, critical thinking is considered a significant element of CT.

2.2.5 Problem Solving

Barr and Stephenson (2011) emphasised that problem-solving is the core dimension of CT. Problem-solving is interchangeable with CT (Grover & Pea, 2013; Israel et al., 2015). It is the mechanism of seeking any available solutions to confront with daily life problems people are engaging in (Brandell, 2010). This process comprises of four fundamental steps, e.g., defining the problem, generating alternative solutions, evaluating and selecting an alternative, and implementing and following up on the solution. The problem-solving process includes these characteristics, e.g., defining the problem in a way that allows us to use computers and other tools to help; logical organisation and analysis of data; data visualisation through abstraction; automatic problem-solving through algorithmic thinking; identifying, analysing, and implementing feasible solutions to achieve the most efficient and effective combination of procedures and resources; and orienting and transferring this problem-solving process to a wide range of problems (Barr & Stephenson, 2011). These characteristics are closely related to the four fundamental steps of problem-solving.

2.3 Previous Researches Using CTS

In numerous research all over the world, the CTS of Korkmaz was adopted and utilised to assess students' CT. For instance, Law et al. (2021) determined the relationship between academic achievement and CT of domestic STEM students in Malaysia; Doleck et al. (2017) explored the CT skills and academic performance relation among students in north-eastern Canada; Günbatar (2019) studied the comparison between in-service and pre-service teachers CT skill in Turkey; Mindetbay et al. (2019) explored the relationship between the efficacy of CT and the academic achievement of grade 8 students in 28 schools in Kazakhstan; Lemay et al. (2021) examined the link between CT and the academic results of students in Turkey; Srakaya et al. (2020) explored the CT skills, STEM attitudes, and thinking styles association among secondary school students in Turkey; Paf and Dinçer (2021) studied the relationship between CT skills and creative problem-solving skills of grade 8–12 students in Turkey; Zgür (2020) investigated the relationship between CT skills, ways of thinking, and demographic variables of grade 5–12 students in Turkey; Alyahya and Alotaibi (2019) studied the relationship between CT skills and grade 8 students in Saudi Arabia; and Durak and Saritepeci (2018) assessed the relationship between CT skills and various variables in Turkey.

3. Methods

3.1 Participants

Through the lens of gaining mutual advantage from a research network, the convenience sampling technique was employed in the current study due to the expectation of the highest responses possible. Data were collected from junior high school students in Thailand. During data screening outliers were observed using the Mahalanobis distance method with a critical point of 58.30, resulting in 266 responses dismissed from the dataset. The final total number of participants comprised 2975 students; 1880 (63.2%) of the participants were female whereas 1095 (36.8%) were male. The average age of participants was 13.84 years with a standard deviation of 2.39.

3.2 Research Instrument

In this study, the researchers adopted the Korkmaz CTS (Appendix 1). The researchers translated CTS items into Thai (Hambleton & Patsula, 1999). Then the Thai version of CTS adjusted the words to suit junior high school students. The Thai CTS consists of 29 items with a 5-level rating on a Likert-scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always). Each CT dimension consists of several items, e.g., creativity (8 items), algorithmic thinking (6 items), cooperativity (4 items), critical thinking (5 items), and problem-solving (6 items).

3.3 Procedure

First, research consent was obtained from the University Institute Research Board (IRB). Educational technology specialists who are fluent in both Thai and English translated the original CTS from English into Thai. The Thai CTS was sent to a language specialist for translation back to English and then compared with the original. The results showed that the original scale items and the items obtained from the English translation were linguistically equivalent. The translation process was completed with all necessary language modifications. Second, the pilot test was conducted using the Thai CTS in order to review psychometric characteristics and make further adjustments (Deniz, 2007). Finally, the scale was used to collect data from junior high school students. All the participants were volunteers and had the right to partially or not complete the survey.

3.4 Data Analysis

All analysis in this study was computed using R programming language (R Core Team, 2020). Each statistic test requires specific loading package and function. Data analysis was performed in three stages after removing all outliers. First, it was scanned for missing values and a preliminary analysis was performed in order to investigate the assumption of normality and multicollinearity. Normality was checked via skewness and kurtosis. Lomax and Hahs-Vaughn (2013) suggested that data are considered normal when skewness and kurtosis are within the range of an absolute value of 1.5. Multicollinearity was checked through Pearson's correlation among all observed variables in a dataset. Multicollinearity is manifested when the strength of the relationship value is high, that is, $r > .8$ (Gana & Broc, 2019). Second, to investigate the structural validity of this CTS scale, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were conducted. Therefore, a dataset was randomly selected and separated into two parts via R. Part one consisted of 500 for performing EFA, whereas part two contained 2475 for undergoing CFA.

An EFA was conducted to discover the rational CTS scale factor structure. Prior to carrying out the EFA, its assumptions were explored through sampling size adequacy and observed variable intercorrelation. To extract the factors, principal axis factoring (PAF) was utilised with oblique rotation (Promax) along with parallel analysis and scree plot. PAF determines the quantity of factors and their nature in corresponding to participants' responses (O'Rourke & Hatcher, 2013). The oblique rotation was selected in terms of theoretical expected factor correlation. Each factor is elected based on its eigenvalues which are higher than 1 (Kaiser, 1960). Factor loading that is significant indicates the relative importance of a variable towards underlying factors. Thus, to interpret the factor, the value of loading must be higher than 0.4 (Stevens, 2012). Cronbach's alpha (α) of all scales and subscales was also investigated due to the verification of measurement scale reliability.

Second, CFA was conducted due to the assurance that the first separated dataset was well-fitted with the proposed EFA structural model. CFA verifies the factor structure by assessing the model fit. The assessment criteria concerned with a significant p-value chi-square divided by the degree of freedom (χ^2/df), comparative fit index (CFI), Tucker-Lewis index (TLI), the standardised root mean square residual (SRMR), and the root mean square error of approximation (RMSEA). A model comprised of 12-30 overserved variables requires at least 250 participants, χ^2/df smaller than 3, CFI or TLI higher than .94, SRMR = 0.08 or less (with CFI above .94), and RMSEA smaller than .07 with CFI of .94 or higher is a well-fitted model (Hair et al., 2022). The authors further postulated that exerting three or four indices is considered adequate to confirm the model fit.

Finally, the validity and reliability of the CFA measurement model were assessed. The measurement model reliability was evaluated via Average Variance Extracted (AVE) and Composite Reliability (CR). AVE values exceeding 0.50 indicate reliability, whereas CR values must exceed 0.60. In terms of the validity of the scale, it was examined through convergent and discriminant validity. Convergent validity is achieved when all AVE values are at least 0.50 or higher. Discriminant validity is achieved when Pearson's correlation among all constructs is smaller than the square root of the AVE of each construct.

4. Findings

4.1 Preliminary Analysis

No missing values were found through data screening. The skewness values of all items were in between 0.72 and -0.94 whereas kurtosis values were between 0.14 to -0.66. These values were within the range of 1.5 absolute value. Therefore, the assumptions pertaining to normality and missing data showed no violation. Pearson's correlation values of all items ranged between 0.78 to -0.23 which were low than 0.80. Therefore, the multicollinearity assumption did not cause any violation in the main analysis. Table 2 shows skewness, kurtosis, and Pearson's correlation between all items.

Table 2: Mean, standard deviation, skewness, kurtosis, and correlation between all items (N = 2975)

Item	C01	C02	C03	C04	C05	C06	C07	C08	A01	A02	A03	A04	A05	A06	O01	O02	O03	O04	T01	T02	T03	T04	T05	P01	P02	P03	P04	P05	P06
C01																													
C02	.50																												
C03	.41	.42																											
C04	.40	.35	.59																										
C05	.40	.38	.55	.58																									
C06	.39	.38	.47	.50	.54																								
C07	.40	.42	.53	.50	.54	.49																							
C08	.38	.41	.50	.51	.53	.47	.55																						
A01	.34	.30	.45	.52	.49	.45	.48	.54																					
A02	.28	.22	.32	.37	.37	.34	.29	.38	.41																				
A03	.30	.23	.33	.40	.39	.35	.30	.37	.43	.78																			
A04	.32	.29	.41	.49	.44	.44	.39	.44	.48	.52	.58																		
A05	.28	.18	.34	.43	.40	.37	.31	.39	.48	.59	.67	.60																	
A06	.27	.19	.34	.43	.39	.37	.30	.38	.47	.56	.62	.59	.73																
O01	.31	.38	.33	.29	.33	.34	.40	.35	.28	.20	.19	.24	.15	.16															
O02	.31	.33	.31	.31	.33	.35	.35	.35	.32	.21	.21	.27	.21	.23	.59														
O03	.32	.37	.32	.29	.33	.34	.37	.35	.29	.18	.18	.25	.17	.19	.63	.65													
O04	.32	.34	.33	.29	.33	.34	.35	.34	.29	.20	.22	.28	.20	.23	.50	.56	.58												
T01	.35	.28	.44	.51	.48	.42	.41	.46	.51	.42	.47	.53	.52	.52	.26	.35	.32	.40											
T02	.30	.26	.38	.43	.38	.36	.34	.40	.44	.45	.48	.51	.52	.52	.20	.27	.25	.32	.60										
T03	.39	.41	.43	.41	.45	.42	.47	.46	.39	.32	.32	.39	.31	.32	.43	.36	.39	.40	.43	.46									
T04	.37	.40	.44	.41	.46	.42	.46	.46	.44	.38	.38	.46	.38	.40	.36	.36	.35	.35	.52	.49	.55								
T05	.38	.35	.44	.46	.46	.44	.45	.50	.49	.40	.43	.51	.45	.47	.33	.36	.35	.35	.56	.50	.49	.60							
P01	.20	.17	.27	.27	.23	.27	.25	.25	.31	.21	.24	.31	.29	.29	.17	.22	.19	.22	.34	.30	.26	.32	.38						
P02	.20	.16	.22	.25	.22	.24	.21	.22	.26	.23	.25	.31	.30	.31	.13	.20	.17	.20	.31	.27	.21	.30	.33	.44					
P03	.11	.04	.14	.17	.14	.14	.12	.12	.20	.14	.18	.23	.22	.21	.06	.13	.08	.11	.22	.18	.11	.19	.24	.43	.45				
P04	.14	.09	.12	.13	.10	.14	.12	.12	.16	.13	.15	.21	.19	.21	.09	.12	.08	.12	.17	.14	.11	.15	.22	.39	.40	.62			
P05	.05	-.03	.07	.06	.04	.03	.02	.04	.12	.12	.13	.16	.17	.18	-.05	.01	-.04	.01	.12	.12	.01	.06	.12	.31	.30	.53	.54		
P06	.02	-.09	.06	.10	.05	.04	-.02	.05	.15	.18	.20	.21	.26	.27	-.21	-.16	-.23	-.11	.20	.17	-.03	.06	.15	.25	.24	.37	.38	.50	
Mean	3.71	4.21	3.61	3.36	3.57	3.56	3.79	3.61	3.27	3.02	2.91	3.11	2.73	2.76	4.12	3.83	3.96	3.79	3.13	3.07	3.90	3.54	3.35	3.13	2.96	2.86	2.85	2.66	2.18
SD	.99	.93	.92	.90	.92	.98	.95	.95	.94	1.12	1.06	.92	1.04	1.03	.98	1.01	1.00	1.04	.93	1.06	1.01	1.05	.94	1.02	1.05	.97	1.00	1.11	1.21
Skewness	-.26	-.94	-.21	.00	-.22	-.25	-.39	-.23	.06	.06	.16	.16	.24	.19	-.81	-.50	-.60	-.43	.02	.01	-.50	-.19	-.08	.01	.06	.13	.11	.26	.72
Kurtosis	-.51	.14	-.34	-.17	-.25	-.39	-.37	-.36	-.29	-.66	-.48	-.11	-.39	-.41	-.24	-.46	-.42	-.59	-.18	-.52	-.58	-.63	-.25	-.42	-.40	-.13	-.25	-.51	-.48

4.2 Exploratory Factor Analysis

The sample adequacy was confirmed by the Kaiser-Meyer-Olkin measure (KMO) for performing EFA. The KMO overall value was 0.92 whereas the individual value of each item was larger than 0.78. These values were greater than 0.5. The correlation of all items demonstrated sufficient adequacy for conducting PAF due to Bartlett's test of sphericity with χ^2 (406) = 7239.29 and a p-value smaller than .001. A five-factor solution was suggested by running a parallel analysis and scree plot, which was reckoned entirely suitable. These five factors incorporated creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving. However, on account of the cut-off point and cross-loading values, one item (A01) was excluded from the Thai CTS instrument. All-item loaded values were greater than 0.4 among all factors. The eventual five-factor illustrated a 52.5% variance. The Cronbach's alpha values for creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving were 0.86, 0.89, 0.83, 0.84, and 0.79, respectively, which presented the reliability of the items as seen in Table 3.

Table 3: Rotated component matrix

Promax rotated factor loadings					
Item	**Creativity**	**Algorithmic Thinking**	**Cooperativity**	**Critical Thinking**	**Problem Solving**
C01	**0.47**	0.00	-0.02	0.05	0.15
C02	**0.43**	-0.05	0.03	-0.05	0.21
C03	**0.82**	-0.02	-0.06	0.04	-0.07
C04	**0.77**	0.16	-0.07	-0.01	-0.15
C05	**0.75**	0.02	0.03	0.02	-0.10
C06	**0.76**	-0.03	-0.01	0.00	-0.04
C07	**0.70**	-0.04	-0.01	-0.06	0.04
C08	**0.52**	0.05	0.11	-0.05	0.07
A02	0.00	**0.82**	-0.07	-0.09	0.06
A03	-0.02	**0.93**	-0.09	-0.06	0.10
A04	0.14	**0.52**	0.09	0.07	0.04
A05	-0.01	**0.75**	0.08	0.05	-0.01
A06	0.00	**0.71**	0.06	0.08	-0.01
T01	0.10	0.05	**0.60**	0.07	-0.03
T02	-0.05	0.27	**0.70**	-0.15	-0.13
T03	0.21	-0.08	**0.60**	-0.12	0.05
T04	0.01	-0.07	**0.75**	-0.04	0.09
T05	0.01	0.02	**0.66**	0.06	0.04

P01	0.09	-0.04	0.17	**0.47**	0.08
P02	0.05	0.03	0.11	**0.42**	0.12
P03	-0.05	-0.07	0.04	**0.78**	0.07
P04	-0.05	0.03	-0.19	**0.79**	0.14
P05	0.01	-0.04	-0.17	**0.79**	-0.10
P06	-0.02	0.08	0.11	**0.56**	-0.39
O01	-0.01	0.01	-0.02	0.00	**0.79**
O02	0.00	0.06	-0.04	0.06	**0.69**
O03	-0.09	0.05	-0.03	-0.01	**0.89**
O04	0.05	0.01	0.18	-0.01	**0.54**
Eigenvalues	3.80	3.18	2.59	2.56	2.55
% of variance	14	11	9	9	9
Cronbach's α	0.86	0.89	0.83	0.84	0.79

Factor loadings over .40 are in ***bold***

4.3 Confirmatory Factor Analysis

The five-factor structure model was verified by CFA. However, six items, e.g., items C01 and C02 of creativity, item T03 of critical thinking, and items P01, P02, and P06 of problem-solving were removed because standardised factor loadings were lower than 0.5, which indicated they were non-significant. The remained factor loadings of measurement items represented as significantly standardized, which ranged from 0.65 to 0.84. The current model was adjusted. Eventually, the fitting indices appeared satisfactory, e.g., χ^2 = 409.72, degree of freedom (df) = 196, χ^2/df = 2.09 which is smaller than 3 (Parsimonious fit), $p < .001$, CFI = .96 which is higher than .94, TLI = .95 which is higher than .94, SRMR = .049 which is less than .08, and RMSEA = .047 which is less than .07 (see Table 4).

Table 4: Model fit indices

Model	df	χ^2	χ^2/df	CFI	TLI	SRMR	RMSEA
Five-factor (from EFA)	340	1187.77	3.49	.87	.86	.078	.071
Modified five-factor (6 items dropped)	196	409.721	2.09	.96	.95	.049	.047
Model	**df**	χ^2	χ^2/df	**CFI**	**TLI**	**SRMR**	**RMSEA**

*TLI = Tucker-Lewis index, CFI = comparative fit index, SRMR = standardised root mean square residual, RMSEA = root mean square error of approximation, ***p < .001*

4.4 Scale Validity and Reliability

Convergent validity was investigated based on AVE value of each construct. They were varied between 0.51 to 0.58, which is slightly higher than 0.50. All the CR values were also higher than 0.60. Thus, the CFA measurement model reliability was earned. Pertaining to the validity, all AVE values were higher than 0.50. Pearson's correlation among all constructs was smaller than the square root of AVE. Therefore, scale validity was also attained (see Table 5). In general, good reliability and validity of the CT scale were gained. Each construct was discrete.

Table 5: CFA Report for every construct in the model

Construct	Item	Factor Loading	CR (Above 0.6)	AVE (Above 0.5)
Creativity	C03	0.72	0.86	0.51
	C04	0.75		
	C05	0.75		
	C06	0.71		
	C07	0.66		
	C08	0.66		
Algorithmic Thinking	A02	0.67	0.89	0.58
	A03	0.77		
	A04	0.76		
	A05	0.82		
	A06	0.79		
Cooperativity	O01	0.77	0.83	0.56
	O02	0.71		
	O03	0.84		
	O04	0.66		
Critical Thinking	T01	0.74	0.81	0.51
	T02	0.70		
	T04	0.67		
	T05	0.71		
Problem-Solving	P03	0.76	0.77	0.53
	P04	0.80		
	P05	0.65		

CR = Composite Reliability, AVE = Average Variance Extracted

5. Discussion

This study aims to adapt Korkmaz CTS into Thai and investigate the validity and reliability. Data were collected from Thai junior high school students in grades 7-9 by using a 29-item questionnaire with a 5-level rating Likert Scale. An exploratory and confirmatory factor analysis was conducted. EFA was evaluated by factor loading and eigenvalues and the results showed that the scale was structurally correct. Subsequently, a CFA was performed to confirm the scale factor structure, which contained five factors resulting from the EFA. The CFA was confirmed, as determined by the chi-square, comparative fit index (CFI), Tucker-Lewis index (TLI), the standardised root mean square residual (SRMR), and the root means square error of approximation (RMSEA). Finally, the reliability and validity were evaluated using the Average Variance Extracted (AVE) and Composite Reliability (CR) values.

From the theoretical framework of Korkmaz et al. (2017), CT consisted of five constructs, e.g., creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving. Creativity refers to a type of ability in producing any creative solutions to a problem. Algorithmic thinking is the ability to proceed in sequence to solve a problem. Cooperativity is the ability to cooperate with different skills in problem-solving. Critical thinking is the ability pertaining to the analysis and assessment-oriented conscious judgments for solving a problem. Problem-solving is the ability to find solutions to problems. The results of the EFA in the current study showed that there were also five dimensions of CT, e.g., creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving. These findings were consistent with the theoretical framework of Korkmaz et al. (2017).

Although the result from EFA showed that there were five constructs, one item, A01, was cut off due to the cut-off point and cross-loading values. This result of our EFA was inconsistent with the research by Korkmaz and Bai (2019) who adapted CTS to the Chinese language and collected data from high school students. Their results showed that nine items were removed. Further, in the current study, six items were removed during the CFA process. Two items were eliminated from the creativity dimension, i.e., item C01 and item C02. One item was removed from the critical thinking dimension, i.e., item T03. Three items were excluded from the problem-solving dimension, i.e., item P01, item P02 and item P06. These findings also showed discrepancies with Korkmaz and Bai (2019). Their elimination of items was different from the current study, probably due to their sample educational level. They used K10-K11 students whereas this research utilised K7-K9 students. However, Thai CTS showed validity and reliability due to the non-violation of convergent and discrimination analyses. In this regard, Thai CTS is suitable for measuring the CT of junior high school students.

6. Conclusion

In this research, Korkmaz CTS was adopted into Thai and its validity and reliability were investigated. The findings suggested that the CTS in terms of Thai adaptation was convincing and was able to measure not only undergraduate and high school students but also junior high school students. The findings of the study offer some implications: First, it contributed to the CT theoretical framework by confirming that CT incorporates five constructs, e.g., creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving. Second, this study added more weight on the reliability and validity of the Korkmaz original CTS and confirmed that CTS can be utilised in order to measure CT at the junior high school level. Therefore, using CTS, schools can measure students' CT faster and with cost-saving. However, there are several limitations to this study. Firstly, the questionnaire measured CT in the form of domain-general, not domain-specific, e.g., computational thinking in computer programming. Second, female participants were more than male because Thai is a collectivistic and feminine culture (Koul, 2018). Third, even though the discriminant validity was accepted, the correlation of the sub-constructs was too high. It almost violated scale validity and reliability. However, this occurred because the scale items of creativity, algorithmic thinking, and critical thinking constructs were quite similar. Finally, this research collected data in Thailand, so the results can be limited to one country only. Thus, it is recommended that future studies may conduct a cross-cultural investigation of CTS scale reliability and validity.

7. References

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Appendix 1 Korkmaz Computational Thinking Scale

English	**Thai**
Creativity	
1. I like the people who are sure of most of their decisions	1. ฉันชอบผู้คนที่มีความมั่นใจในการตัดสินใจของตัวเอง
2. I like the people who are realistic and neutral	2. ฉันชอบผู้คนที่จริงใจและเป็นกลาง
3. I believe that I can solve most of the problems I face if I have sufficient amount of time and if I show effort	3. ฉันเชื่อว่าฉันสามารถแก้ไขปัญหาที่ฉันเผชิญได้มาก ถ้าฉันมีเวลาเพียงพอและใส่ใจ
4. I have a belief that I can solve the problems possible to occur when I encounter with a new situation	4. ฉันมีความเชื่อว่าฉันสามารถแก้ไขปัญหาในสถานการณ์ใหม่ ๆ ได้
5. I trust that I can apply the plan while making it to solve a problem of mine	5. ฉันมั่นใจว่าฉันสามารถทำตามแผนที่ฉันวางไว้ได้และแก้ไขปัญหาของตัวฉันเองได้
6. Dreaming causes my most important projects come to light	6. การฝัน (จินตนาการ) นำพาให้โครงงานของฉันบรรลุได้
7. I trust my intuitions and feelings of "trueness" and "wrongness" when I approach the solution of a problem	7. ฉันเชื่อในสัญชาตญาณของฉันและรับรู้ว่าสิ่งใดถูกหรือผิดเวลาฉันพยายามหาทางแก้ไขปัญหา
8. When I encounter with a problem, I stop before	8. เมื่อฉันเผชิญปัญหา ฉันหยุดเพื่อนึกคิดวิธีแก้ไขปัญหาก่อนไปเรื่องอื่น

proceeding to another subject and think over that problem	
Algorithmic Thinking	
9. I can immediately establish the equity that will give the solution of a problem	9. ฉันสามารถคิดข้อดีข้อเสียของวิธีแก้ไขปัญหาได้ทันที
10. I think that I have a special interest in the mathematical processes	10. ฉันมีความชื่นชอบกระบวนการทางคณิตศาสตร์
11. I think that I learn better the instructions made with the help of mathematical symbols and concepts	11. ฉันถนัดการเรียนการสอนที่ใช้สัญลักษณ์ทางคณิตศาสตร์และแนวคิดทางคณิตศาสตร์
12. I believe that I can easily catch the relation between the figures	12. ฉันเชื่อว่าฉันถนัดในการหาความเชื่อมโยงระหว่างสองสิ่งอย่าง
13. I can mathematically express the solution ways of the problems I face in the daily life	13. ฉันสามารถอธิบายวิธีการแก้ไขปัญหาชีวิตประจำวันด้วยวิธีทางคณิตศาสตร์
14. I can digitize a mathematical problem expressed verbally	14. ฉันสามารถแปลงปัญหาทางคณิตศาสตร์ที่แสดงด้วยวาจาได้
Cooperativity	
15. I like experiencing cooperative learning together with my group of friends	15. ฉันชอบการเรียนรู้แบบร่วมเรียนรู้ไปด้วยกันกับเพื่อนของฉัน
16. In the cooperative learning, I think that I attain/will attain more successful results because I am working in a group	16. ฉันคิดว่าฉันจะประสบความสำเร็จมากกว่าหากฉันได้เรียนรู้แบบร่วมมือกันเป็นกลุ่ม
17. I like solving problems related to group project together with my friends in cooperative learning	17. ฉันชอบแก้ไขปัญหาด้วยกันกับเพื่อน ๆ เวลาทำโครงงานด้วยกันเป็นกลุ่ม
18. More ideas occur in cooperative learning	18. ฉันเชื่อว่าไอเดียจะเกิดขึ้นมากกว่าเวลาทำงานร่วมกันเป็นกลุ่ม
Critical Thinking	
19. I am good at preparing regular plans regarding the solution of the complex problem	19. ฉันเก่งในการจัดเตรียมแผนการแก้ไขปัญหาอยู่เสมอเพื่อรับมือกับปัญหาที่ซับซ้อน
20. It is fun to try to solve the complex problem	20 ฉันสนุกกับการลองแก้ไขปัญหาที่ซับซ้อน
21. I am willing to learn new challenging things	21. ฉันยินดีที่จะเรียนรู้สิ่งใหม่ ๆ ที่ท้าทาย

22. I am proud of being able to think with a great precision	22. ฉันภูมิใจที่สามารถคิดได้อย่างแม่นยำ
23. I make use of a systemic method while comparing the options at my hand and while reaching a decision	23. ฉันใช้วิธีคิดเป็นระบบเวลาเปรียบเทียบตัวเลือกและเวลาตัดสินใจ
Problem Solving	
24. I have problems in the demonstration of the solution of a problem in my mind	24. ฉันมีปัญหาในการแสดงวิธีการแก้ปัญหาในใจ
25. I have problems in the issue of where and how I should use the variables such as X and Y in the solution of a problem	25. ฉันมีปัญหาว่าฉันควรใช้ตัวแปร เช่น X และ Y
26. I cannot apply the solution ways I plan respectively and gradually	26. ฉันไม่สามารถใช้วิธีการแก้ปัญหาทีละขั้นตอนกับปัญหาตามแผนที่ฉันคิดขึ้นได้
27. I cannot produce so many options while thinking of the possible solution ways regarding a problem	27. ฉันไม่สามารถสร้างทางเลือกได้หลายทางเวลาแก้ไขปัญหา
28. I cannot develop my own ideas in the environment of cooperative learning	28. ฉันไม่สามารถสร้างไอเดียของตัวเองได้เวลาแก้ไขปัญหาตอนทำงานเป็นกลุ่ม
29. It tires me to try to learn something together with my group of friends in cooperative learning	29. ฉันเหนื่อยที่จะต้องเรียนรู้ร่วมกันกับเพื่อนเวลาทำงานเป็นกลุ่ม