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Investigation of the Relationship Between Computational Thinking and Design Thinking Skills of Science Teacher Candidates

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ABSTRACT

Objective: Today's problems, which affect society and the environment, require individuals to have comprehensive skills. In this regard, it is essential to possess Computational Thinking (CT) and Design Thinking (DT) because it encompasses many dimensions and facilitates learning. Since DT processes are production-oriented, they can concretize computational processes that seem abstract to students. Therefore, using DT and CT together can improve both skills' development. However, it is seen that there needs to be a gap in investigating the relationship between CT and the DT skills of science teacher candidates. Therefore, the current research investigated the relationship between CT and DT skills among 94 science teacher candidates in the first and fourth years of their education and whether their skills differed based on grade level. **Method:** For this objective, a relational research model from quantitative research methodologies was utilized to understand whether variables interacted and gain valuable insights. **Results:** The results showed a positive relationship between science teacher candidates' CT and DT skills. Moreover, their skills differed according to grade level. **Novelty**: In this respect, this research contributes to the literature by stating that it could be beneficial to incorporate CT and DT skills in courses designed to acquire these two skills.

INTRODUCTION

In the context of education, it is essential for educators to critically examine various concepts and their interactions with one another, including Computational Thinking (CT) and Design Thinking (DT) skills. While CT and DT skills are often considered separate, they can be used interchangeably in similar situations. Hence, it might be beneficial to consider CT and DT skills together instead of independently. This intersection might align well with 21st-century skills because today's society and the environment require individuals to have more comprehensive skills, emphasizing the importance of a holistic skill set required to address the challenges encountered in the new century (Chalkiadaki, 2018). 21st-century skills that conform to current circumstances and demands can be divided into three categories. The first category includes life and career skills, such as adaptability, accountability, and social interaction. The second category is learning and innovation skills, encompassing critical thinking, collaboration, and problem-solving. The third category is information, media, and technology skills, including information communication technology, media, and information literacy.

Today's students can access information and communicate with each other by using countless technology-based tools at any time. Therefore, information, media, and technology skills are becoming increasingly important. Some scientists declared these skills that 21st-century individuals should have with different terms using different perspectives. One is CT, which includes learning and innovative thinking and information, media, and technology skills. CT has taken place in literature as a way of thinking that will help individuals solve the complex problems of this century (Korkmaz et al., 2015; Şen, 2022). The first use of the CT concept is in Papert's 1996 study and defined as an essential thinking skill that every individual should have, including solving problems, designing systems, understanding human behaviors, reformulating problem-solving processes, and dividing complex problems into manageable chunks. Indeed, it is not just for people in the computer field; on the contrary, it is a multidimensional skill everyone should have. The multidimensional structure of CT could be divided into five dimensions: (1) the ability to use a computer, (2) algorithmic-analytic thinking, (3) creative problem-solving, (4) the ability to collaborate, and (5) critical thinking (Dolmacı & Akhan, 2020; Korkmaz et al., 2017). The multidimensional structure of CT overlaps with the learning and innovative skills of 21st-century skills. The fact that CT overlaps with 21st-century skills and the versatility to integrate various disciplines has enabled CT to become a widely studied field. When literature is examined, the relationship between CT and some 21st-century skills, such as digital competence, creative thinking, and problem-solving are investigated (Boom et al., 2018; Esteve-Mon et al., 2020; Israel-Fishelson et al., 2021; Oluk & Çakır, 2019; Román-González et al., 2017). However, there is a need to examine the relationship between other skills and CT dimensions, which can be beneficial to gain a more comprehensive understanding of CT. Lee et al. (2020) stated that CT could be integrated into various disciplines and is necessary to understand the 21st century. Regarding integrating CT into various disciplines, Shute et al. (2017) defined CT as a way of solving problems that can be used in various contexts and enables the creation of viable solutions. Hence, CT is crucial for every individual in creating solutions to today's interdisciplinary problems. The characteristics of computational processes are also presented in studies (Shute et al., 2017). In 2011, Barr et al. outlined the different aspects of the CT, which include using computers and tools to identify and solve problems, organizing and analyzing data logically, representing data through models and simulations, employing algorithmic thinking to automate problem-solving, exploring potential solutions and selecting the best one, and applying these problem-solving processes to everyday situations. Also, they stated that these aspects of CT should be supported and developed with various skills such as self-confidence and stability, suppressing impatience, managing open-ended problems, and working in cooperation. Therefore, it is significant for individuals to use CT skills to complete these processes effectively. These CT skills are generally instructed via programming activities, which causes students to focus only on codes and makes the learning process difficult.

DT is another term that deals with the competencies individuals need to possess in the 21st century from a different perspective (González-Pérez & Ramírez-Montoya, 2022). DT is identified as a thinking skill that allows individuals to analyze and recognize complicated patterns, generating creative ideas by considering different perspectives (Stephens & Boland, 2014), transform these ideas into products, and cultivate individuals who create solutions and approach situations critically (Girgin, 2019), and enable building relationships between various disciplines. DT has four dimensions: (1) relation, (2) process, (3) individual, and (4) ethics, to analyze. These dimensions represent the characteristics of DT. Relation describes human-product interaction, empathy, and collaborative working; Process represents the approach to procedure, such as being open to taking risks and having a holistic perspective; Individual defines the features of designers, including innovative thinking, being optimistic, critical inquiring, being comfortable with ambiguity; Ethics describes individuals' moral values in the design process (Sürmelioğlu & Erdem, 2021). In addition to dimensions, DT has processes that include defining problems, creating ideas and prototyping, testing, evaluating, and reorganizing (if necessary) (Li & Zhan, 2022; Sung & Kelly, 2019). DT is a user-centered approach, which is spread over the whole process, including teamwork, working collaboratively, empathic perspective, creative thinking abilities, awareness of the process, handling ambiguity, and being open to risks. On the other hand, it is a holistic approach due to its process and thinking dimensions (Schweitzer et al., 2016). Therefore, DT can be seen as a significant component of activities to develop CT skills.

DT studies have increased in the last decade due to enabling the gain of 21st-century skills and having impactful outcomes. Especially in education, DT skills are used through STEM-based activities by presenting problems that enable students to connect different disciplines (Li & Zhan, 2022). Due to the multidimensional nature of STEM-based activities and the engineering design processes of these activities, it is inevitable to use DT in STEM activities. Additionally, it has many contributions to students with the ability to build creative thinking confidence, improve academic achievement, easily understand concepts, facilitate the learning process, increase motivation for the course, and examine and construct various materials; to teachers with the ability to use collaborative, interdisciplinary activities more frequently and to design STEM activities appropriate to students' level (Atacan, 2020; Aydemir & Çetin, 2021; Girgin, 2019; Öztürk & Korkut, 2020; Şahin, 2019). Therefore, DT is an essential element teachers should consider in lesson planning. For this reason, teacher candidates should learn these skills at university and reflect them in their teaching life. Since DT skills are generally integrated into STEM-based activities, using them in science courses is appropriate. Therefore, it is more crucial for science teacher candidates to possess these skills to help students develop their DT skills than other teachers (Li & Zhan, 2022).

Relationship Between Computational Thinking and Design Thinking

CT processes are generally instructed via programming activities, causing students to focus only on codes and making the learning process difficult. Focusing only on the technical aspects when developing students' CT skills via computer-based instruction and not paying attention to how the system works causes these skills not to be fully understood (Saritepeci, 2020). In this regard, DT can facilitate the gaining of CT skills by helping to understand how a system works by providing a holistic approach. Also, DT processes involving visual tools and allowing for tangible results by creating products can enable a better understanding of CT that usually seems abstract to students (Wang et al., 2022). It is stated that to develop DT skills, which have the potential to concretize CT processes by enabling the creation of products, individuals should be in an environment aimed at developing these thinking skills from an early age. Similarly, it is emphasized that it is essential to develop CT skills early to make them grounded and transferable to daily life situations. In this regard, the role of teachers, and therefore teacher candidates, gain importance. Since DT practices are generally integrated into STEM-based activities in teaching, and CT skills are also used in STEM, it is considered appropriate to use these skills within the scope of science education (Günbatar & Bakırcı, 2019; Sarı & Karaşahin, 2020; Wang, 2022). Choi & Kim (2017) noticed that there needs to be a teacher training course integrating DT with CT for teacher education, and they aimed to create a course that integrated DT into a CT course for primary school teachers and interviewed them about this integration. As a result, teachers indicated that the computational process they added to their lesson plans was beneficial during the design thinking process due to CT providing creative prototyping. Additionally, teachers pointed out that CT and DT have things in common: while computing enables the forming of tangible objects, DT fosters building innovative solutions.

Moreover, Kelly Gerro (2021) proposed a framing for CT and DT since these skills often comprehend independently. However, the availability of using DT and CT in similar situations makes them usable in the same settings. Therefore, CT and DT can consider together rather than thinking independently. According to their proposal, although CT and DT have collective features, they are segregated at some points. This segregation is explained by these thinking skills' characteristics and usage in daily life. In this understanding, DT is used in more general situations but with specific solutions; CT is employed in more specific conditions but with general (automated solutions by the abstraction dimension of CT) solutions. Being aware of these differences and integrating these thinking skills in the same settings could be the better way to employ these skills. Additionally, utilizing these differences while integrating CT and DT could make these thinking skills more developable because these differences can complete each other.

Integrating DT into CT processes can lead to innovative approaches that enhance science education. This combination provides a comprehensive understanding of systems and their components, resulting in a more profound comprehension of CT. Furthermore, it helps students grasp scientific concepts more effectively, especially when using project-based learning methodologies that demonstrate the value of possessing both DT and CT skills (Öztürk & Korkut, 2020). Developing CT and DT skills early to transfer them to daily life and be well-grounded is essential. To achieve this, teacher candidates' proficiency in CT and DT skills is essential, and their courses should contribute to developing these skills. Examining the literature reveals a gap in investigating the relationship between CT and DT skills of science teacher candidates. This research aims to close the gap and contribute to the literature by investigating the relationship between CT and DT skills of science teacher candidates at the beginning and end of their education and if there is a difference in their skills according to grade level. In this regard, this research pursues two questions:

1. Is there a relationship between first- and fourth-grade science teacher candidates' CT and DT skills?
2. Is there a significant difference between first- and fourth-grade science teacher candidates' CT and DT skills?

RESEARCH METHOD

The research procedure, displayed in Figure 1, outlines the process followed in this research.

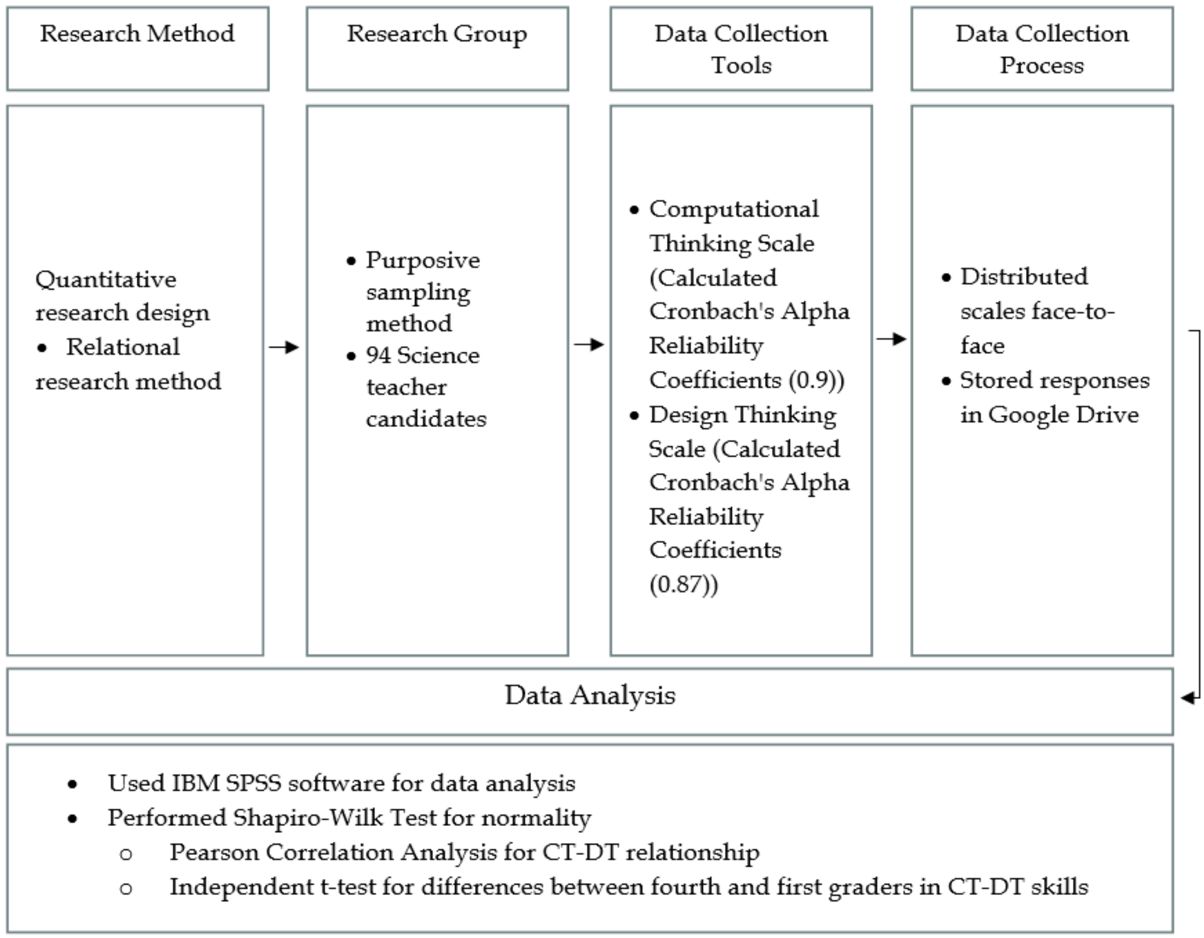

Figure 1. Research procedure.

Research Design

A relational model was utilized as a quantitative research method in this research. The purpose was to examine the relationship between science teacher candidates' CT and DT skills. Relational research seeks to comprehend group characteristics and their differences (Özdemir & Doğruöz, 2021).

Research Group

The research group comprised ninety-four science teacher candidates: 45 first-grade (47.90%) and 44 fourth-grade (52.10%). The purposive sampling technique, a non-random sampling method, selected the participants. In this sampling method, participants are chosen for the sample group not randomly from the research population but based on specific characteristics. Courses aimed at improving first-year science teacher candidates' CT and DT skills are minimal at the university because they take some introductory science courses, such as physics, chemistry, and mathematics, and a few pedagogical courses. Fourth-grade science teacher candidates have taken many pedagogic courses, such as science courses, teaching practice courses, interdisciplinary science teaching courses, science teaching laboratory courses, and technology-related courses that develop students' DT and CT skills (YÖK, 2018). Therefore, there may be some differences between these two groups regarding CT and DT skills. For this purpose, first- and fourth-grade science teacher candidates were selected for the sample group.

Data Collection Instruments

The data were collected using the "Computational Thinking Scale" and "Design Thinking Scale." The Computational Thinking Scale was developed by Dolmacı & Akhan (2020) for university students. It consisted of 40 items in five dimensions: (1) algorithmic-analytical thinking skills, (2) creative problem-solving skills, (3) ability to collaborate, (4) critical thinking, and (5) ability to use a computer. Cronbach's alpha reliability coefficient for the scale is 0.94. Cronbach's alpha reliability coefficients for the scale's dimensions ranged from .74 to .91. The Design Thinking Scale was developed by Sürmelioğlu & Erdem (2021), consisting of 25 items in four dimensions, (1) relationship, (2) process, (3) individual, and (4) ethics. Cronbach's alpha reliability coefficient for the scale is 0.93. Cronbach's alpha reliability coefficients for the scale's dimensions ranged from .81 to .90.

In addition to the values calculated in the scale development studies, Cronbach's alpha reliability coefficients were calculated to determine whether the Computational Thinking Scale and Design Thinking Scale were reliable for the sample group of this research. The Cronbach's alpha reliability coefficient is 0.90 for the Computational Thinking Scale and 0.87 for Design Thinking Scale. The fact that the values obtained are higher than 0.7 indicates that both scales used have high reliability for the sample group.

Data Collection Process

Data were collected face-to-face by distributing the Computational and Design Thinking Scales to the participants. Filling out the scales took between 15-20 minutes. Participants' responses to the scales were stored in Google Drive and analyzed through IBM SPPS software.

Data Analysis

In order to determine the techniques to be used in the data analysis, the Shapiro-Wilk test was first used to test the normal distribution because the number of students in the two groups was less than 50 (45 first and 49 fourth graders). According to Shapiro-Wilk normality test results, first-grade ($p = 0.72$ $p > 0.05$) and fourth-grade ($p = 0.18$ $p > 0.05$) science teacher candidates for the Design Thinking Scale were usually distributed. Similarly, the data collected from first-grade ($p = 0.37$ $p > 0.05$) and fourth-grade ($p = 0.28$ $p > 0.05$) science teacher candidates for the Computational Thinking Scale were generally distributed in Table 1. Since the data had a normal distribution, Pearson Correlation analysis and independent sample t-test were selected to analyze the data from the parametric analysis techniques. Within the scope of current research, Pearson correlation analysis was used to investigate whether there is a relationship between CT and DT skills, and the independent sample t-test was used to determine whether the difference between the means of two independent groups' DT and CT skills is significant.

Table 1. Shapiro-Wilk normality test results.

	Grade Level	Shapiro-Wilk		
		Statistic	***df***	**Sig.**
DT	1st grade	.98	45	.73
	4th grade	.96	48	.18
CT	1st grade	.97	45	.37
	4th grade	.97	48	.28

RESULTS AND DISCUSSION

Results

Pearson correlation analysis was performed to establish whether there is a relationship between the CT and DT skills of first- and fourth-year science teacher candidates. The correlation analysis results indicated a positive and moderate correlation (r = 0.57, $p < 0.01$) between first-year science teacher candidates' CT and DT skills, likely in Table 2.

Table 2. Pearson correlation analysis results of first-year science teacher candidates' CT and DT skills.

		CT	DT
CT	Pearson Correlation	.57**	1
	Sig. (2-tailed)	.01	
	N	45	45

**. p < 0.01

The conclusions of the correlation analysis between the dimensions of first-year science teacher candidates' CT and DT skills. A positive and moderate correlation was revealed between the algorithmic-analytical thinking dimension of CT and the process dimension of DT (r = 0.36, $p < 0.05$). A positive and moderate level relationship was detected between the creative problem-solving dimension of CT and the process (r = 0.61, $p < 0.05$) and individual (r = 0.47, $p < 0.05$) dimensions of DT. A positive and moderate level relationship was found between the cooperation dimension of CT and the relationship dimension of DT (r = 0.36, $p < 0.05$). Similarly, there was a positive and moderate level relationship between the critical thinking dimension of CT and the relationship (r = 0.41, $p < 0.01$), process (r = 0.58, $p < 0.01$), individual (r = 0.42 $p < 0.01$), and ethics (r = 0.44, $p < 0.01$) dimensions of DT (Table 3). Based on the relationships between the dimensions, it is seen that the critical thinking dimension of CT is related to all of the DT dimensions. Therefore, the critical thinking dimension may play a significant role in developing DT skills.

Table 3. Pearson correlation analysis results of first-year science teacher candidates' CT and DT Skills dimensions.

	Dimensions	DT			
		Relation	Process	Individual	Ethics
CT	Ability to use a computer	.26	.08	.23	.28
	Algorithmic-analytical thinking	.03	**.36***	.25	.20
	Creative problem solving	.19	**.61****	**.47****	.20
	Ability to cooperate	**.36***	.25	.18	.21
	Critical thinking	**.41****	**.58****	**.42****	**.44****

**. p < 0.01
*. p < 0.05

The conclusions of the correlation analysis between fourth-grade science teacher candidates' CT and DT skills. It was found that there was a positive and robust level of correlation between CT and DT (r = 0.81, $p < 0.01$) (Table 4). It is seen that the fourth graders gained a deeper understanding of CT and DT skills during their education due to the courses they took.

Table 4. Pearson correlation analysis results of fourth-year science teacher candidates' CT and DT skills.

		CT	DT
CT	Pearson Correlation	1	.81**
	Sig. (2-tailed)		.01
	N	49	48

**p < 0.01

The conclusions of the correlation analysis between the dimensions of fourth-grade science teacher candidates' CT and DT skills. It was found that there was a positive and moderate-level correlation between the ability to use a computer dimension of CT and the relationship ($r = 0.35$, $p < 0.05$), process ($r = 0.42$, $p < 0.01$), and individual ($r = 0.37$, $p < 0.01$) dimensions of DT. The algorithmic-analytical thinking dimension of CT and all dimensions of DT were positive and moderate-level correlated: relationship ($r = 0.52$, $p < 0.01$), process ($r = 0.56$, $p < 0.01$), individual ($r = 0.51$, $p < 0.01$), and ethical ($r = 0.42$, $p < 0.01$). Similarly, a positive and moderate level relationship was discovered between the creative problem-solving dimension of CT and the relationship ($r = 0.400$, $p < 0.01$), process ($r = 0.51$, $p < 0.01$), and individual ($r = 0.68$, $p < 0.01$) dimensions of DT. A positive and moderate-level relationship was revealed between the ability to collaborate dimension of CT and all dimensions of DT: relationship ($r = 0.67$, $p < 0.01$), process ($r = 0.39$, $p < 0.01$), individual ($r = 0.37$, $p < 0.01$), ethical ($r = 0.38$, $p < 0.01$). Lastly, a positive and moderate-level relationship was detected between the critical thinking dimension of CT and the relationship ($r = 0.35$, $p < 0.05$), process ($r = 0.41$, $p < 0.01$), and individual ($r = 0.58$, $p < 0.01$) dimensions of DT (Table 5). Almost all CT and DT skills dimensions are interrelated in analyzing the relationships between the dimensions. However, the ethical dimension of DT was only related to the algorithmic-analytical thinking and ability to collaborate dimension of CT. The results indicate that fourth-grade science teacher candidates do not associate the ability to use a computer, creative problem-solving, and critical thinking practices with ethics at a significant level.

Table 5. Pearson correlation analysis results of fourth-year science teacher candidates' CT and DT skills dimensions.

Dimensions		DT			
		Relation	**Process**	**Individual**	**Ethics**
CT	Ability to use a computer	**.35***	**.42****	**.37****	.21
	Algorithmic-analytical thinking	**.52****	**.56****	**.51****	**.42****
	Creative problem solving	**.40****	**.53****	**.68****	.24
	Ability to cooperate	**.67****	**.39****	**.37****	**.38****
	Critical thinking	**.35***	**.41****	**.58****	.23

**. p < 0.01

*. p < 0.05

An independent sample t-test analysis was performed to deduce whether there was a difference between first- and fourth-year science teacher candidates' CT and DT skills. A significant difference was revealed between first- and fourth-grade science teacher candidates' CT skills; a significant difference was in favor of fourth graders ($p < 0.01$). Similarly, a significant difference was discovered between first- and fourth-grade science teacher candidates' DT skills; a significant difference was favored by fourth graders ($p < 0.01$) in Table 6. Accordingly, fourth-grade science teacher candidates have better CT and DT skills than first-grade students. It could be due to the grade level and education they received throughout the four years.

Table 6. Independent t-test results of CT and DT skills.

	Groups	*N*	*M*	*SD*	t-test	
					t	*p*
CT	1st Grade	45	3.79	.36	-3.87	**.01**
	4th Grade	49	4.09	.39		
DT	1st Grade	45	3.78	.42	-3.43	**.01**
	4th Grade	48	4.11	.76		

Table 7 presents the t-test results, the difference between first- and fourth-grade students' CT and DT skills dimensions. There was a significant level difference between first- and fourth-year science teacher candidates' CT skills dimensions of ability to use a computer ($p < 0.01$), algorithmic-analytical thinking ($p < 0.01$), and critical thinking ($p = 0.05$) in favor of fourth graders. This finding may indicate that science teacher candidates in the fourth grade consider themselves more competent in technical subjects, and courses they took during their education may help them improve their technical skills. Among the dimensions of CT skills, there are also dimensions in which there is no significant level difference between first- and fourth-year students. While the mean of the creative problem-solving dimension was $\bar{x} = 3.82$ for first graders, it was $\bar{x} = 4.06$ for fourth graders. Although there is no significant difference in the creative problem-solving dimension, the average of the fourth graders is higher than the first graders.

Similarly, there is no significant relation between the first ($\bar{x} = 3.74$) and fourth ($\bar{x} = 3.79$) graders in the ability to collaborate dimension of CT. Additionally, the ability to collaborate dimension averages were lower than the others. Therefore, it is possible to argue that science teacher candidates' collaboration skill is less developed than other skills, and the content for developing this skill during their education may be inadequate. Lastly, a significant level difference was discovered favoring fourth graders in the process ($p = 0.02$) and the individual dimension of DT ($p < 0.001$). This finding may be because fourth-grade students have received education for longer than first-grade students. Since fourth-year students are in the last year of their education, they may have had more opportunities to develop proficiency, such as a holistic perspective and creative confidence, under the process dimension through their courses. For example, the Community Service Practices course may have contributed to developing both the individual and the process dimensions since it enabled students to create a project by thinking about society.

Table 7. Independent t-test results of CT-DT scale dimensions.

Variables	Dimensions	Groups	*N*	*M*	*SD*	t-test	
						t	*p*
CT	Ability to use a computer	1st Grade	45	3.90	.49	-5.08	**.01**
		4th Grade	49	4.44	.53		
	Algorithmic-analytical thinking	1st Grade	45	3.64	.48	-4.46	**.01**
		4th Grade	49	4.07	.44		
	Creative problem solving	1st Grade	45	3.82	.49	-2.28	.025
		4th Grade	49	4.06	.52		
	Ability to cooperate	1st Grade	45	3.74	.60	-.35	.722
		4th Grade	49	3.79	.88		
	Critical thinking	1st Grade	45	4.05	.49	-2.86	**.05**
		4th Grade	49	4.35	.53		
DT	Relation	1st Grade	45	3.75	.49	-1.74	.085
		4th Grade	48	3.95	.58		
	Process	1st Grade	45	3.67	.61	-3.18	**.02**
		4th Grade	48	4.07	.60		
	Individual	1st Grade	45	3.81	.63	-3.59	**.01**
		4th Grade	48	4.25	.53		
	Ethics	1st Grade	45	3.99	.58	-2.58	.011
		4th Grade	48	4.31	.59		

Discussion

Relationship between CT and DT Skills

In this research, the first research question was "Is there a relationship between first- and fourth-grade science teacher candidates' CT and DT skills?" and it was found that there was a moderate positive relationship between CT and DT skills in first-grade science teacher candidates and a strong positive relationship in fourth-grade science teacher candidates. CT is an essential skill for problem-solving and can be integrated into many disciplines, including design-oriented processes (Psycharis, 2018). This flexibility provided by CT might explain the relationship between CT and DT skills. Similarly, in Choi & Kim's study (2017), teachers indicated that CT and DT share similarities. While computing allows for the creating of physical objects, DT encourages the development of new and creative solutions.

Moreover, there are common points of the practices to equip students with CT and DT skills. CT skills are generally developed through activities such as coding (Akçay et al., 2019), visual programming (Atman-Uslu et al., 2018; Oluk et al., 2018), robotics (Jaipal-Jamani & Angeli, 2017; Korkmaz et al., 2020). DT skills are developed through activities that build discipline relationships by presenting problem situations and STEM-based activities (Li & Zhan, 2022). Also, it is seen that DT skills are structured by utilizing engineering design processes (Kewalramani et al., 2020) and using technological environments in the product creation process (Lin et al., 2020). Thus, the educational processes in the studies conducted for acquiring CT and DT skills have common points, such as project development, problem-solving, using different disciplines, and design processes, which may explain the relationship between these skills. This relationship revealed within the scope of this research can provide a perspective on the use of CT and DT skills together. Additionally, it may offer a new understanding of utilizing design-based processes such as product creation used in developing DT skills in the acquisition of CT skills and utilizing computational processes in the acquisition of DT skills and developing both skills together.

Difference between First- and Fourth-Grade Science Teacher Candidates' CT and DT Skills

The second research question was, "Is there a significant difference between first- and fourth-grade science teacher candidates' CT and DT skills?". The findings revealed significant differences between first- and fourth-grade science teacher candidates. The relationship between CT and DT skills of the fourth graders was strong, while the relationship was moderate in the first graders. Additionally, the CT and DT skills of the fourth graders were significantly different from those of the first graders, and this difference was in favor of the fourth graders. Similarly, differences in the dimensions of CT and DT skills in favor of the fourth graders. This result arising from the grade level is in parallel with earlier studies. Similarly, Kuleli (2018) found a significant difference between the computational thinking skills of first- and fourth-grade science teacher candidates in favor of fourth-grade. Also, Korucu et al. (2017) found that computational thinking skills significantly differed by grade level. Furthermore, Çakır et al. (2021) found that fourth-grade science teacher candidates' skill levels were significantly better than first graders. They especially found this difference in Creative Problem Solving and Algorithmic Thinking dimensions. Similarly, in this research, fourth-grade science teacher candidates were significantly better than first-graders in the scope of Algorithmic Thinking. However, in this research, a significant difference was not found in the Creative Problem Solving dimension, although fourth graders mean higher than first graders. These differences may arise from fourth-grade science teacher candidates who have taken more courses on developing these skills than first-grade science teacher candidates. The courses taken by fourth-grade students, such as Instructional Technologies, Interdisciplinary Science Teaching, and Laboratory Applications, can enable the development of these skills due to their content. On the contrary, first-grade science teacher candidates have just completed secondary education, have taken courses aimed at building a theoretical background rather than courses aimed at developing CT and DT skills, and have generally been taught conservatively.

The dimensions of CT and DT have some common points. The Individual dimension of DT and the Critical Thinking of CT have similar standpoints regarding the characteristics of these skills. For instance, the Individual dimension of DT includes critical inquiry; similarly, the critical thinking dimension of CT conveys the same intention. These dimensions can be seen in fourth graders' courses, such as Laboratory Applications, Interdisciplinary Science Teaching, and Instructional Technology. It is known that laboratory applications enhance learners' critical thinking (Setiawan et al., 2018), and fourth-grade science teacher candidates took more lab courses than first graders. Correspondingly, the Interdisciplinary Science Teaching course provides learners with a broad perspective while teaching science. Additionally, the Instructional Technology course ensures learners' critical approach while determining appropriate technologies integration into education. Since the Individual and Critical dimensions of DT and CT can be seen in these courses, fourth-year students might be statistically better than first-year students.

Moreover, the Relation dimension of DT and the Ability to Collaborate dimension of CT are similar since both dimensions target collaboration (Tsortanidou et al., 2019). Although fourth graders score more than first graders, there is no statistical difference between first and fourth graders. This result could arise due to the need for more environment or course content regarding the collaboration of science teacher candidates. This lack of collaboration in science education or general teacher education programs (Aksoy & Gözütok, 2017) can explain why fourth graders are not statistically better than first graders in the Relation and ability to collaborate dimensions of DT and CT.

CONCLUSION

Fundamental Finding: In this research, two questions, “any relationship between first- and fourth-grade science teacher candidates' CT and DT skills," and "whether there was a difference between first- and fourth-grade science teacher candidates' CT and DT skills," were investigated. Consequently, it was found that there was a moderate positive relationship between CT and DT skills in first-grade science teacher candidates and a strong positive relationship in fourth-grade science teacher candidates. When teacher candidates' CT and DT skills are examined regarding grade level, statistically significant differences were found in favor of science teacher candidates in the last grade of their education. **Limitation:** However, this research also had a limitation; the data collection tools involved many questions, which may have led to respondent fatigue and a decrease in the quality of their answers. **Implication:** Results obtained within this research are significant by revealing a relationship between computational thinking and design thinking skills and showing that these skills might be used together and support the development of both skills. **Future Research:** Future research can consider this relationship, support computational processes that seem abstract to students with design thinking skills, and examine their effect on advancing computational thinking skills. Additionally, differences between students who have just begun their education and those in their last year of education reveal the significance of the courses' content in the educational processes. For this reason, curriculum developers may consider integrating the skills required by the new century into the course content and incorporating these skills into the curriculum of science teacher candidates from the early stage of their education.

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