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Relationships between Computational Thinking Skills, Ways of Thinking and Demographic Variables: A Structural Equation Modeling

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Abstract

The aim of this study is to determine the extent at which students' computational thinking (CT) skills are explained by certain variables. To this end, the existence of explanatory and predictive relationships between students' CT skills and the variables in question has been examined and Structural Equation Model was employed for building a model in order to establish whether the variables predict students' CT skills or not. A correlational survey method was used in this research and the data collection tools of "Personal Information Form", "Computational Thinking Skills Scale" and "Thinking Ways Scale" were administered to 405 students who were studying in 5th-12th grades in the 2018-2019 academic year in various schools in the Province of Edirne, Turkey. According to the research results, it was determined that CT skill was predicted by different ways of thinking; as well as other variables such as academic achievement in math, science and Information Technology (IT) courses, IT usage experience and level of education.

Introduction

The development in information and communication technologies has led to important changes in many aspects of daily life, including but not limited to economy, social conduct and education. This development process and the resulting changes has caused information to become the most valuable universal asset. The global increase in the value and importance of information has, in turn, enabled societies that are able to access information and use it efficiently to develop faster and become more productive in comparison with others. In this sense, it is emphasized that the strong societies of the future will also be those that are composed of individuals that a) can use appropriate technologies actively and efficiently and with a purpose of accessing the right information in the right context b) can think innovatively, creatively, critically and algorithmically c) have mastered their problem solving skills and d) possess the skills of cognitive flexibility and computational thinking (CT) (Davies, Devin Fidler, & Gorbis, 2011; ISTE, 2015; OECD, 2018; Phillips, Yu, Hameed, & El Akhdary, 2017). Thus, Wing (2006) and Kalelioglu, Gülbahar & Kukul (2016) maintain that, regardless of their age, all individuals forming strong societies, should have alongside their technological competences some basic CT skills aimed at solving the problems they encounter in daily life.

CT skills not only bolster general competencies necessary in daily life but also support the development of learners in different scientific aspects of the field of education and provide the opportunity of evaluating a wide range of information in different areas (Werner, Denner, Campe, & Kawamoto, 2012). Wing (2014) suggests that aside from reading, writing and basic mathematic skills, every individual living in the 21st century should have CT skills. Whereas, Kong (2006) emphasizes the need for the improvement of CT skills for the fostering of a creative generation that can solve problems with technological affordances. On the other hand, it is emphasized that for individuals to be prepared for the world of the future, the acquisition of CT skills is also crucial in terms of management of technologies and the information that can be accessed through these technologies more actively and efficiently (Lee, Mauriello, Ahn, & Bederson, 2014). It is also expressed by many international institutions, establishments and researchers that CT skills is a competence that should be obtained by everyone (Burke, O'Byrne & Kafai, 2016; CSTA, 2011; ISTE & CSTA, 2011; Kim, Kwon & Lee, 2014; NRC, 2010).

The 2023 Education Vision document (MoNE, 2019) of the Turkish Ministry of National Education (MoNE), published in 2019, emphasizes that CT skills are crucial skills for all learners. The importance of giving students an education encompassing programming, coding and integrated STEM approaches has also been emphasized. The purpose for this approach has been rationalized as the need towards the acquisition of production-related

skills alongside skills of data processing. Likewise, in 2017, the curriculums of both the information technologies and the software courses and the computer sciences courses in Turkey were updated. The aim for this was to ensure that students at secondary school acquire CT skills and that they are technology literate and students at high school acquire programming skills, and to raise individuals whose CT skills are improved with the digital competences and programming skills obtained (MoNE, 2017).

Computational Thinking and Components

The concept of Computational Thinking (CT) was first used by Wing (2006), who underlines that it is a rather general concept using the words “CT represents the attitudes and skills, which are not only valid for computer scientists but for everyone.” Even though a consensus on the clear definition of the term has not been reached yet, it is emphasized that CT is based on problem solving processes such as algorithmic thinking, creative, logical thinking, problem solving, understanding the problem and formulating it (Barr, Harrison & Conery, 2011; Brennan & Resnick, 2012; Grover & Pea, 2013; ISTE & CSTA 2011; Wing, 2006). Wing (2014) described CT as a process of thinking, in which computer can be conceptualized efficiently and the problems (as an expression of solutions) are formulated in various ways, so that the boundaries of the concept can be determined clearer and understood better.

Wilensky (2015) defines CT as “*the ability to think with the computer-as-tool*”, while Israel et al. (2015) defines it as the use of computer for the modeling of ideas and the development of programs. In one of the mostly attributed CT definitions in the literature, this concept was defined as “*a common reflection of creativity, algorithmic thinking, critical thinking, problem solving, thinking collusively and communication skills*” (ISTE, 2015). Likewise, whereas Curzon (2015) explains CT as a basic skill that can be described as problem solving for people, Shute, Sun & Asbell-Clarke (2017) define CT as a basic concept, which comprises the active and efficient solution of problems with or without the help of computer and the constant reutilization of the solutions obtained in different contexts. There are many different definitions, which explain the concept CT, prioritizing different viewpoints. When the definitions regarding the concept are examined, CT is found to include many skills and/or properties. These characteristic components, that explain the concept “CT” and were gathered from studies in the literature, were listed in Figure 1.

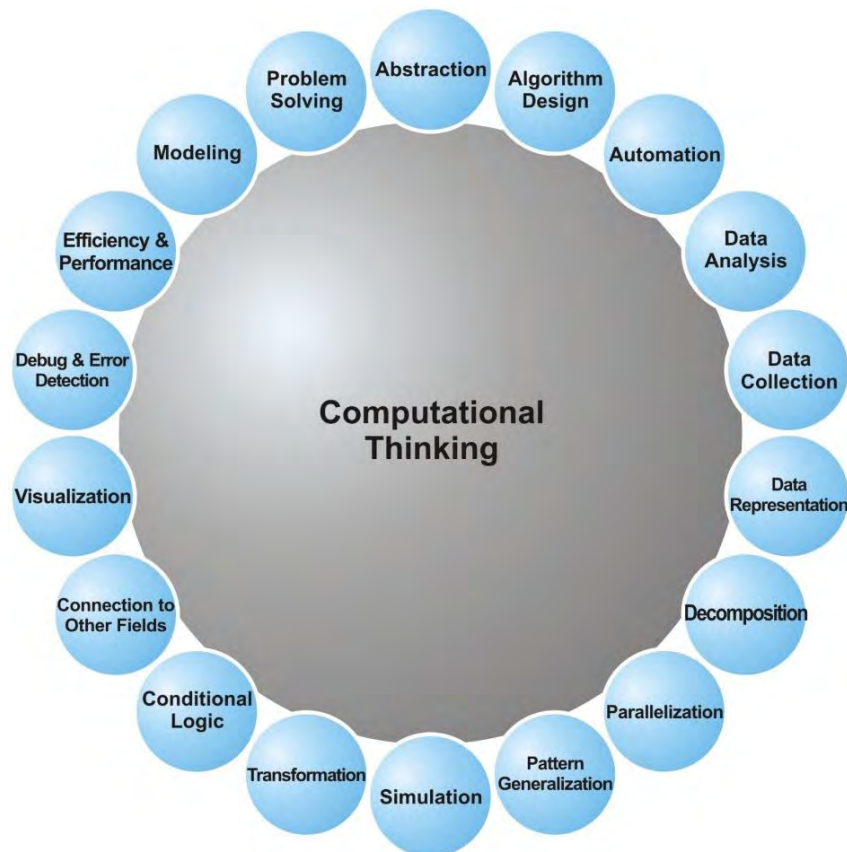


Figure 1. The Components of Computational Thinking (Adapted from: Hsu, Chang, & Hung, 2018)

The Objective of the Research

It is emphasized that the acquisition of CT skills throughout the education process and the determination of the factors effective in the process of skill acquisition [age, educational level (Atmatzidou & Demetriadis, 2016, Juškevičienė & Dagienė, 2018), academic achievement level regarding computer sciences (Allan, Barr, Brylow, & Hambrusch, 2010), academic achievement level regarding the mathematics-science areas (Barr & Stephenson, 2011; Sneider, Stephenson, Schafer, & Flick, 2014; Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013), innovativeness and creativity (Mishra & Yadav, 2013; Repenning et al., 2015), etc.] are very important. Besides, it is frequently expressed in studies that there is need for more work at K5-12 level (Atmatzidou & Demetriadis, 2016; Barcelos & Silveira, 2012; Barr & Stephenson, 2011; Burke et al., 2016; CSTA, 2011; ISTE & CSTA, 2011; Juškevičienė & Dagienė, 2018; Kong, 2006; Yağcı, 2018). In this context, the aim of this study is to determine the extent at which students' CT skills is explained by certain variables such as students' ways of thinking, educational level and average duration of Internet use, as well as academic achievement in math, science and IT courses. To this end, the existence of explanatory and predictive relationships between students' CT skills and these variables has been examined and tests have been carried out to establish whether these variables predict students' CT skills.

Theoretical Background and Research Hypotheses

The Role of Educational Level in terms of CT Skills

It is possible to encounter studies; which indicate that algorithmic thinking, critical thinking, problem solving and abstract thinking skills, are considered to be among CT skills of students and are also related to their cognitive development (Rijke et al., 2018) and that; as the students' cognitive skills increases with each grade level in school, so does their CT skill levels (Atmatzidou & Demetriadis, 2016; Román-González et al., 2017). Researchers relate the increase in CT skill levels alongside school grade level to the directly proportional increase in the individual's abstraction skill together with his/her increasing age (Marini & Case, 1994). This result is explained by references to Piaget's cognitive development theory, which states that an individual continues to develop his/her abstract reasoning skill until the age of 11-12 (Lister, 2011). In studies conducted by Durak & Saritepeci (2018), and Román-González et al. (2017) for the purpose of investigating the effect of change in education level -in other words, in grade level- on CT skills, they revealed that there is a positive relationship between class level and CT skill. In other words, CT skill naturally increases alongside grade level of a student. In another study, Rijke et al. (2018) examined the CT skills of the students between the ages of 8 and 12 and revealed that the skill level increases in direct proportion to age. Even though it was put forth that there is a relation between age and CT skills, only a few studies (Román-González et al., 2017) examining the relation between CT skills and class level were found, showing that there is a need for more studies to establish generalizability. Accordingly, the following hypothesis was put forth in the study:

H1. Students' education level significantly and positively predicts their CT skill levels

The Role of Math and Natural Science Courses in CT Skills

Wing has defined the concept "CT" as the design of systems that serve to help the solution of the problems encountered using the approaches in the fields of mathematics and engineering. This definition indicates that other than computer sciences, there are also mathematics and physical sciences at the root of CT (Bundy, 2007). In other words, it is emphasized that, other than the basic concepts in computer science, skills such as problem solving, abstract thinking, algorithmic thinking (Kafai & Burke, 2013), analytical thinking, abstract thinking, creative thinking, which are all widely used mathematics and science courses play important roles in the solution of the problems encountered (Barr & Stephenson, 2011; Sengupta et al., 2013; Weintrop et al., 2016). Furthermore, the particular ways of thinking associated with the fields of mathematics and science and the ways of thinking peculiar to CT skills support one another (Barcelos & Silveira, 2012; Blikstein & Wilensky, 2009; Felleisen & Krishnamurthi, 2009). Within this scope, in a research conducted by Lewis and Shah (2012), it was revealed that there is a positively correlation between academic achievement states of primary school 4th class students regarding their basic knowledge of mathematics and their CT skill levels. Grover et al. (2015) conducted another research that reveals the relation between the skill of mathematical thinking and CT skills. In this research, 54 secondary school students were trained for 7 weeks with the aim of improving problem solving. Therefore, CT skill and the education attainment realized after the research did not only improve the students' CT performances but also their logical thinking abilities and mathematical skills. On the other hand,

the studies conducted by Durak & Saritepeci (2018), Román-González et al. (2017) and Román-González, Perez-González, Moreno-León, & Robles (2018) revealed that CT performance is an important indicator in predicting academic success in the fields of informatics, mathematics and language learning and that there is a positive correlation between CT performance and academic success. Likewise, Korkmaz, Çakır, Özden, Oluk & Sarioğlu (2015) mentioned that there is a more significant relation between CT skills of students receiving education in the departments of mathematics, science and technology in comparison with students receiving education in other fields. This has helped researchers emphasize the mutual interaction between CT skills and mathematics, science and computer sciences. Within this context, this research also aims to reveal the relation between CT skills and the state of math and science courses academic achievement. From this point forth, the following hypotheses were formed:

H2. Students' academic achievement in the mathematics course significantly and positively predicts their CT skill levels.

H3. Students' academic achievement in the science course significantly and positively predicts their CT skill levels.

The Role of IT Course Academic Achievement in CT Skills

While Wing (2006) defined CT skills as problem solving, system design and understanding of human behavior by utilizing the concepts of computer science, the related literature studies attracted attention to the synergic relation between computer sciences and CT skills (Conde et al., 2017; Juškevičienė & Dagienė, 2018; Korkmaz, Çakır, & Özden, 2017; Sengupta et al., 2013). Likewise, Basu, Biswas & Kinnebrew (2017) emphasized that there is a relation between concepts related to programming such as sorting, cycles and variables and CT skills. While Ioannidou, Bennett, Repenning, Koh, & Basawapatna (2011) stated that CT skills and programming skills are not the same thing, Israel et al. (2015) brought in a different perspective to this comment and emphasized that having a skill of programming provides an advantage in terms of CT skills. In a research conducted to reveal the relation between CT skills and programming skill (Shute, 1991), it was found that the realization of cognitive functions, the definition of the problem and the identification of systematic approaches regarding the solution are the most important precursors of the programming skill. Shute (1991) stresses that CT skills and programming skills are closely related, since these skills, which come into view within the process of the learning of programming are also the basic CT skills. In some other literature studies conducted on the basis of the synergic relation between programming skills and CT skills, it is maintained that the teaching of programming is crucial in terms of the development of CT skills (Werner et al., 2012; Denner, Werner, Campe, & Ortiz, 2014; Koorsse, Cilliers & Calitz, 2015; Lye & Koh, 2014; Pellas & Peroutseas, 2016) and that the teaching of programming makes important contributions to learners regarding the acquisition of CT skills and the improvement of these skills (Kalelioglu & Gülbahar, 2014; Kazakoff, 2015; Kim & Kim, 2016). The following hypothesis was formed in order to reveal the relation between CT skills and IT course academic achievement.

H4. Students' academic achievement in the IT course significantly and positively predicts their CT skill levels.

The Role of IT Usage Experience and Average duration of Internet Use in CT Skills

It is maintained that within the scope of the teaching of CT skills or the improvement of these skill levels, computer science and applications (Shute et al., 2017), especially programming education has an important part (ISTE, 2015; Koorsse et al., 2015; Lye & Koh, 2014; NRC, 2012; Pellas & Peroutseas, 2016; Sariterepeci & Durak, 2017) and that there are multifaceted connections between the digital competences and CT skills of individuals (Gretter & Yadav, 2016; Grizzle et al., 2014; Juškevičienė & Dagienė, 2018; Wilson, Grizzle, Tuazon, Akyempong, & Cheung, 2013). Studies in the literature indicate the positive effect of the CT skills, which an individual can use in the solution of all the problems in his/her life, upon education in the holistic sense. It is therefore considered necessary for all learners to be introduced to computer science and its applications, such as programming, as early in their lives as possible (Barcelos & Silveira, 2012; Kafai & Burke, 2013). Tor & Erden (2004) also indicate that the learners' being introduced to technology at the earliest age possible and likewise the improvement of CT and programming skills at the earliest age possible will help the information obtained by learners become more qualified. On the other hand, Yadav et al. (2011), who emphasize the mutual interaction between CT skills and computer science, maintain that improvement in CT skills may also affect the use of computer science applications in an individual's education process positively. It

is maintained that for the relation between CT skills and IT use experience to be understood better and the generalization of the results obtained from the studies on the body of literature, there is need for more study (Durak & Saritepeci, 2018; Gretter & Yadav, 2016; Pellas & Peroutseas, 2016; Sariterepeci & Durak, 2017).

Studies the literature, which stress the synergic relation between computer sciences and applications and CT skills, also hint at the effects of the frequency of the use of Internet, which is one of today's most widely used technologies as far as the skill is concerned. Even though the limited amount of research conducted indicate that there is no relation between the frequency of internet use and CT skills, it is stated that more studies need to be performed for this phenomenon to be understood better (Durak & Saritepeci, 2018; Oluk & Korkmaz, 2016). Within this context, the following hypothesis was determined in the study:

H5. Students' experience of using IT significantly and positively predicts their CT skill levels.

H6. Students' average duration of Internet use significantly and positively predicts their CT skill levels.

The Role of Ways of Thinking in terms of CT Skills

Theory of Mental Self-Government is the general theory of thinking skills offered by Sternberg and Grigorenko (1997) aimed at explaining thinking skills. The theory draws attention to people's need to manage their actions and activities and indicates that the individual forms the necessary resources, determines his/her boundaries and priorities and shows reaction and resistance to changes within this process. Sternberg and Grigorenko (1997) emphasize that the theory is based on the reflection of the mind, which organizes thinking on the external world and their thinking styles based on theory is defined as the ways of thinking that people choose to use within the process of generating solution to any event or situation.

On the other hand, Sünbül (2004) defines thinking styles as the approaches and tendencies that individuals exhibit following the mental processes they develop to cope with various problems, events, phenomena and variables. While Adak (2006) emphasizes that thinking styles are obtained as a result of individual's interaction with the environment and to a large extent in the learning and socialization processes, Çatalbaş (2006) states that every individual generates different forms of processing data (thinking styles) in his/her interaction with the environment and throughout the process of producing solutions to the problems s/he encounters. As for Parlette & Rae (1993), they define thinking style as an information processing method that the individual realizes with the aim of perceiving the environment and solving the problems s/he encounters within the process of adapting to the environment. They emphasize that the individual uses certain methods and approaches and develops different perspectives regarding the solution of the problem, collects different data, which will lead him/her to the solution, orders these data in different ways, produces different solutions using the data obtained and the solutions produced are put into practice in different ways.

In the studies, where the variables considered to be effective on the students' academic achievement were examined, it was found that the thinking styles that the students used is an important variable (Cano-Garcia & Hughes, 2000; Çatalbaş, 2006; Kaya, 2009; O'Hara & Sternberg, 2000; Sternberg & Grigorenko 1997; Zhang, 2001; 2004) and that there are important relations between thinking style and class level, the duration of the teaching experience and the area of the subject taught (Çatalbaş, 2006; Sternberg & Grigorenko, 1995). Likewise, Desoete, Roeyers & Buysse (2001) revealed in their studies that the students, who have high mathematical performance in problem solving, have higher levels of using metacognitive strategies when compared to others. In this regard, when it is considered that the thinking style peculiar to the field of mathematics bears resemblances to CT in some respects (Barcelos & Silveira, 2012; Blikstein & Wilensky, 2009; Felleisen & Krishnamurthi, 2009; Kafai & Burke, 2013) it is thought that revealing thinking styles that predict CT skills is important in terms of the improvement of skills like creative thinking, decision making and problem solving, which are among 21st century skills (Durak & Saritepeci, 2018). From this point forth, the following hypothesis was established in the study:

H7. Students' ways of thinking significantly and positively predict their CT skill levels.

Method

The goal of this study has been to investigate the nature of relationships between students' CT skills and certain variables, as well as establishing whether or not the said variables predict the skills. It therefore follows a

correlational research design (Creswell, 2008). In this context, a statistical model that explains the predictive relationship between the variables and CT skills has been tested.

Research Model and Hypotheses

The research model, which has been inspired by current scientific literature, has been shown in Figure 2.

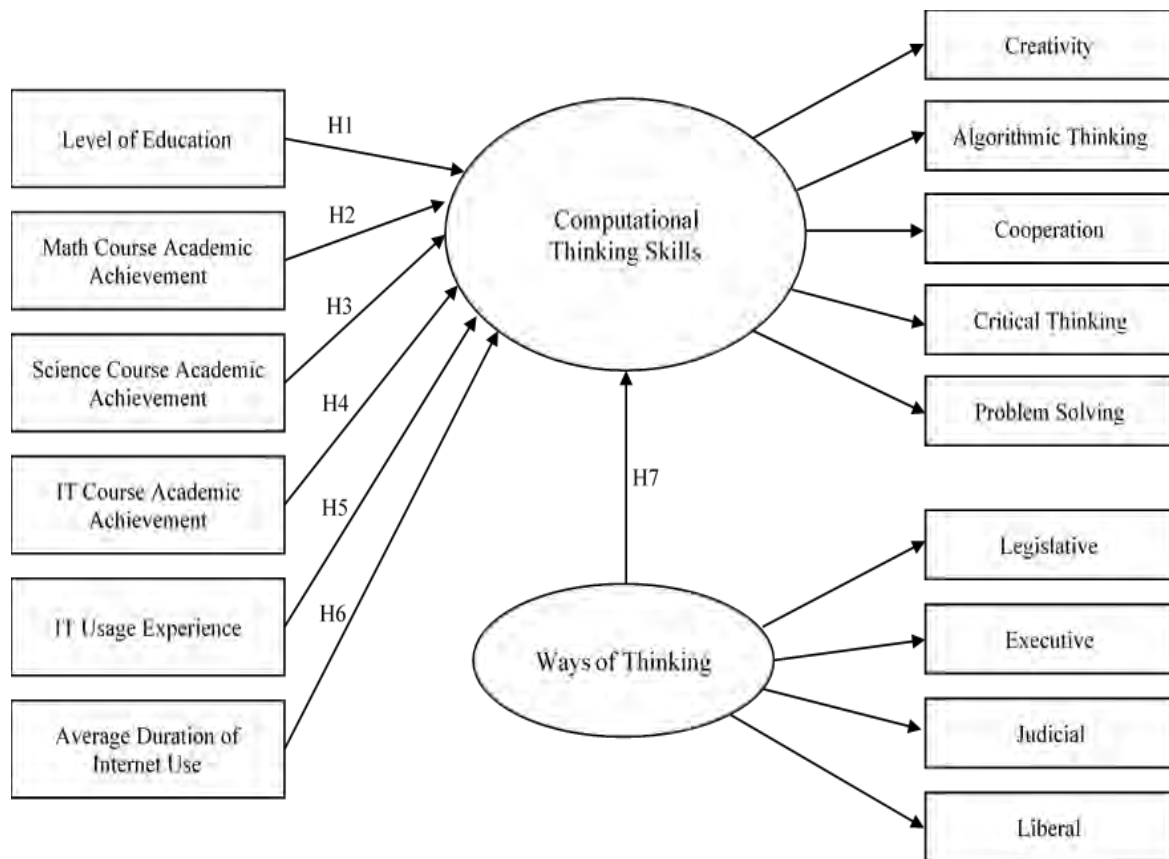


Figure 2. Hypotheses-based Research Model

The research hypotheses of the study were determined as follows:

- H1. Students' education level significantly and positively predicts their CT skill levels
- H2. Students' academic achievement in the mathematics course significantly and positively predicts their CT skill levels.
- H3. Students' academic achievement in the science course significantly and positively predicts their CT skill levels.
- H4. Students' academic achievement in the IT course significantly and positively predicts their CT skill levels.
- H5. Students' experience of using IT significantly and positively predicts their CT skill levels.
- H6. Students' average duration of Internet use significantly and positively predicts their CT skill levels.
- H7. Students' ways of thinking significantly and positively predict their CT skill levels.

Participants and Procedure

As per convenience sampling method, 405 volunteer participants with a mean age of 14.75 (SD=2.14), consisting of students in schools that the researcher managed to gain access to for volunteer recruiting purposes, were selected. Of the participants, 207 (51.1%) were female and 199 (48.9%) were male. The data were collected in 2018-2019 academic year in secondary school (5th, 6th, 7th and 8th grades - 42.7%) and high school (9th, 10th, 11th and 12th grades - 57.3%) levels.

Data Collection Instruments

“Personal Information Questionnaire”, “Computational Thinking Skills Scale” and “Thinking Ways Scale” have been used in the study. Information regarding the instruments has been given below.

Personal Information Questionnaire: A questionnaire developed by the researcher, which consists of 14 items and seeks to gather data pertaining to students’ personal information, means of accessing IT and various ways of using these technologies; as well as previous academic achievement levels in math, science and IT courses. The questionnaire items are of various types but are generally consisting of Likert-type items.

Computational Thinking Scale: The scale, developed by Korkmaz, Çakır & Özden (2015) was used to measure the CT skill of students. The scale consists of 22 items and five factors, namely, “Creativity - 4 items”, “Algorithmic Thinking - 4 items”, “Cooperation - 4 items”, “Critical Thinking - 4 items” and “Problem Solving - 6 items” and participants indicate their opinions on a 5-point Likert scale (Korkmaz, Çakır & Özden, 2015). Cronbach’s alpha reliability coefficient was found as .81 in the original study and in the current study, Cronbach’s alpha reliability coefficient was found as .85.

Ways of Thinking Scale: The scale was developed by Sternberg and Wagner (1992) and adapted to Turkish by Fer (2005). It reveals the dominant way of thinking with 13 ways of thinking and 104 items, all within the scope of five main dimensions (see Table 1). Participants indicate their opinions on a 7-point Likert scale. In this study 32 items were used within Legislative, Executive, Judicial and Liberal thinking ways ($\chi^2/df = 1.013$, RMSEA=.008, SRMR= .0568, GFI=.904, AGFI=.875, NNFI=, CFI=.996, IFI=.996). In the current study, Cronbach’s alpha reliability coefficient was found as .91.

Data Analysis

In this study, descriptive statistics, correlations were performed using SPSS 23 and path analysis was conducted with AMOS 16.0. To evaluate the goodness-of-fit of the path model, chi-square (χ^2) test, RMSEA, SRMR, GFI, AGFI, NNFI, CFI and IFI were used.

Findings

Descriptive Statistics and Correlations Between Study Variables

Means, standard deviations, and correlation matrix for the variables researched are shown in Table 1.

Table 1. Zero-Order Correlations and Descriptive Statistics for Study Variables

Variables	M	SD	1	2	3	4	5	6	7	8
1. Level of education	4.75	2.21								
2. IT usage experience	3.37	1.23	.131**							
3. Average duration of Internet use	3.76	.98	-.033	.038						
4. Academic achievement in the mathematics course	2.96	1.23	.084	.020	-.041					
5. Academic achievement in the science course	3.11	1.21	.054	.093	-.008	.086				
6. Academic achievement in the IT course	3.92	1.01	.121*	.005	-.001	.079	.105*			
7. Ways of Thinking	173.46	8.66	.140**	.100*	.007	.083	.106*	.137**		
8. Computational Thinking Skill	72.80	7.52	.177**	.126*	-.056	.181**	.158**	.117*	.379**	

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

As observed in Table 1, IT usage experience was positively and significantly correlated with level of education ($r = .13$, $p < .01$). In addition, IT course academic achievement was positively and significantly correlated with level of education ($r = .12$, $p < .05$) and science course academic achievement ($r = .11$, $p < .05$).

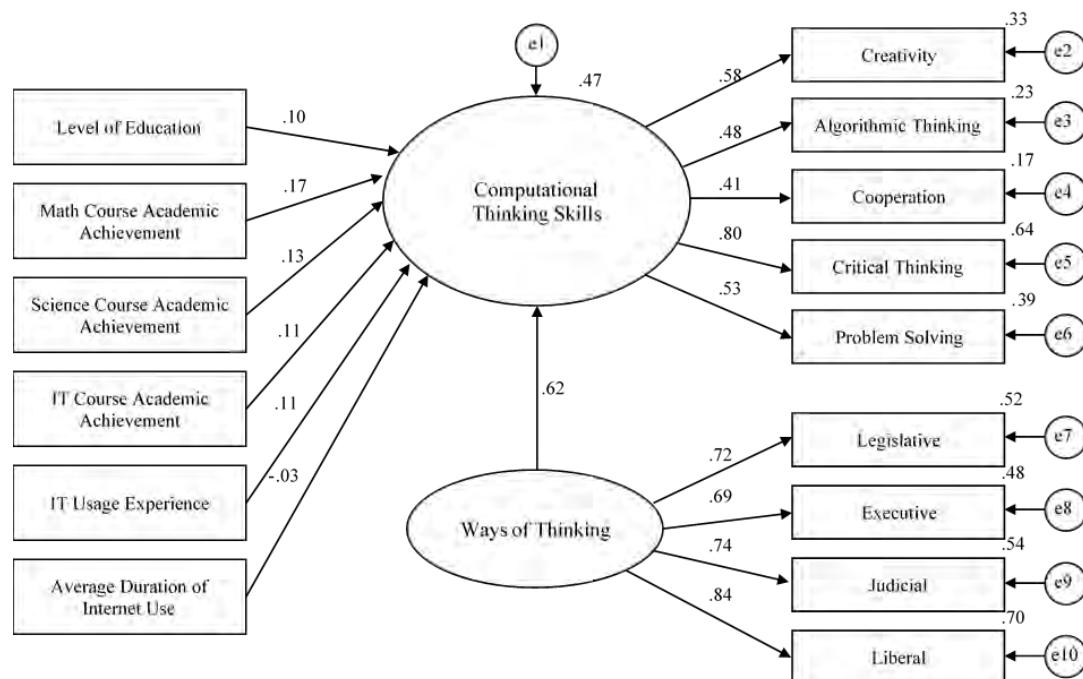
Path Model of Relations between Study Variables

The path model is given in Figure 3. It reflects relations between CT skill, ways of thinking and other variables. Detailed information, including fit indexes and goodness of fit criteria for the model have been presented in Table 2.

Table 2. Values of Goodness of Fit Index

Fit Values	Good Fit Values	Acceptable Fit Values	Values Reached	Reference
χ^2/df	$\chi^2/df \leq 3$	$\chi^2/df \leq 5$	2.212	Kline (2005)
RMSEA	$0 < RMSEA < 0.05$	$RMSEA \leq 0.06$	.055	Hu & Bentler, 1999; Thomson, 2004
SRMR	$0 < SRMR \leq 0.05$	$0.05 < SRMR \leq 0.08$	.068	Brown, 2006; Hu & Bentler, 1999
GFI	$0.95 \leq GFI \leq 1$	$0.90 \leq GFI \leq 0.95$	.937	Hooper, Coughlan & Mullen, 2008
AGFI	$0.90 \leq AGFI \leq 1$	$0.85 \leq AGFI$	.915	Shevlin & Miles 1998
NNFI	$0.95 \leq NNFI \leq 1$	$0.90 \leq NNFI \leq 0.95$	.901	Tabachnick & Fidell, 2001; Thomson, 2004
CFI	$0.95 \leq CFI \leq 1$	$0.90 \leq CFI$	.907	Hu & Bentler, 1999; Tabachnick & Fidell, 2001
IFI	$0.95 \leq IFI \leq 1$	$0.90 \leq IFI$	.908	Hair et al., 2006

Calculated values of the fit indices may be examined to determine the level of competence of a structural equality model, and in this case, indicates that the model fitted the data well (Byrne, 2001; Hu & Bentler, 1999; Schreiber, Nora, Stage, Barlow, & King, 2006). An examination of variables regarding students' computational skill has revealed that the ways of thinking variable had the highest correlation coefficient ($\beta = 0.62$). This was followed by the variable of mathematics course academic achievement ($\beta = 0.17$). CT skill latent variables included 5 sub-factors and "Critical Thinking" sub-factor among these showcased the highest factor load. The variable of "ways of thinking", on the other hand, is comprised of four different ways of thinking, among which the "Liberal" sub-factor showcased the highest factor load. The relative importance order of the predictive variables on the level of CT skill was determined as ways of thinking, math course academic achievement, science course academic achievement, IT course academic achievement, IT usage experience and level of education.



Chi-Square = 196.863 df = 89 p = 0.000

Figure 3. Standard Coefficients of Structural Equation Model

Data shown in Table 3 suggest that:

- *H1 hypothesis stating Students' education level significantly and positively predicts their CT skill levels* was accepted ($\beta = 0.105$; $p < 0.05$). As such, it can be said in general that, as the level of education at K12 increases, so does CT skill levels.
- *H2 hypothesis stating that Students' academic achievement in the mathematics course significantly and positively predicts their CT skill levels* was accepted ($\beta = 0.167$; $p < 0.01$). It can thus be expected that individuals who succeed in a mathematics course to have higher level of CT skills than those who have lower levels of mathematical achievement.
- *Hypothesis H3 stating that Students' academic achievement in the science course significantly and positively predicts their CT skill levels* was accepted ($\beta = 0.133$; $p < 0.05$). Therefore, a significant and positive relationship between the academic achievements of participating students in the natural sciences course with the level of CT skills has been shown to exist.
- *H4. Students' academic achievement in the IT course significantly and positively predicts their CT skill levels* hypothesis was accepted ($\beta = 0.108$; $p < 0.05$). This reveals another significant and positive relationship between academic achievements of participating students in IT-related courses and their level of CT skills.
- *H5. Students' experience of using IT significantly and positively predicts their CT skill levels* hypothesis was accepted ($\beta = 0.108$; $p < 0.05$). This shows yet another significant and positive relationship between the students' experiences of using IT and their level of CT skills.
- *H6. Students' average duration of Internet use significantly and positively predicts their CT skill levels* hypothesis, which is related to average duration of Internet use, has been rejected ($\beta = -0.029$; $p > 0.05$).
- *H7. Students' ways of thinking significantly and positively predict their CT skill levels* hypothesis was accepted ($\beta = 0.622$; $p < 0.01$). Accordingly, the effect of ways of thinking on CT skills has been shown to be at the highest level as compared to the other variables. In addition, it has been determined that there is a positive relationship between each way of thinking and CT skills.

Table 3. Results of the Hypothesis

Hypothesis	Path	β	B	SE	C. R.	p	Supported?
H1	Level of education \rightarrow CT skill	.105	.057	.027	2.141	.032	Yes
H2	Academic achievement in the mathematics course \rightarrow CT skill	.167	.163	.049	3.346	< .001	Yes
H3	Academic achievement in the science course \rightarrow CT skill	.133	.132	.049	2.704	.007	Yes
H4	Academic achievement in the IT course \rightarrow CT skill	.108	.129	.058	2.218	.027	Yes
H5	Experience of using IT \rightarrow CT skill	.108	.106	.048	2.219	.027	Yes
H6	Average duration of Internet use \rightarrow CT skill	-.029	-.035	.059	-.598	.550	No
H7	Ways of thinking \rightarrow CT skill	.622	.138	.017	7.909	< .001	Yes

Discussion and Recommendations

The purpose of this study was to determine the relations between education levels, academic achievements in the mathematics, science and IT courses, experience of using IT, average duration of Internet use, ways of thinking, and CT skills of K12 students. According to the findings of the model analysis, it was revealed that CT skills were highly predicted by ways of thinking. Ways of thinking also was the most effective variable in the prediction of CT skills in the validated model. The highest portion of variation in CT skills was found to be explained by academic achievement in the mathematics course, followed by achievement in science and IT courses, IT usage experience and education level respectively.

It was found that education level predicted CT skill level in a significant and positive way, in other words, that the increase in the class level also increased the CT skill. This finding shows similarities with the results in the body of literature (Durak & Saritepeci, 2018; Román-González et al., 2017). It is thought that in the emergence of this finding, not only the increase in the students' class level but also their digital competences and the increase in their competences and experiences regarding computer sciences were effective. On the other hand, this finding also shows parallelism with the results of the studies, which indicate that cognitive development is

an important factor in the improvement of CT skills (Atmatzidou & Demetriadis, 2016; Basogain et al., 2012; Binkley et al., 2012; Grover & Pea, 2013; Roman-Gonzalez et al., 2017).

In the research, it was found that the variables of the academic achievements in the mathematics and in the science courses predicted the CT skill level significantly and positively, in other words, that the CT skill levels of students who had high grades in mathematics and science courses were higher when compared to those with lower grades. The results of the body of literature are in line with this finding (Barcelos & Silveira, 2012; Blikstein & Wilensky, 2009; Calder, 2010; Durak & Saritepeci, 2018; Felleisen & Krishnamurthi, 2009). Hence, Wing's (2008) comment indicating that CT is a concept, which includes ways of thinking peculiar to the fields of mathematics, science and engineering, supports this finding obtained in the research. NRC (2012), on the other hand, emphasizes the importance of the teaching of CT and mathematics in science education and focuses on the positive relationship between science education and CT skills. Likewise, in another study conducted by Alyahya and Alotaibi (2019), a positive correlation was found between the students' CT skills and TIMSS mathematics achievements. Besides, it was determined that students with high academic success in mathematics and science courses, especially responded in the most positive way to the two articles in the Algorithmic Think sub dimension ("*I can immediately form the equation, which will give the solution of a problem*", "*I think that I learn the expressions made with the help of mathematical symbols and concepts more easily*"), therefore, that these positive opinions were the articles, which increased the CT skill level average the most. This indicates that throughout the solution process of a problem encountered in the emergence of this finding, it may be effective to include similar skills such as problem solving, abstraction, systematic and analytical thinking (Barr & Stephenson, 2011; Sengupta et al., 2013; Weintrop et al., 2016), which are widely used in the fields of mathematics and science. On the other hand, the results obtained by Román-González et al. (2017) and Román-González et al. (2018), which state that CT performance is an important indicator in estimating the academic achievement in the fields of informatics and mathematics, serve to support the obtained finding. For the obtained finding to be understood better, qualitative and quantitative studies are needed.

Another finding of the research indicates that the students' academic achievement in the IT course predicts their CT skill levels significantly and positively and that the increase in the academic success of the computer course also increases the CT skill level. This finding coincides with the result of many studies, which emphasize the importance of the IT course and programming education within the scope of the improvement of CT skills (Barcelos & Silveira, 2012; Denner et al., 2012; Denner et al., 2014; Durak & Saritepeci, 2018; Israel et al., 2015; Kafai & Burke, 2013; Kalelioglu & Gülbahar, 2014; Kazakoff, 2015; Koorsse et al., 2015; Lye & Koh, 2014; NRC, 2012; Pellas & Peroutseas, 2016; Román-González et al., 2018; Shin, Park, & Bae, 2013). It is thought that in the emergence of the related finding, it was effective that the students who are academically more successful in the computer lesson, therefore who have higher programming skills when compared to their peers also have developed thinking skills, which is among CT skills. Because, programming skills are based on competences such as algorithmic thinking, modelling and problem solving. Thus, Kim & Kim (2016) and Kazakoff (2015) also state that the teaching of programming makes significant contributions to the learners regarding the acquisition of CT skills and the improvement of these skills.

The finding that students' CT skill levels are significantly and positively predicted by the variable of experience of using IT, is another finding of the research. This finding obtained shows parallelism with the research result (Durak & Saritepeci, 2018; Juškevičienė & Dagienė, 2018) which emphasizes the mutual relation between the increase in the individual's digital competence and his/her CT skills. On the other hand, in the emergence of the finding that CT skill levels are predicted significantly and positively by the variable experience of using IT, due to the positive correlation between CT skills and computer sciences (Shute et al., 2017), it is considered effective that the students who are more experienced and competent regarding the use of the related technologies have higher CT skills when compared to their peers. Within this scope, Juškevičienė & Dagienė (2018) emphasize that digital competences such as the competence of digital communication and collaboration, information and media literacy and the effective and efficient use of digital content inclusive of the goals have great importance in the acquisition of CT skills and draw attention to the importance of background knowledge and experience regarding the use of IT in obtaining digital competence.

The finding that the variable most strongly predicting students' CT skills is the way of thinking, should be considered important. In the research, it was seen that the Legislative, Executive, Judicial and Liberal sub dimensions of the ways of thinking scale also predicted CT skills. It is thought that students' awareness of thinking styles and using them within the process of problem solving affect the development of their CT skills positively. Thus, Cohen (1998) states that learning thinking styles and designing the necessary processes in this direction will also serve to the increase of skills such as problem solving and abstraction.

In the study, it was found that the variable of Internet use frequency does not predict CT skill in a statistically meaningful way. In other words, this finding indicates that the increase in the frequency of Internet use does not increase the improvement of CT skills. The finding that the Internet use frequency variable does not predict CT skill in a statistically meaningful way also shows similarities with the results of the studies in the body of literature (Durak & Saritepeci, 2018). On the other hand, in another study conducted by Oluk & Korkmaz (2016) aimed at revealing the relation between the frequency of the use of technological tools and CT skills, it was found that there is no relation between daily computer use and CT skills. It is thought that students' not being involved in activities aimed at the improvement of their CT skills in the period they spend using the internet may be effective in the emergence of this finding.

Conclusion

In conclusion, the finding of our study contributes to the research field by exploring the comprehensive effects of education level, academic achievements in the mathematics, science and IT courses, experience of using IT, average duration of Internet and ways of thinking on K12 students' CT skill levels. The positive effect of K12 students' academic achievement in the mathematics, science and IT courses on students' CT skill levels is significant, which confirms the relationship between computational thinking and the skills used in solving problems in mathematics, science and computer science. In addition, level of education and IT usage experience were found to be effective in increasing CT skill levels, which reveals that it is essential for students to acquire digital competence and to be educated at an early age in the context of computer science. Lastly, it was revealed that ways of thinking was the most effective variable in the prediction of CT levels. It is therefore necessary to educate students in ways that foster ways of thinking associated with the successful development of CT skills.

Recommendations

In the research, only the relation between students' success in mathematics, science and IT courses and their CT skills was evaluated. Therefore, in the new studies that will be performed in the field, especially the relation between the academic achievement in the courses related to verbal areas and CT skills may be examined. On the other hand, in the research, only the relation between four thinking styles and CT skills was examined. Within this scope, the relation between different thinking styles and CT skills may be examined in the following studies. Considering the model developed in the context of the research, learning environments aimed at the improvement of CT skills may be designed. The IT course, which appears through the model within the scope of the research and which is proved to affect the improvement of CT skills positively, may be obligated in the secondary and high school curricula.

Besides, due to the relation between the success in science and mathematics and CT skills, which was revealed through the model and supported with the results of the studies in the body of literature, STEM education may be prioritized. For CT skills to develop, activities with or without computers, where students' thinking styles are considered may be developed. On the other hand, for the findings obtained to be generalized considering that students' thinking styles may differ according to their cultures (Bernardo, Zhang, & Callueng, 2002), intercultural comparative studies may be conducted.

Although the current study has revealed the relationship between education level, academic achievement in the mathematics, science and IT courses as well as experience in using IT, average duration of Internet use and ways of thinking of K12 students, several limitations need to be considered. Firstly, the data in this study were collected through convenience sampling method, which could not cover students with different levels of CT skills. In order to determine genuine cause-effect relationships, further research that follows experimental design patterns in examining the effects of certain independent variables and ways of thinking upon CT skills is recommended (Creswell, 2008).

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