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The Impact of STEM Attitude and Thinking Style on Computational Thinking Determined via Structural Equation Modeling

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Abstract
This study aimed to investigate the relationships among computational thinking (CT) skills, science, technology, engineering and mathematics (STEM) attitude, and thinking styles with the help of structural equation modeling and to determine to what extent the variables of STEM attitude and thinking styles explained CT skills. The study, conducted with relational screening model, included 703 secondary school students. "STEM attitude scale," "thinking styles scale," and "computational thinking scale" were used as data collection tools. The data were analyzed by structural equation modeling. Based on the study results, it was concluded that the proposed model was valid and STEM attitude and thinking styles had a significant effect on CT skills. It was found that STEM attitude and thinking styles together explained 43% of CT skills.

Keywords Computational thinking · STEM attitude · Thinking styles · Structural equation modeling

Introduction

The present century has witnessed that physical strength is replaced by intellectual and technological power in both individual and global competition. In this competition, training is the shortest way to success. The countries that are aware of this transition have made the required transformations in their education systems in order to educate individuals who are able to pursue lifelong learning, solve problems, think critically, and work productively and collaboratively. With this transformation, the skills that individuals should possess have also changed. One of the important skills that today's individuals should have is the computational thinking (CT).

CT, which has gained high popularity in recent years, is actually a concept that has been discussed for a long time (Grover and Pea, 2013). Wing approached CT in her 2006 study as a fundamental qualification for everyone, not only for computer scientists, and this approach marked the starting point for this concept's popularity. In a later work, Wing (2014) emphasized that CT should be learned by everyone just like reading, writing, and basic mathematical skills. Hsu, Chang and Hung (2018), who called attention to a similar point, regarded CT as a universal skill that should be possessed in everyday life. Many researchers in this field believe that computational thinking is a fundamental twenty-first century literacy that should be acquired by students at all levels of education, from preschool to higher education (Barr and Stephenson 2011; Grover and Pea 2013; Shute et al. 2017). Different tools such as computer-free activities, visual programming, block-based programming, and educational robotics are found to be employed to develop this skill. However, just as there is no consensus on the definition and scope of CT, it is also not clear how best to develop (Pérez-Marín et al. 2020) and to evaluate it (Hsu et al. 2018). Identifying which variables affect CT may help eliminate these questions. Considering their characteristics, it can be argued that STEM attitude and thinking styles may have an impact on CT. In line with this direction, this study aimed to determine to what extent STEM attitude and thinking styles predicted secondary school students' CT skills.

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CT: Definition and Scope

Although it is topic of discussion for many years, no consensus has emerged on the definition of CT (Barr and Stephenson 2011; Grover and Pea 2013; Kalelioglu et al. 2016). Wing (2006) defines CT as formulating a difficult problem in a way that can be solved and draws attention to the fact that the main purpose is not to make people think like computers. Selby and Woollard (2013) regards CT as a combination of abstraction, decomposition, algorithmic design, evaluation, and generalization skills. In a similar approach, Shute et al. (2017) defines CT as a way of thinking and acting with skills such as decomposition, abstraction, generalization, algorithmic design, debugging, and iteration. The concept can be defined as the process of mental activities performed to transform a problem into a form that human or machine can solve (Wing 2011). Kong et al. (2018) stated that it is imperative to provide students with CT skills to ensure educating a generation who can solve problems using technology and creativity.

Although there is no consensus on the definition of CT, the common points highlighted in the definitions are remarkable. Kalelioglu et al. (2016) identified the three most accepted components of CT as abstraction, algorithmic thinking, and problem solving. Korkmaz et al. 2017emphasized that CT skills include the components of creativity, algorithmic thinking, collaboration, critical thinking, problem solving, and communication. Weintrop et al. 2016stated that CT has components such as resolution in working with difficult problems, coping with complex situations, breaking down complex pieces into smaller ones, and making the problem recognizable. While some researchers (Barr et al. 2011; Wing 2006) emphasized that CT is based on the processes of solving, identifying, and formulating problems, Kalelioglu et al. (2016) identified that CT skill is essentially a problem-solving process. Similarly, the operational definition made by International Society for Technology in Education (ISTE) and Computer Science Teachers Association (CSTA) regards CT as a problem-solving process with the following characteristics (ISTE and CSTA 2011):

- Formulating problems to solve problems with computers and other tools.
- Logically organizing and analyzing data.
- Representing data through abstraction such as models and simulations.
- Automating solutions through algorithmic thinking.
- Identifying, analyzing, and implementing possible solutions to ensure the most effective and efficient combination of steps and resources.
- Generalizing and transferring the problem-solving process to a wide range of problems.

Brennan and Resnick (2012) proposed a framework that addressed CT in three dimensions:

1. CT concepts that include learning of programming elements (loops, events, conditions, etc.)
2. CT applications that include CT concepts (reusing and remixing, iterative and incremental, and testing and debugging, etc.)
3. CT perspectives that include students' understanding of themselves, technological world, and their relationship to each other.

Computational thinking is a key skill that contemporary individuals should possess (Román-González et al. 2018; Wing 2016). Individuals with CT skill can solve the problems they encounter in different domains (Barr et al. 2011). It has an important role in educating students as individuals who are equipped to compete in the future world. Researchers argue that CT at all levels of education, from preschool to tertiary education, should be included as a key literacy skill for the twenty-first century (Barr and Stephenson 2011; Grover and Pea 2013; Shute et al. 2017). As a result, CT is included in K-12 education in many countries (Angeli and Valanides 2020; Barr et al. 2011; Grover and Pea 2013; Hsu et al. 2018; Roman-Gonzalez et al. 2017). However, questions have emerged and remain to be answered how this skill can be best provided to students (Pérez-Marín et al. 2020), how to integrate it into the curriculum (Lye and Koh 2014), and how it can be assessed (Hsu et al. 2018).

CT and STEM

STEM is an interdisciplinary approach to solving real-world problems by integrating separate disciplines consistently (Breiner et al. 2012; Gunbatar and Bakirci 2019; Labov et al. 2010; Morrison 2006). This approach guides individuals to solve problems related to daily life by establishing a relationship among science, technology, engineering, and mathematics (Dugger 2010) and enables them to integrate, analyze, interpret, and integrate natural phenomena (Wang 2013). STEM education aims to equip students with twenty-first century skills such as problem solving, logical thinking, communication, critical thinking, and media literacy (Bybee 2010; Morrison 2006). Students' positive attitude towards STEM plays an important role in the acquisition of the skills targeted by STEM education. Hence, identification of STEM attitudes is important in terms of making changes that will increase and support student learning (Mahoney 2010; Tseng et al. 2013).

Computational thinking skills do not only refer to computer sciences, they can be transferred to any field such as mathematics (Bilbao et al. 2017; Luo et al. 2020; Sengupta et al. 2013), science (Luo et al. 2020; Sengupta et al. 2013), biology (Young 2018), engineering (Dagiene and Stupuriene 2016), and many more (Angeli and Valanides 2020; Grover and Pea 2013; Selby and Woollard 2013). In its origin, CT is a concept related to science and mathematics as well as to computer sciences (Bundy 2007). Barr and Stephenson 2011stated that CT has an important role in the development of skills used in science and mathematics such as problem solving, abstraction, algorithmic thinking, creative thinking, logical thinking, and analytical thinking as well as using the basic concepts of information processing and computer sciences. Bilbao et al. (2017) and Dagiene and Stupuriene (2016) emphasized that CT can be particularly useful in mathematics, science, and engineering. While Garcia-Peñalvo and Mendes (2018) and Snodgrass et al. (2016) reported that CT will play an important role in STEM education, research has shown that training with CT tools provides better learning of STEM domains (Repenning et al. 2010; Sengupta et al. 2013; Wilensky and Reisman 2006). As a matter of fact, there are studies conducted to integrate CT skills into science and mathematics curricula (Luo et al. 2020; Sengupta et al. 2013; Swanson et al. 2017). Henderson et al. 2007and Weintrop et al. 2016 stated that CT is at the center of all STEM disciplines, and Cheung (2013) emphasized that CT will lead innovation in STEM fields. Gunbatar and Bakirci (2019) concluded that teacher candidates' CT skills were a factor affecting their intention to teach STEM. Similarly, Batı et al. (2017) indicated that one of the most important twenty-first century skills associated with STEM education is CT. As can be seen, the relationship between CT and STEM has been revealed via previously conducted studies. However, these studies focused on the effect of CT on STEM, and no studies were conducted to investigate the impact of STEM on CT. Weintrop et al. (2016) indicated how CT is used in STEM domains is unclear and pointed out that STEM disciplines can be used to ensure the acquisition of more permanent CT skills. STEM attitude plays an important role in increasing STEM success of students (Faber et al. 2013). STEM attitude can be defined as an individual's thinking, feelings, and behaviors towards STEM. This research sets out to contribute to the literature by determining the impact of STEM attitude on CT.

CT and Thinking Styles

Thinking style is the preferred way that individuals process information in a manner that is more utilizable and appropriate for them (Sternberg and Grigorenko 1993). Thinking styles which are affected by hereditary characteristics and social environment are classified in various categories. Among these, individuals with holistic thinking style prefer to approach the object as a whole instead of looking at separate parts. When persons with analytical thinking styles encounter a problem, they divide the problem into smaller parts first and focus on solving the actual problem by producing solutions to these parts (Dewey 2007).

Research has shown that thinking styles are effective in academic achievement (Holmes et al. 2013) and attitude towards course (Wang and Tseng 2013). Identifying and developing thinking styles is important for the development of twenty-first century skills such as creative thinking, decision making, problem solving, evaluation, and reasoning (Sternberg and Grigorenko 1997). Computational thinking concept is a framework that includes skills such as problem solving, abstraction, algorithmic thinking, reflective thinking, critical thinking, and analytical thinking (Barr and Stephenson 2011; Korkmaz et al. 2017; Wing 2008). Yildiz Durak and Saritepeci (2018) stated that CT skills can be improved more easily and permanently through activities that take students' thinking styles into consideration. In this context, understanding which thinking styles predict CT can provide important information to researchers, educators, and developers. This study aimed to determine how holistic or analytical thinking styles affect CT skill.

Research Hypotheses

With the help of literature review conducted within the scope of the study, the concepts of STEM attitude, thinking style, and CT skill were explained and the relationship among these variables was presented. Based on the theoretical foundations mentioned above, the following hypotheses were developed to test to what extent STEM attitude and thinking style affected CT skills and the rate of explaining each variable:

> H_1: Students' STEM attitudes affect their CT skills positively and significantly.
> H_2: Students' thinking styles affect their CT skills positively and significantly.
> H_3: Together, students' STEM attitudes and thinking styles explain their CT skills significantly.

Method

Research Design

This study aimed to explore the relationship between students' CT skills, STEM attitudes, and thinking styles and to determine the extent to which the variables of STEM attitudes and thinking styles affected CT skills. For this purpose, relational screening model was used in the study. Relational screening model aims to determine the change between two or more variables and the degree of this change (if any) (Karasar 2012). The model, which was developed with the support of the literature, was tested with structural equation modeling (SEM). SEM is the general name of statistical analyses that are used to test observed and latent variables. The main objective of SEM is to test whether a model based on a theoretical basis is compatible with the collected data (Gürbüz and Şahin 2014).

Participants

The study group consisted of 703 secondary school students from 2 different public schools. Of the participants, 49.2% were female ($f = 346$) and 50.8% were male ($f = 357$). Of the students, 30.4% were in fifth grade ($f = 214$), 22.3% in sixth grade ($f = 157$), 21.3% in seventh grade ($f = 150$), and 25.9% of the participants were eighth graders ($f = 182$).

Data Collection Tools

Computational thinking skills scale

Computational thinking skills scale developed by Korkmaz et al. (2017) for university students and adapted by Korkmaz et al. 2015for secondary school students was used in order to identify participants' CT skills. The 5-point Likert-type scale consists of 22 items collected under 5 factors (creativity, algorithmic thinking, cooperativity, critical thinking, problem solving). The items included in factors can be listed as creativity (4 items), algorithmic thinking (4 items), cooperativity (4 items), critical thinking (4 items), and problem solving (6 items). Internal consistency analyses were performed to determine the reliability of the scale. As a result of these analyses, Cronbach alpha coefficient for the overall scale was calculated as .809 while sub-factors were calculated as follows: creativity .640, algorithmic thinking .762, cooperativity .811, critical thinking .714, and problem solving .867. The results of the confirmatory factor analysis demonstrated that the fit indices of the scale model were acceptable [χ^2 (195, $N = 241$) = 448,11,628, $p < .01$, CMIN/DF = 2298 RMSEA = .074, S-RMR = .078, GFI = .89, AGFI = .84, CFI = .91, NNFI = .91, IFI = .90)

Validity and reliability analyses for the CT scale were repeated within the scope of this research, and the results are provided.

Confirmatory Factor Analysis Figure 1 presents the results of the confirmatory factor analysis (CFA) performed to determine whether the original factor structures of the CT scale were validated in the scope of the present research.

The goodness-of-fit values obtained by the CFA regarding the validity of the CT skills scale χ^2[199, $N = 703$] = 456,692; $p < .01$; χ^2/SD = 2295; RMSEA = .043; S-RMR = .035; GFI = .945; AGFI = .930; CFI = .965; NFI = .939; IFI = .965) demonstrate that the proposed 5-factor model is compatible with data and is acceptable (Hu & Bentler, 1999; Kline, 2011; Şimşek, 2007). According to these results, the proposed 5-factor theoretical structure of the CT skills scale was confirmed.

Reliability Analysis The Cronbach alpha internal consistency coefficient was calculated to determine the reliability of the overall CT skills scale and its sub-factors. The internal consistency coefficient of the scale consisting of 22 items and 5 factors was .861 for the whole scale, .822 for creativity sub-factor, .809 for the algorithmic thinking sub-factor, .835 for the cooperativity sub-factor, .794 for critical thinking sub-factor, and .887 for problem solving sub-factor. According to results, it can be argued that the scale is highly reliable.

STEM attitude scale STEM attitude scale developed by Faber et al. (2013) and adapted to Turkish by Yıldırım and Selvi (2015) was used to determine secondary school students' STEM attitudes. The 5-point Likert scale consists of 37 items and 4 factors (mathematics, science, engineering, twenty-first century skills). The items included in factors can be listed as mathematics (8 items), science (9 items), engineering (9 items), and twenty-first century skills (11 items). The Cronbach alpha value of the overall scale was calculated as .94. For sub-factors, the Cronbach alpha value was .89 for mathematics, .86 for science, .86 for engineering, and .89 for twenty-first Century skills. The researchers indicated that the scale was confirmed by the CFA analysis (χ^2/df = 4,72; RMSEA = .063; S-RMR = .053; CFI = .96; GFI = .87; AGFI = .85; NFI = .95; IFI = .95).

Validity and reliability analyses for STEM attitude scale were repeated in this study, and the results are provided.

Confirmatory Factor Analysis Figure 2 presents the results of CFA performed to determine whether the original factor structures of the STEM attitude scale were validated in the context of this study.

The goodness-of-fit values obtained by the CFA regarding the validity of STEM attitude scale (χ^2[620, $N = 703$] = 1862,304; $p < .01$; χ^2/SD = 3004; RMSEA = .053; S-RMR = .0526; GFI = .866; AGFI = .848; CFI = .914; NFI = .877; IFI = .914] suggest that the proposed 4-factor model is compatible with data and is acceptable (Hu and Bentler 1999; Kline 2011; Şimşek 2007). According to these results, the proposed 4-factor theoretical structure for STEM attitude scale was confirmed. Although some items presented low values, a decision was made to keep them in order to keep the content validity of the scale intact.

Reliability Analysis Cronbach alpha internal consistency coefficient was calculated to determine the reliability of the STEM attitude scale and its sub-factors. The internal consistency coefficient of the scale consisting of 37 items and 4 factors was .949 for the overall scale, .826 for the mathematics sub-factor, .871 for the science sub-factor, .905 for engineering sub-

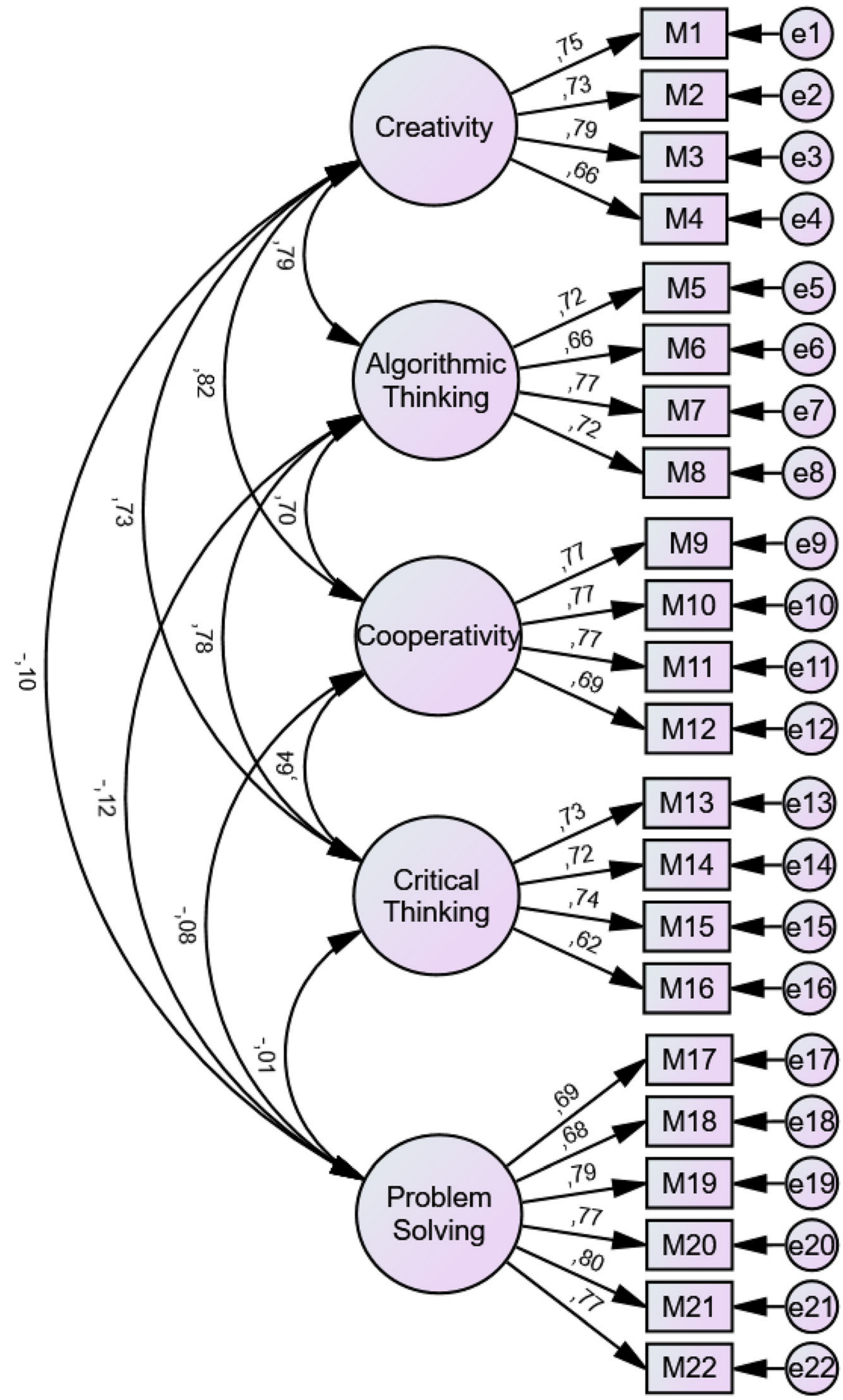


Fig. 1 Confirmatory factor analysis for computational thinking skills scale

factor, and .937 for twenty-first century skills sub-factor. According to these results, it can be argued that the scale is highly reliable.

Thinking Styles Scale Thinking styles scale developed by Arıol (2009) was used to determine participants' holistic and analytical thinking styles. The scale, which consists of a total of 5 items, includes situations for each item that determine holistic and analytical thinking styles and "no idea" option for those who cannot distinguish between these two styles. Participants were asked to mark the option that they regard to be accurate and select the "no idea" option in cases where they cannot distinguish between these two styles. For example, item 2 includes the following expressions: "I generally do not have difficulty in explaining how I solve the problem" (analytical thinking option), "When I am asked to explain how I solve the problem, I usually have difficulty in explaining how I think" (holistic thinking option), and "No

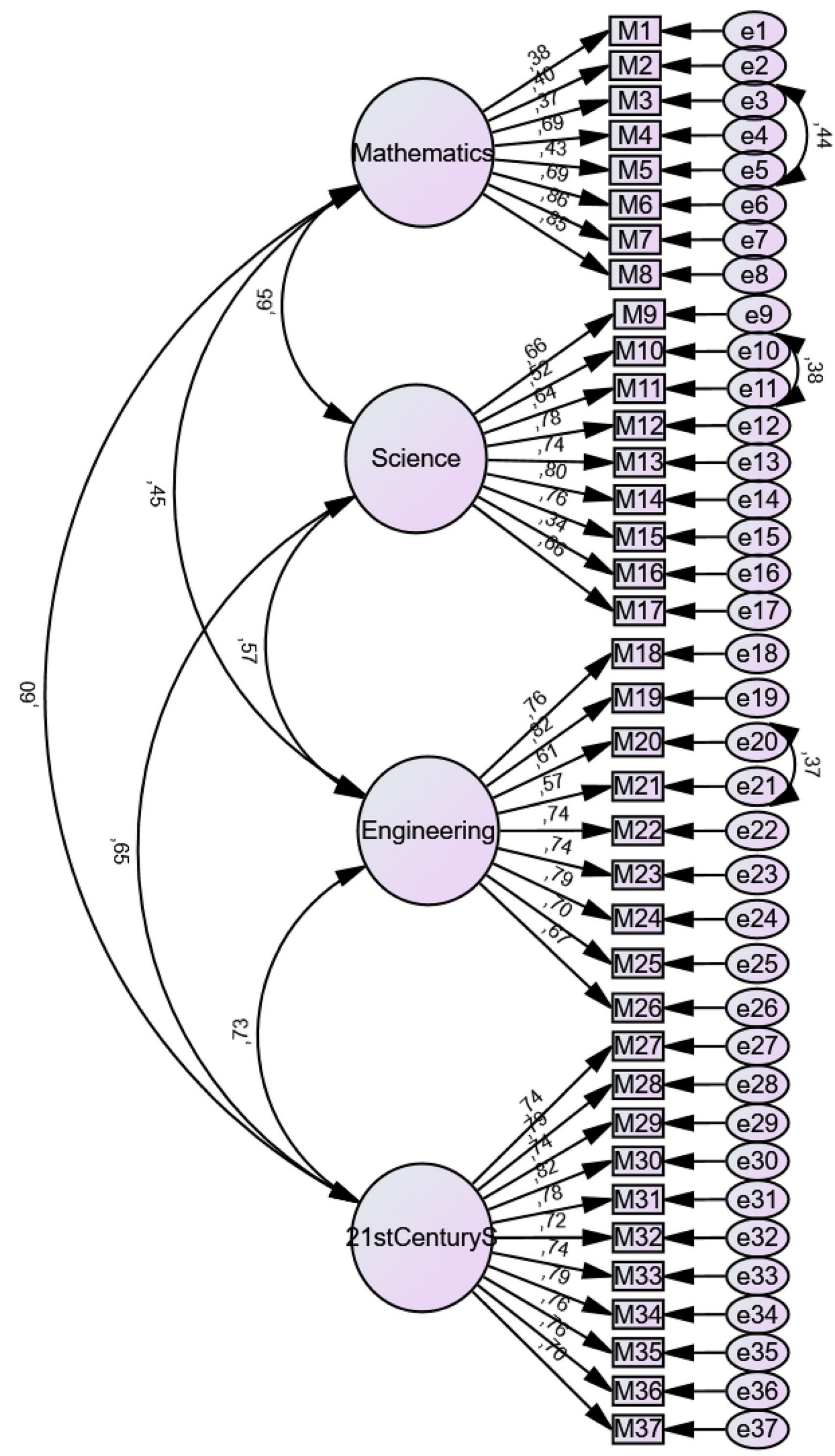


Fig. 2 Confirmatory factor analysis for STEM attitude scale

idea." Answers in the scale were coded in the following manner: 1 point for analytical thinking option, 2 points for no idea option, and 3 points for holistic thinking option. A minimum of 5 and a maximum of 15 points can be obtained from the scale. Student scores that are closer to 5 demonstrate analytical thinking style while scores closer to 15 demonstrate holistic thinking style. Arıol (2009) calculated the reliability coefficient of the scale as .78 as a result of the analysis performed by test-retest method. Expert opinion was sought, and item-total correlation was examined for validity. The scale was originally prepared with 8 items, and the number of items in the scale was reduced to 7 in accordance with the opinion of 18 experts. Following the application with 305 students, 2 items, whose item discrimination indexes were found to be below 0.40, were eliminated from the scale which was then finalized (Arıol 2009).

Validity and reliability analyses of thinking styles scale were repeated in the scope of this research, and the results are provided.

Confirmatory Factor Analysis Figure 3 presents the results of the CFA performed to determine whether the original factor structures of the thinking styles scale were validated in the context of this study.

The goodness-of-fit values obtained by the CFA regarding the validity of the holistic and analytical thinking scale (χ^2[5, N = 703] = 18,782; $p < .01$; χ^2/SD = 3756; RMSEA = .063; S-RMR = .0325; GFI = .989; AGFI = .967; CFI = .863; NFI = .951; IFI = .963) show that the proposed single-factor model is compatible with data and is acceptable (Hu and Bentler 1999; Kline 2011; Şimşek 2007). According to these results, the proposed single-factor theoretical structure of the thinking styles scale was confirmed.

Reliability Analysis Cronbach alpha internal consistency coefficient was calculated to determine the reliability of thinking styles scale. The internal consistency coefficient of the scale consisting of 5 items and a single factor was calculated as .649. This value shows that reliability of the scale is acceptable ($\alpha < 0.5$ unacceptable, $0.5 \le \alpha < 0.6$ poor, $0.6 \le \alpha < 0.7$ acceptable, $0.7 \le \alpha < 0.9$ good, ≥ 0.9 excellent) (George and Mallery, 2003).

Data Analysis

For data analysis, the data were verified first. Frequency distributions, maximum and minimum values were examined, and it was confirmed that the data remained within the specified limits. The missing data analysis conducted subsequently demonstrated that a small amount of data was missing (1%). The small amount of missing data in this study was filled by mean substitution technique based on the recommendation of Lomax and Schumacker (2004). Whether the basic assumptions required for SEM were met was tested prior to the analysis. Since the sample size of the study was more than 200, the recommended sample size for SEM analysis, the assumption for sample size was met (Bayram 2010). For the univariate normality distribution of the data, skewness and kurtosis coefficients for each variable were calculated and it was observed that these values changed in the range of ±2 (Table 1) (Kline 2011).

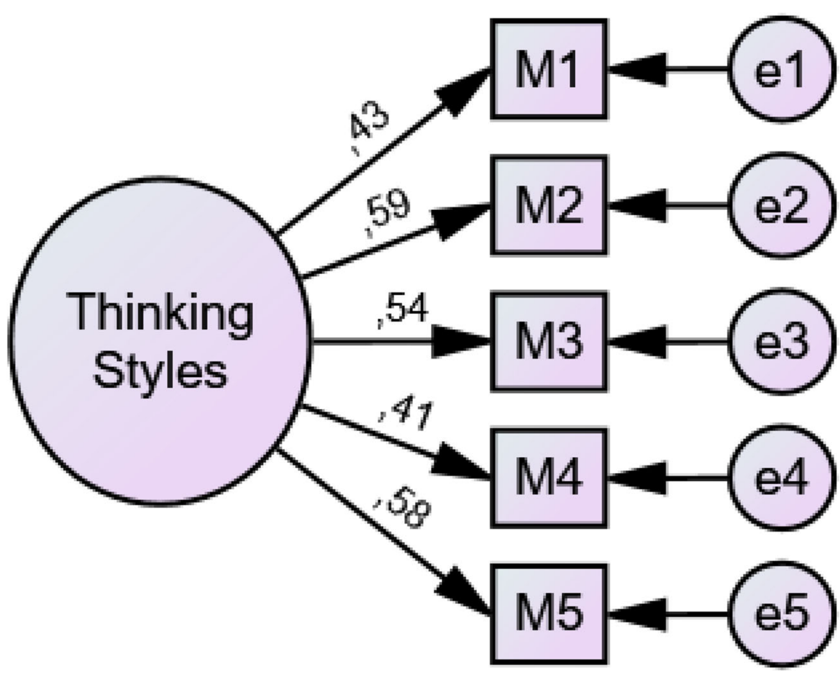


Fig. 3 Confirmatory factor analysis for thinking styles scale

The commonly used two-stage method was used in SEM analysis (Meydan and Şeşen 2011). In the first stage, the valid reliability of the scales included in the model was tested. It was concluded that the original factor structures of the scales were also validated with the data collected within the scope of this research. In the second stage, the relationships between the structures in the model were examined. Maximum likelihood estimation technique was used in the analysis for parameter estimation. At the end of the analysis, χ^2/df, CFI, GFI, TLI, NFI, IFI, RMSEA, and SRMR fit indices were used for evaluating the fit of the model.

Findings

The findings obtained in the framework of this study are presented in two sections. First, descriptive statistics for the variables in the model are given and then the relationships between the variables included in SEM, the rate of explaining each variable, and the findings about the model fit are provided.

Descriptive Statistics for the Variables

Table 1 presents the descriptive statistics for the variables included in the research model.

Table 1 shows that the skewness values of the variables changed between − 1.531 and 1.072 and kurtosis values varied between − 1.217 and 1.858. Based on these values, it can be argued that univariate normality assumption is met (Kline 2011).

Findings Regarding the Model

Figure 4 presents the findings related to the SEM model proposed in this study.

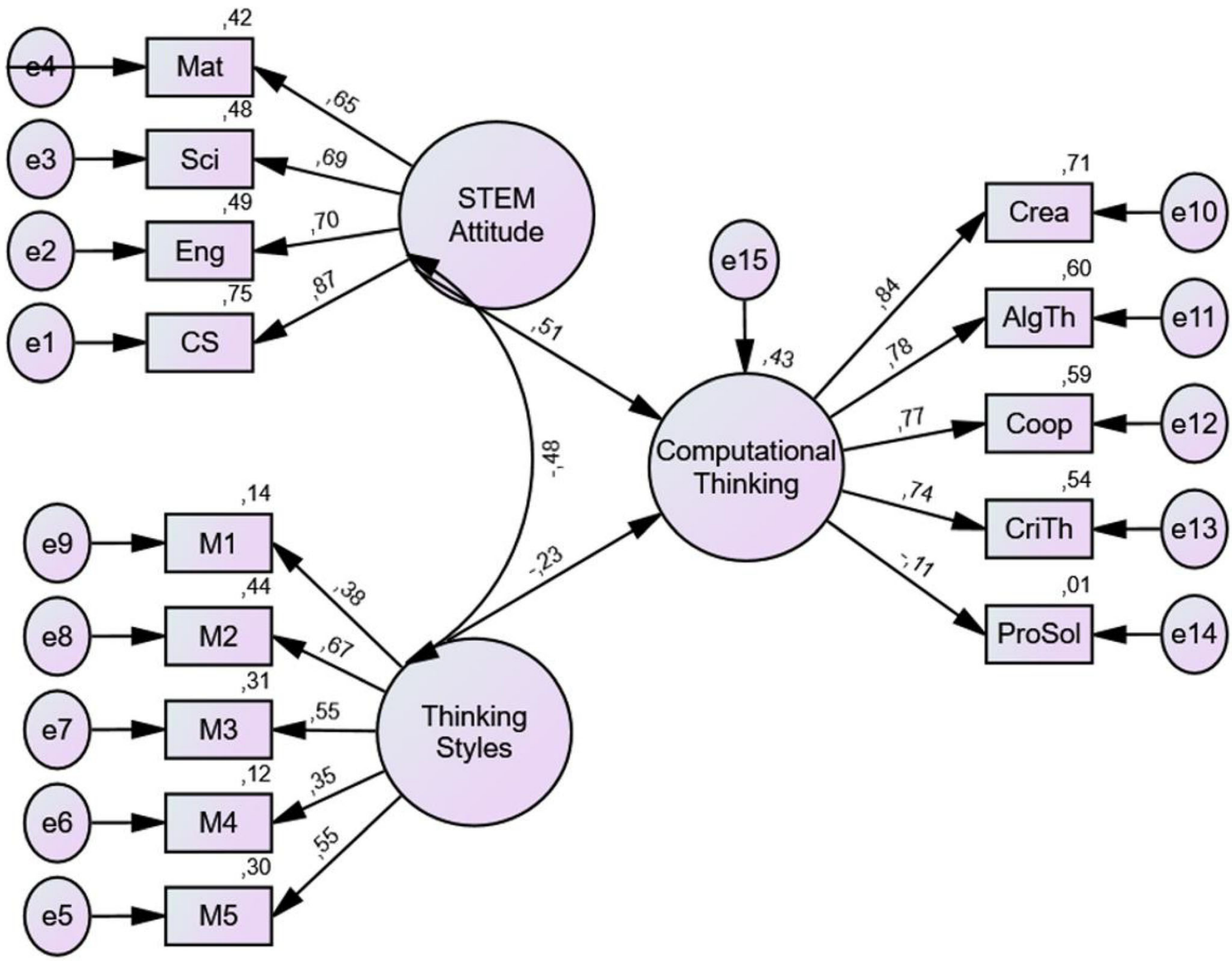
The goodness-of-fit indices calculated as a result of SEM conducted to determine to what extent STEM attitudes and thinking styles affected CT skills were found to be as follows: $\chi^2[74,\ N = 703] = 373{,}692;\ p < .01;\ \chi^2/SD = 5050$; RMSEA = .076; S-RMR = .0325; GFI = .926; AGFI = .895; CFI = .908; NFI = .888; IFI = .908. The obtained fit indices indicate that the measurement model is validated (Hu and Bentler 1999; Kline 2011; Şimşek 2007). Table 2 demonstrates the acceptable, excellent fit values for goodness-of-fit indices, and the obtained values:

As a result of the testing the structural model, it was found that the factor loadings of STEM attitude latent variable were between .42 and .75; the factor loadings of the thinking styles latent variable were between .14 and .44, and the factor loadings of CT latent variable were between .01 and .71. Table 3 presents the SEM results.

Table 3 shows that STEM attitude positively and significantly affected CT skills ($\beta = .51, p < .01$). This result demonstrates that H_1 (Students' STEM attitudes affect CT skills positively and significantly) was confirmed. It was concluded that thinking style negatively and significantly affected CT skills ($\beta = -.23,\ p < .01$). According to this result, H_2 (Students' thinking styles affect CT skills positively and significantly) was rejected. However, since low scores obtained from thinking styles scale point to analytical thinking skills, this result was also significant. On the other hand, it was observed that STEM attitude and thinking style together explained 43% of CT skills. This result confirmed the H_3 hypothesis (Together, students' STEM attitudes and thinking styles together explain CT skills significantly).

Table 1 Descriptive statistics of measurement items

Item	Min	Max	Mean	SD	Skewness	Kurtosis
Mathematics	8	40	30.13	6.86	− .499	− .420
Science	9	45	33.16	7.92	− .592	− .124
Engineering	9	45	31.79	9.40	− .592	− .445
Twenty-first century skills	11	55	41.99	11.10	− .879	.042
Creativity	4	20	16.91	3.74	− 1.531	1.858
Algorithmic thinking	4	20	15.68	3.96	− .852	− .025
Cooperativity	4	20	16.50	4.03	− 1.234	.710
Critical thinking	4	20	15.47	4.10	− .811	− .058
Problem solving	6	30	15.05	7.60	.489	− .926
M1	1	3	1.88	.69	.183	− .878
M2	1	3	1.51	.70	1.072	− .156
M3	1	3	1.76	.73	.438	− 1.009
M4	1	3	1.87	.76	.244	− 1.217
M5	1	3	1.72	.79	.583	− 1.140



Mat: Mathematics, **Sci**: Science, **Eng**: Engineering, **CS**: 21st Century Skills, **Crea**: Creativity, **AlgTh**: Algoritmic thinking, **Coop**: Cooperativity, **CriTh**: Critical thinking, **ProSol**: Problem solving

Fig. 4 The impact of STEM attitude and thinking styles on CT

Table 2 Structural equation model fit indices

Fit values	Good fit values	Acceptable fit values	Values reached
χ^2/SD	$0 \leq \chi^2/SD \leq 3$	$0 \leq \chi^2/SD \leq 5$	5050
RMSEA	0 ≤ RMSEA ≤ .05	.05 < RMSEA ≤ .08	.076
S-RMR	0 ≤ SRMR ≤ .05	.05 ≤ SRMR ≤ .10	.0325
GFI	0.95 ≤ GFI < 1.00	0.90 ≤ GFI < 0.95	.926
AGFI	0.95 ≤ GFI < 1.00	0.90 ≤ GFI < 0.95	.895
CFI	0.95 ≤ CFI < 1.00	0.90 ≤ CFI < 0.95	.908
NFI	0.95 ≤ NFI < 1.00	0.90 ≤ NFI < 0.95	.888
IFI	0.95 ≤ IFI < 1.00	0.90 ≤ <IFI < 0.95	.908

Results

The hypotheses developed in this study which explored the impact of secondary school students' STEM attitudes and thinking styles on their CT skills were tested through SEM. As a result of the research, the model proposed in line with relevant literature was tested and it was concluded that the model was valid. Accordingly, secondary school students' STEM attitudes and thinking styles significantly affected their CT skills.

Based on the obtained results, it can be argued that when the STEM attitudes are more positive, the CT skills will increase as well. Another finding obtained in this study demonstrated that students' thinking style had a significant effect on their CT skills. Accordingly, it can be argued that the increase in analytical thinking style increases CT skills.

Table 3 Standardized regression weight results for the impact of STEM attitude and thinking style on CT skills

Path	Path coefficient (β)	Standardized estimate	Standard error	Critical ratio (CR)	Significance value (p)
STEM attitude ➔ CT	.51	.168	.016	10.601	***
Thinking styles ➔CT	− .23	− 1.595	.356	− 4.484	***

***$p < .01$

Results of the study demonstrated that secondary school students' CT skills were directly affected by STEM attitude and thinking styles. Accordingly, it was concluded that 43% of CT skills were explained by STEM attitude and thinking style. Although this result is significant for literature, it is also observed that 57% of CT is explained by other variables. Further research may identify the other variables that affect CT by including other variables in the model.

Discussion and Recommendations

Wing (2006) describes CT as problem solving, designing systems, and trying to understand human behavior in the light of basic computer science. CSTA (2011) describes CT as a form of thinking that can be used across all disciplines to solve problems, design systems, and create new information. Selby and Woollard (2013), in their study on literature to create a detailed definition of CT, stated that the relationship between problem solving and CT is often emphasized and that the general view that CT is actually a problem-solving activity is widespread. Google 2016describes CT as a problem-solving process involving multiple features and behaviors. Wing (2008) states that he refers to many skills such as problem-solving, creative thinking, algorithmic thinking, and analytical thinking. ISTE (2015) states that CT skill is an expression of algorithmic thinking, creative thinking, problem-solving, critical thinking, collaborative learning, and communication skills. In this context, it is possible to say that CT is an interdisciplinary thinking and problem-solving skill. Similarly, it is emphasized in the literature that stem is also an interdisciplinary approach (Schwartz et al. 2006).

Meyrick (2011) stated that providing STEM training in educational settings would improve twenty-first century skills. Roberts (2012) states that individuals must have twenty-first century skills in order to be able to invent and innovate and that equipping students with these skills can be achieved through STEM education. STEM education is not just an educational approach that focuses on technological innovations. A true STEM education should enable students to understand how things work and improve their use of technology (Bybee 2010). Nowadays, the way to train individuals with twenty-first century skills is through STEM education. In this context, it is possible to say that there are interdisciplinary approaches to both computer thinking skills and stem-related twenty-first century skills. Therefore, it is possible to say that students' attitudes towards STEM and their CT skills are related variables. STEM and CT are among the popular research topics emphasized by researchers in recent years. Many researchers investigated the use of CT on STEM domains (Pollack et al. 2017; Sengupta et al. 2013; Swanson et al. 2017) and its impact (Gunbatar and Bakirci 2019; Repenning et al. 2010; Wilensky and Reisman 2006). Research results exhibited that CT has an important role in STEM education (Batı et al. 2017; Garcia-Peñalvo and Mendes 2018; Henderson et al. 2007; Pollack et al. 2017; Sengupta et al. 2013; Wilensky and Reisman 2006). However, there is a gap in the literature on the impact of STEM attitude on CT. This study concluded that STEM attitude had a significant effect on CT. While CT is a framework that incorporates multiple components, STEM is an interdisciplinary approach, combining different disciplines. The finding that these two concepts, shaped around the twenty-first century skills, affect each other is an expected result. In this respect, it can be said that the tested model is supported by the literature.

In their study, Yildiz Durak and Saritepeci (2018) reported that thinking style is the most important predictor of CT. This result indicates that students' thinking styles should be taken into consideration in the acquisition and development of CT. To ensure that this skill is gained by students, it is very important for teachers to set the necessary learning environments in advance (Hsu et al. 2018). Activities to develop students' analytical thinking skills will positively affect their CT skills. Because according to Dewey (2007) when students with analytical thinking styles encounter a problem, they divide the problem into smaller parts first and focus on solving the actual problem by producing solutions to these parts (Dewey 2007). Identifying and developing thinking styles is important for the development of twenty-first century skills such as creative thinking, decision making, problem solving, evaluation, and reasoning (Sternberg and Grigorenko 1997). In this context, it is possible to say that the analytical thinking style is directly related to CT. In this respect, it can be said that the tested model is supported by the literature.

Based on the results obtained in this research, it can be suggested to undertake curriculum development studies that take STEM attitude and thinking styles into consideration to facilitate acquisition and development of CT skills. In addition, this model can be replicated with different samples to test its validity and generalizability. Considering the impact of analytical thinking style, research can focus on identifying the scope of CT. In addition, studies investigating the effect of CT on different thinking styles can be conducted.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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