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Research Article

The relationship between the 21st-century skills and computational thinking skills of prospective mathematics and science teachers

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This study aimed to determine the strength of the relationship between 21st-century skills and the computational thinking skill levels of prospective teachers, as well as the affect of 21st-century skills on computational thinking. This study adopted a correlational design as part of a quantitative methodology. The study sample consists of 300 prospective teachers, selected using purposive sampling. Multidimensional 21st Century Skills and Computational Thinking scales were used as data collection tools. The results revealed that the 21st-century skill components of prospective teachers did not differ by department; however, relationships were found with gender, grade level, and academic achievement. Additionally, a significant correlation was identified between department, gender, grade level, and academic achievement in relation to the components of computational thinking skills. A significant positive correlation was found between 21st-century skill components and computational thinking skill levels, with the 21st-century skill components of prospective teachers significantly influencing their computational thinking levels. As prospective teachers' information and technology literacy, critical thinking and problem solving, entrepreneurship, innovation, social responsibility and leadership skills increase, their computational thinking levels also increase. It was recommended that prospective teachers' awareness of the importance of 21st-century skills be enhanced, and that mathematics and science curricula be designed to incorporate future-oriented skills.

Keywords: Computational thinking; Mathematics teacher; Science teacher; 21st-century skills

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1. Introduction

Although skill has been considered essential throughout history, in the century in which we are only living in the first quarter, developing more complex skills and using them effectively has become inevitable, unlike in the past. To keep up with the digital transformations that reorganize social understandings, raising individuals equipped with high-level cognitive skills is necessary and, more importantly, to make this sustainable (Organisation for Economic Cooperation and Development [OECD], 2023). This is because the vision of the 21st-century information society is built on a more dynamic, fluid, and competitive structure than in past societies (Leopold et al.,

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2018). Therefore, as technology advances inevitably, nations must move beyond their static forms and evolve into skill-based ecosystems that can adapt to change. According to Trilling and Fadel (2009), 21st-century skills expected from individuals interact dynamically. Therefore, rather than providing individuals with memorized information, this approach aims to equip them with skills they can use throughout their lives (Binkley et al., 2012). Rapid social, economic, and technological changes, particularly over the last thirty years, have influenced social trends and educational systems that prepare individuals for future careers. To address emerging needs, reports have defined essential skills, and frameworks or application strategies have been developed (Voogt & Roblin, 2012). Today, these skills are referred to as 21st-century skills.

An essential component of modern education is the ability to demonstrate computational thinking [CT]. The origin of CT, a cognitive skill that supports effective problem-solving, can be traced back to Papert's (1980) book on child education with Logo. He believed that powerful computational technology and ideas would offer transformative opportunities for student learning. He summarized this as follows: "…the child programs the computer, and in doing so both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science to mathematics…" (p. 5). To expand CT to fit the increasingly computational nature of modern sciences, Weintrop et al. (2016) developed a taxonomy that divides CT into four main categories: data handling, modeling-simulation, computational problem-solving, and systems thinking. This provided a theoretical background for the growing role of computation in mathematics and science and how it should be incorporated into school courses. The understanding of CT, which is growing in impact, has become a crucial field of study for individuals in the 21st-century. In 21st-century education, CT provides a systematic approach to analyzing and solving complex problems, enhancing both the professional competence and the analytical and problem-solving abilities of prospective mathematics and science teachers (Grover & Pea, 2013; Wing, 2006).

2. Literature Review and Research Questions

2.1. 21st-century Skills

21st-century skills encompass the essential abilities individuals need to succeed in their careers, education, and personal lives. Although no standard definition of 21st-century skills exists, various approaches and theoretical frameworks by different organizations garner significant attention. The first widely accepted framework on 21st-century skills is the Partnership for 21st Century Learning [P21] framework, developed by business leaders, education experts, and policymakers to prepare individuals for the demands of the modern era. The P21 framework outlines the knowledge, skills, expertise, and resources individuals need in their careers, personal lives, and civic responsibilities, particularly as Industry 4.0 (smart production and business, etc.) and Society 5.0 (super smart society) concepts emerge (Partnership for 21st Century Skills, 2019). The P21 framework comprises four systems: standards and assessments, curriculum and instruction, professional development, and learning environments. While key 21st-century themes are central to the framework, its primary components are skill-based learning outcomes: life and career skills, learning and innovation skills, and information, media, and technology skills (P21, 2019).

The Assessment and Teaching of 21st Century Skills [ATC21S] published another model on 21st-century skills. ATC21S organizes 21st-century skills into a holistic structure, categorized as ways of thinking (creativity and innovation, critical thinking, problem-solving, decision making, learning to learn), ways of working (communication, collaboration), tools for working (information and ICT literacy), and living in the world (citizenship, life and career, personal and social responsibility) (Binkley et al., 2012). The World Economic Forum's [WEF] 2016 report, New Vision for Education: Fostering Social and Emotional Learning through Technology, states that in the 21st-century, students need more than traditional academic learning. The report emphasizes that students must master social and emotional skills such as collaboration, communication, and problem-solving (WEF, 2016).

Another framework that sets the standards for students, teachers, and administrators in the USA in the 21st century is the National Educational Technology Standards [NETS-S]. Initially designed at the national level, the standards have been accepted at the international level with the inclusion of educational technology standards. The NETS-S standards provide a roadmap for schools worldwide, particularly for effectively incorporating software technologies, AI applications, digitalization, and online learning environments (ISTE, 2016). ISTE identified key 21st-century skills, such as being empowered learners, digital citizens, innovative designers, creative communicators, computational thinkers, knowledge constructors, and global collaborators. The core foundations set as goals for 2030 include attitudes, values, knowledge, and skills, which are central to further learning (OECD, 2019).

Skill-oriented competencies like innovation, entrepreneurship, social responsibility, leadership, problem-solving, technology literacy, career awareness, and STEM—collectively referred to as new generation skills—are increasingly emphasized in national curricula today, making their development a key objective (AlAli & Wardat, 2024; Erdogan & Bozeman, 2015; Halpern, 2014; Hussein et al., 2024; ISTE, 2016; Savickas, 2005; Tashtoush et al., 2023; Voogt & Roblin, 2012; Wang & Degol, 2017). Studies indicate improvements in students' 21st-century skills by grade level, the influence of achievement on these skills, and the importance of competencies like innovation, leadership, social responsibility, and risk-taking (e.g., Blackwell et al., 2007; Cropley, 2001; Dyer et al., 2019; Eagly & Johannesen-Schmidt, 2001; Facione, 2011; Hussein et al., 2024; İlhan & Unal, 2021; Moon et al., 2023; Paul & Elder, 2006; Voogt et al., 2013).

2.2. Computational Thinking

CT is a complex thinking process that involves formulating problems and solutions (Wing, 2006). Due to this characteristic, individuals activate multidimensional thinking processes by applying abstraction skills to daily life problems (Wing, 2008b). As modern issues become increasingly complex, the understanding of CT has become both a tool and a valuable goal for educators. CT helps individuals overcome particularly challenging intellectual tasks and fosters a variety of skills (Looi et al., 2024; Shute et al., 2017; Sneider et al., 2014). The ISTE and Computer Science Teachers Association [CSTA] have introduced a general framework that highlights the key elements of CT's problem-solving process. The presented framework includes the skills of formulating, algorithmic and logical thinking, abstracting, analyzing solutions, and generalizing (ISTE & CSTA, 2011). CT requires mathematical understanding and impacts many disciplines (Looi et al., 2024). Due to its strengths, CT enhances students' learning in mathematics and other fields, supporting their academic development (e.g., Gadanidis et al., 2017; Jarrah et al., 2023; Kaup et al., 2023; Mumcu et al., 2023; Sneider et al., 2014; Sung et al., 2017; Tabesh, 2017).

Given the close relationship between mathematics and other sciences, CT impacts not only mathematics but also numerous branches of science. Since CT requires mathematical understanding, it significantly enhances skills such as algorithmic-probabilistic-algebraic thinking, problem-solving, and data organization. CT improves individuals' abstract thinking, inference, modeling, and accuracy testing abilities (Gadanidis et al., 2017; Shute et al., 2017; Ye et al., 2023). Although CT relies on a skill-based approach, it consistently requires mathematical competencies. While the goal is to solve problems creatively and efficiently, symbolic and conceptual thinking are essential. CT encompasses cognitive skills and seeks conclusions through intuitive reasoning. The components of this thinking are reformulating problems, recursion, separation, abstraction, and systematic testing (Wing, 2006). Abstraction is considered a crucial step in CT, offering insights into using process skills to address specific problems. Thus, applying CT strengthens the connection between mathematical concepts and computer science (Sneider et al., 2014; Wing, 2006; Ye et al., 2023).

One of the crucial characteristics of CT is its requirement for abstraction abilities (Wing, 2006). Abstraction is considered essential for creating new mathematical structures and advancing other sciences and mathematics (Hershkowitz et al., 2019). Thus, reduces problem complexity by creating categories and restructuring fields (Wing, 2008a, 2008b). Abstraction is the core component that distinguishes CT from other thinking skills (Grover & Pea, 2013). Therefore, to better understand the nature of CT, we must examine abilities requiring mathematical thinking, interdisciplinary skills, and skills associated with CT (Sneider et al., 2014). The National Research Council [NRC] (2011) report defines CT's core values, including hypothesis testing, data management, parallelism, abstraction, and debugging, demonstrating that CT is a thinking process that transcends science.

The literature on CT reveals that this skill, an essential 21st-century component in today's digital age, is linked to various types of skills. For instance, Hershkovitz et al. (2019) found that CT has a mutual relationship with creative thinking. In addition, studies have explored the relationships and development of CT and algorithmic thinking with topics such as performance, problem-solving, collaboration, criticism, and creativity (Doleck et al., 2017). Other research has examined CT in relation to computer programming self-efficacy (Avcu & Ayverdi, 2020), metacognition (Yadav et al., 2022), digital competence (Esteve-Mon et al., 2020), and math knowledge and understanding (Bartolini-Bussi & Baccaglini-Frank, 2015; Gadanidis et al., 2018; Rodríguez-Martínez et al., 2020). These studies are primarily empirical, examining the effects of CT on various skills.

2.3. Importance of the Study and Research Questions

Education systems and teachers are responsible for equipping students with the skills needed to succeed in the modern world. Among these skills, CT skills and 21st-century skills stand out. While CT encompasses algorithmic and systematic thinking in problem-solving, 21st-century skills involve competencies in areas such as effective use of information technologies, critical thinking, problem-solving, innovation, entrepreneurship, responsibility, and leadership (Grover & Pea, 2013). These skills contribute not only to individuals' academic success but also to their influence in society (Voogt et al., 2013). The extent to which prospective teachers possess these skills and the relationships among these skills are crucial for future teaching strategies and curriculum development. Prospective science and mathematics teachers were included in this study because these fields are directly related to CT skills. Mathematics and science are fields where problem-solving, critical and analytical thinking, and algorithmic approaches play a central role (Shute et al., 2017). Thus determining the CT competencies of prospective mathematics and science teachers will provide important data for future educational practices and curriculum development. However, the readiness of current mathematics and science teachers for these new skills requires assessment. Research shows that many teachers are not adequately equipped to teach such skills and that current curricula may be inadequate for developing these skills (Voogt & Roblin, 2012). This situation reveals that teacher education programs and current teachers' in-service training should be restructured to include these skills. While 21st-century skills are increasingly emphasized in education programs, evaluating current teachers' preparedness to teach these skills is critical for the success of this educational shift (Binkley et al., 2012). This study examines the strength of the relationship between prospective teachers' 21st-century skills and CT skills, as well as the effect of 21st-century skills on CT skill levels. In addition, the 21st-century skills and CT levels of prospective teachers were examined using various variables. In line with these objectives, the following research questions [RQs] were formulated and investigated:

RQ 1) Is there a significant difference in the 21st-century skill levels of prospective teachers based on their department, gender, class level, and academic grade point average?

RQ 2) Is there a significant difference in the CT skill levels of prospective teachers based on their department, gender, class level, and academic grade point average?

RQ 3) Is there a relationship between the 21st-century skills and the CT skills of prospective teachers?

RQ 4) Do prospective teachers' 21st-century skill components predict their CT levels? If a significant predictor exists, what is the order of importance among the 21st-century skill components?

3. Methodology

3.1. Research Model

Using a quantitative approach, the study adopted the correlational model. This model incorporates the main characteristics of general correlational designs. Correlational research seeks to determine whether there is a simultaneous change between two or more variables and, if so, its extent (Fraenkel et al., 2012). This approach enables researchers to predict outcomes by identifying relationships between variables without intervention or manipulation (Curtis et al., 2016). This approach enables researchers to identify meaningful patterns by examining observed changes.

3.2. Population and Sample

The study sample consists of prospective teachers from the Mathematics and Science Education Department. Purposive sampling, a type of non-random sampling, was used to select the sample. In this sampling, the participants' department was used as the criterion. One of the primary purposes of criterion sampling is to examine situations that contain predefined criteria (Yıldırım & Şimşek, 2021). The criterion or criteria reflecting the nature of the research are determined by the researcher, or a predefined list of criteria is used (Marshall & Rossman, 2016). The group of prospective teachers was analyzed based on gender, grade level, academic grade point average [GPA], and department. Participants' distribution by gender, grade level, GPA, and department is presented in Table 1.

Table 1
Descriptive statistics of participants

Variables	*Frequency*	*Percentage (%)*
Department		
Mathematics	159	53.0
Science	141	47.0
Gender		
Female	200	66.7
Male	100	33.3
Grade level		
1st Grade	74	24.7
2nd Grade	79	26.3
3rd Grade	74	24.7
4th Grade	73	24.3
GPA		
1.00-2.49	40	13.3
2.50-2.99	81	27.0
3.00-3.49	98	32.7
3.50-4.00	81	27.0

According to the descriptive statistics in Table 1, the study group consists of 300 prospective teachers. Among the prospective teachers, 159 (53.0%) study in the mathematics education, while 141 (47.0%) study in the science education department. According to the gender variable 200 (66.7%) of prospective teachers are female, and 100 (33.3%) are male. In terms of grade level, 74 students are in the first grade (24.7%), 79 in the second grade (26.3%), 74 in the third grade (24.7%), and 73 in the fourth grade (24.3%). According to GPA, 40 students have grades between 1.00-2.49 (13.3%), 81 between 2.50-2.99 (27.0%), 98 between 3.00-3.49 (32.7%), and 81 between 3.50-4.00 (27.0%).

3.3. Data Collection Tools

3.3.1. Personal information form

The personal information form, developed by the researcher, contains variables related to the general purpose of the research. The information form includes multiple-choice questions on department, gender, grade level, and GPA.

3.3.2. Multidimensional 21st century skills scale

The scale developed by Cevik and Sentürk (2019) consists of 41 items and five distinct subfactors. These factors include Information and Technology Literacy [ITLS], Critical Thinking and Problem-Solving [CTPSS], Entrepreneurship and Innovation [EIS], Social Responsibility and Leadership [SRLS], and Career Consciousness [CC]. The scale items are scored between "strongly disagree" and "completely agree" in a 5-point Likert-type format. The Cronbach's alpha value, indicating reliability, was reported as .86 by the scale developer. This value suggests that the scale is reliable. Confirmatory factor analysis was performed to test the scale's construct validity. Results indicated that the scale's five-factor structure fit the data set well [χ^2/df =2.60; RMSEA=.05; GFI=.90; NFI=.91; SRMR=.058; NNFI=.94; CFI=.95]. The scale's total Cronbach alpha reliability coefficient was found to be .95 in this study. Also, the reliability coefficients for each subfactor of the scale were further calculated. The reliability coefficients were .93 for ITLS, .82 for CTPSS, .91 for EIS, .67 for SRLS, and .88 for CC. The results indicate that the scale and its subfactors provide reliable results.

3.3.3. Computational thinking scale

The scale developed by Korkmaz et al. (2017) consists of 29 items and five distinct sub-factors. The factors are creativity, problem-solving, cooperativity, algorithmic thinking, and critical thinking. The scale items are scored on a scale from "never" to "always" in a 5-point Likert format. The Cronbach alpha value, indicating reliability, was reported as .82 by the scale developer. This value indicates that the scale can be used to obtain reliable results. Confirmatory factor analysis was conducted to test the scale's construct validity. Results confirmed that the scale's five-factor structure fit the collected data set well [CMIN/DF =3.23; RMSEA=.062; GFI=.91; AGFI=.90; CFI=.95; IFI=.97; SRMR=.044]. In this study, the scale's total Cronbach alpha reliability coefficient was found to be .95. The reliability coefficients for each subfactor of the scale were further calculated. The reliability coefficients were .91 for creativity, .89 for algorithmic thinking, .87 for cooperativity, .88 for critical thinking, and .87 for problem-solving. The calculated values indicate that the scale can be used reliably with all its subfactors.

3.4. Data Analysis

Appropriate statistical methods were used to reach the findings for the research sub-objectives. First, the Mahalanobis distance of the data set was calculated, and no outliers were found at $p < .001$ (Kline, 2011). At another stage, the normal distribution of continuous variables was evaluated using skewness and kurtosis values. With skewness and kurtosis values between ±1.50, the data indicate a normal distribution (Tabachnick & Fidell, 2013). The skewness and kurtosis values for the total mean score of the 21st-century skills scale ranged between −.150 and −.606, indicating a normal distribution. The skewness and kurtosis values of the scale's subfactors range from −.109 to −.616 for ITLS, −1.129 to 1.190 for CTPSS, −.235 to .176 for EIS, −.355 to −.088 for SRLS, and -.652 to -.351 for CC, indicating a normal distribution. The skewness and kurtosis values for the total mean score of the CT scale range from .029 to −.264, indicating a normal distribution. Also, the skewness and kurtosis values for the subfactors of the scale range from −.339 to −.199 for creativity, −.693 to .363 for algorithmic thinking, −.644 to .196 for cooperativity, −.164 to −.339 for critical thinking, and −.337 to −.249 for problem-solving, indicating a normal distribution. Since the sample size is greater than 30, parametric tests can be used (Lumley et al., 2002). In this respect, parametric tests were preferred for hypothesis testing. The independent sample *t*-test was used to assess significant differences in 21st-century skills and CT across gender and department. The independent sample *t*-test is ideal for testing significant differences between the means of two independent samples (Can, 2023). One-way Analysis of Variance [ANOVA] was conducted to examine differences in 21st-century skills and CT levels of prospective teachers across class levels and academic GPA. ANOVA is a parametric test used to assess significant differences between the means of three or more groups (Hair et al., 2010). The Pearson Product Moment Correlation coefficient was calculated to assess the relationship between the 21st-century skills and CT levels of prospective teachers. This coefficient indicates the strength and direction of the linear relationship between two continuous variables (Field, 2013). Certain assumptions must be met before performing multiple linear regression analysis to determine the effect of 21st-century skills on CT levels (Çokluk et al., 2021). In this context, the linear relationship between the variables was first examined with scatter plots, and no linearity problem was found.

In the next step, the presence of multicollinearity among the independent variables was examined. The correlation coefficient table indicated no multicollinearity among the independent variables ($r < .80$). Additionally, the highest VIF [Variance Inflation Factor] value was found to be 2.461. VIF values equal to or greater than 10 (VIF ≥ 10) indicate a multicollinearity problem (Çokluk et al., 2021). Finally, the lowest calculated Tolerance value was found to be .406. Tolerance values equal to or less than .10 (Tolerance ≤ .10) indicate a connectivity problem (Çokluk et al., 2021). The analyses were performed using SPSS Statistics 25.0 software.

4. Results

4.1. Examining Prospective Teachers' 21st-century Skills by Variables

The 21st-century skill levels of prospective teachers were examined by gender, department, grade level, and academic GPA to assess significant differences. The descriptive statistics and *t*-test results for the gender variable of prospective teachers, obtained from the 21st-century skills are presented in Table 2.

Table 2
21st-century descriptive and skills t-test results by gender

Variable	*Gender*	*N*	*Mean*	*SD*	*MD*	*t*	*df*	*p*
Information and technology literacy skills [ITLS]	Female	200	4.02	0.501	−0.176	−2.857	298	<.01
	Male	100	4.20	0.505				
Critical thinking and problem-solving skills [CTPSS]	Female	200	4.05	0.750	−0.110	−1.235	298	.218
	Male	100	4.16	0.677				
Entrepreneurship and innovation skills [EIS]	Female	200	3.55	0.649	−0.195	−2.374	298	<.05
	Male	100	3.74	0.716				
Social responsibility and leadership skills [SRLS]	Female	200	3.69	0.633	−0.175	−2.184	298	<.05
	Male	100	3.87	0.693				
Career consciousness [CC]	Female	200	4.33	0.538	0.000	0.012	298	.990
	Male	100	4.33	0.593				
Multidimensional 21st century skills (total)	Female	200	3.92	0.431	−0.145	−2.629	298	<.01
	Male	100	4.07	0.486				

Note. SD: Standard Deviation; MD: Mean Difference; df: Degrees of Freedom.

The *t*-test results for the multidimensional 21st century skills (total) level in Table 2 show a mean score of 3.92 for female prospective teachers and 4.07 for male prospective teachers. The difference between the two groups was statistically significant ($t_{(298)} = -2.629$, $p < .01$). The *t*-test results for the scale's subfactors indicate statistically significant differences in the ITLS ($t_{(298)} = -2.857$, $p < .01$), EIS ($t_{(298)} = -2.374$, $p < .05$) and SRLS sub-factors ($t_{(298)} = -2.184$, $p < .05$). This result shows that male prospective teachers have higher levels of 21st-century skills in the ITLS, EIS, and SRLS dimensions compared to female prospective teachers. No statistically significant difference was found between the two groups in the multidimensional 21st-century skills CTPSS ($t_{(298)} = -1.235$, $p > .05$) and CC dimensions ($t_{(298)} = 0.012$, $p > .05$). The descriptive statistics and *t*-test results for the department variable of prospective teachers, obtained from the 21st-century skills scale, are presented in Table 3.

Table 3

21st-century descriptive and skills t-test results by department

Variable	*Department*	*N*	*Mean*	*SD*	*MD*	*t*	*df*	*p*
Information and technology literacy skills (ITLS)	Mathematics	159	4.07	0.488	−0.013	−0.235	298	.815
	Science	141	4.09	0.533				
Critical thinking and problem-solving skills (CTPSS)	Mathematics	159	4.13	0.709	0.110	1.308	298	.192
	Science	141	4.02	0.745				
Entrepreneurship and innovation skills (EIS)	Mathematics	159	3.60	0.637	−0.024	−0.315	298	.753
	Science	141	3.62	0.721				
Social responsibility and leadership skills (SRLS)	Mathematics	159	3.76	0.620	0.004	0.057	298	.955
	Science	141	3.75	0.700				
Career consciousness (CC)	Mathematics	159	4.34	0.544	0.025	0.397	298	.692
	Science	141	4.32	0.571				
Multidimensional 21st century skills (total)	Mathematics	159	3.98	0.428	0.009	0.174	298	.862
	Science	141	3.97	0.485				

The *t*-test results for the multidimensional 21st century skills (total) level in Table 3 show a mean score of 3.98 for mathematics prospective teachers and 3.97 for science prospective teachers. The difference between the two groups was not statistically significant ($t_{(298)}$ = 0.174, p > .05). The *t*-test results for the sub-dimensions of the scale indicate no statistically significant differences between the two groups in the ITLS ($t_{(298)}$= −0.235, p > .05), CTPSS ($t_{(298)}$ = 1.308, p > .05), EIS ($t_{(298)}$= −0.315, p > .05), SRLS ($t_{(298)}$ = 0.057, p > .05) and CC ($t_{(298)}$ = 0.397, p > .05) dimensions. These results suggest that the 21st-century skill levels of mathematics and science prospective teachers are close to each other. The descriptive statistics and One-Way ANOVA results for the grade level variable of prospective teachers, obtained from the 21st-century skills scale, are presented in Table 4.

Table 4

21st-century skills descriptive and ANOVA results by grade level

Assessment	*Grade Level*	*N*	*Mean*	*SD*	*F*	df_1-df_2	*p*
Information and technology literacy skills (ITLS)	1st Grade	74	3.87	.487	7.710	3-296	<.001
	2nd Grade	79	4.08	.523			
	3rd Grade	74	4.12	.500			
	4th Grade	73	4.25	.452			
Critical thinking and problem-solving skills (CTPSS)	1st Grade	74	3.97	.732	1.793	3-296	.149
	2nd Grade	79	4.05	.731			
	3rd Grade	74	4.07	.729			
	4th Grade	73	4.24	.705			
Entrepreneurship and innovation skills (EIS)	1st Grade	74	3.46	.691	2.623	3-296	.051
	2nd Grade	79	3.56	.692			
	3rd Grade	74	3.69	.689			
	4th Grade	73	3.74	.609			
Social responsibility and leadership skills (SRLS)	1st Grade	74	3.55	.665	4.146	3-296	<.01
	2nd Grade	79	3.72	.640			
	3rd Grade	74	3.85	.673			
	4th Grade	73	3.89	.612			
Career consciousnes (CC)	1st Grade	74	4.20	.611	2.130	3-296	.096
	2nd Grade	79	4.34	.524			
	3rd Grade	74	4.36	.547			
	4th Grade	73	4.42	.527			
Multidimensional 21st century skills (total)	1st Grade	74	3.80	.445	6.503	3-296	<.001
	2nd Grade	79	3.95	.448			
	3rd Grade	74	4.02	.462			
	4th Grade	73	4.11	.413			

The mean scores (total) by grade level in Table 4 show that the first grade's mean score is 3.80, the second grade's is 3.95, the third grade's is 4.02, and the fourth grade's is 4.11. The ANOVA results indicate a significant difference between grade levels in terms of multidimensional 21st-century skill levels ($F_{(3\text{-}296)}$ = 6.503, p < .001). The Bonferroni test results indicate significant difference between the first and third grades and between the first and fourth grades. The ANOVA results for the dimensions of the scale indicate significant differences in the ITLS ($F_{(3\text{-}296)}$ = 7.710, p < .001) and SRLS ($F_{(3\text{-}296)}$ = 4.146, p < .01) dimensions. The Bonferroni test results indicate a significant difference between the first grade and the third and fourth grades in the ITLS and SRLS dimensions. According to these results, prospective teachers' skill levels in 21st-century skills, ITLS, and SRLS sub-dimensions increase with grade level. However, this result is not valid for second-year students. On the other hand, no significant differences were found in the CTPSS ($F_{(3\text{-}296)}$ = 1.793, p > .05), EIS ($F_{(3\text{-}296)}$ = 2.623, p > .05), and CC ($F_{(3\text{-}296)}$ = 2.130, p > .05) dimensions based on the grade level. The descriptive statistics and One-Way ANOVA results for the academic grade point average variable of prospective teachers, obtained from the 21st-century skills scale, are presented in Table 5.

Table 5
21st-century skills descriptive and ANOVA results by GPA

Assessment	*Academic GPA*	*N*	*Mean*	*SD*	*F*	df_1-df_2	*p*
Information and technology literacy skills (ITLS)	1.00-2.49	40	4.07	0.474	3.332	3-296	<.05
	2.50-2.99	81	3.94	0.457			
	3.00-3.49	98	4.14	0.497			
	3.50-4.00	81	4.16	0.563			
Critical thinking and problem-solving skills (CTPSS)	1.00-2.49	40	4.10	0.640	5.157	3-296	<.01
	2.50-2.99	81	3.85	0.852			
	3.00-3.49	98	4.10	0.702			
	3.50-4.00	81	4.29	0.597			
Entrepreneurship and innovation skills (EIS)	1.00-2.49	40	3.48	0.638	3.908	3-296	<.01
	2.50-2.99	81	3.44	0.631			
	3.00-3.49	98	3.68	0.668			
	3.50-4.00	81	3.76	0.714			
Social responsibility and leadership skills (SRLS)	1.00-2.49	40	3.51	0.698	4.891	3-296	<.01
	2.50-2.99	81	3.63	0.648			
	3.00-3.49	98	3.80	0.643			
	3.50-4.00	81	3.92	0.617			
Career consciousness (CC)	1.00-2.49	40	4.27	0.635	1.603	3-296	.189
	2.50-2.99	81	4.24	0.592			
	3.00-3.49	98	4.35	0.525			
	3.50-4.00	81	4.42	0.505			
Multidimensional 21st century skills (total)	1.00-2.49	40	3.90	0.442	6.046	3-296	<.01
	2.50-2.99	81	3.82	0.416			
	3.00-3.49	98	4.02	0.433			
	3.50-4.00	81	4.10	0.482			

Table 5 shows that prospective teachers with GPAs between 1.00 and 2.49 have a score of 3.90, those with GPAs between 2.50 and 2.99 have a score of 3.82, those with GPAs between 3.00 and 3.49 have a score of 4.02, and those with GPAs between 3.50 and 4.00 have a score of 4.10. The ANOVA results indicate a significant difference between the academic successes of prospective teachers in terms of 21st-century skill levels ($F_{(3\text{-}296)}$ = 6.046, p < .01). Hochberg's test results indicate a significant difference between prospective teachers with GPAs between 2.50 and 2.99 and those with GPAs between 3.00 and 3.49. Also, a significant difference was found between prospective teachers with GPAs between 2.50 and 2.99 and those with GPAs between 3.50 and 4.00. The ANOVA results for the sub-dimensions of the scale indicate significant differences in ITLS ($F_{(3\text{-}296)}$ = 3.332, p < .05), CTPSS ($F_{(3\text{-}296)}$ = 5.157, p < .01), EIS ($F_{(3\text{-}296)}$ = 3.908, p < .01), SRLS

($F_{(3\text{-}296)}$ = 4.891, p < .01). Hochberg's test indicates a significant difference between prospective teachers with GPAs between 2.50 and 2.99 and those with GPAs between 3.50 and 4.00 in the ITLS, CTPSS, and EIS dimensions. A significant difference was found between prospective teachers with GPAs between 1.00 and 2.49 and those with GPAs between 3.50 and 4.00 in the SRLS dimension. On the other hand, no significant difference was found between the academic successes of prospective teachers in the CC ($F_{(3\text{-}296)}$ = 1.603, p > .05) dimension. The findings show that higher GPAs led to increased 21st-century skills in prospective teachers.

4.2. Examining the CT Skill levels of Prospective Teachers in terms of Various Variables

The CT levels of prospective teachers were examined by gender, department, grade level, and academic GPA to assess significant differences. The CT Scale was used to assess these differences. The descriptive statistics and t-test results for the gender variable of prospective teachers, obtained from the CT Scale, are presented in Table 6.

Table 6

CT skills descriptive and t-test results by gender

Variable	*Gender*	*N*	*Mean*	*SD*	*MD*	*t*	*df*	*p*
Creativity	Female	200	4.20	0.482	−0.121	−2.146	298	<.05
	Male	100	4.33	0.424				
Algorithmic thinking	Female	200	3.78	0.742	−0.125	−1.348	298	.179
	Male	100	3.91	0.785				
Cooperativity	Female	200	3.83	0.843	−0.185	−1.837	298	.067
	Male	100	4.02	0.776				
Critical thinking	Female	200	3.79	0.687	−0.280	−3.417	298	<.01
	Male	100	4.07	0.629				
Problem-solving	Female	200	3.77	0.666	−0.110	−1.335	298	.183
	Male	100	3.88	0.699				
CT skills (total)	Female	200	3.90	0.490	−0.156	−2.620	298	<.01
	Male	100	4.06	0.480				

The *t*-test results of the CT skills (total) level in Table 6 show a mean score of 3.90 for female prospective teachers and 4.06 for male prospective teachers. The difference between the two groups was statistically significant ($t_{(298)} = -2.620$, p < .01). The *t*-test results for the sub-dimensions indicate statistically significant differences in the creativity ($t_{(298)} = -2.146$, p < .05) and critical thinking ($t_{(298)} = -3.417$, p < .01) dimensions. This result shows that male prospective teachers have higher levels of CT skills in the creativity and critical thinking dimensions compared to female prospective teachers. No statistically significant difference was found between the two groups in the CT dimensions of algorithmic thinking ($t_{(298)} = -1.348$, p > .05), cooperativity ($t_{(298)} = -1.837$, p > .05), and problem-solving ($t_{(298)} = -1.335$, p > .05). Table 7 presents the CT skills' descriptive stats and *t*-test results by department.

Table 7

CT skills descriptive and t-test results by department

Variable	*Department*	*N*	*Mean*	*SD*	*MD*	*t*	*df*	*p*
Creativity	Mathematics	159	4.22	0.447	−0.044	−0.818	298	.414
	Science	141	4.27	0.488				
Algorithmic thinking	Mathematics	159	4.00	0.581	0.365	4.283	298	<.001
	Science	141	3.63	0.880				
Cooperativity	Mathematics	159	3.80	0.791	−0.196	−2.074	298	<.05
	Science	141	4.00	0.853				
Critical thinking	Mathematics	159	3.88	0.637	−0.004	−0.055	298	.956
	Science	141	3.89	0.729				
Problem-solving	Mathematics	159	3.86	0.659	0.103	1.326	298	.186
	Science	141	3.75	0.697				
CT skills (total)	Mathematics	159	3.98	0.438	0.056	1.002	298	.317
	Science	141	3.93	0.545				

The t-test results of the CT skills (total) level in Table 7 show a mean score of 3.98 for mathematics prospective teachers and 3.93 for science prospective teachers. The difference between the two groups is not statistically significant ($t_{(298)} = 1.002$, $p > .05$). The *t*-test results for the sub-dimensions indicate statistically significant differences in algorithmic thinking ($t_{(298)} = 4.283$, $p < .001$) and cooperativity ($t_{(298)} = -2.074$, $p < .05$) dimensions. This result shows that mathematics prospective teachers have more CT skills in the algorithmic thinking dimension, while science prospective teachers have more CT skills in the cooperativity dimension. On the other hand, no statistically significant difference was found between the two groups in the dimensions of creativity ($t_{(298)} = -.818$, $p > .05$), critical thinking ($t_{(298)} = -0.055$, $p > .05$), and problem-solving ($t_{(298)} = 1.326$, $p > .05$). The descriptive statistics and One-Way ANOVA results for the grade level variable of prospective teachers, obtained from the CT skills scale, are presented in Table 8.

Table 8

CT skills descriptive and ANOVA results by grade level

Assessment	*Grade Level*	*N*	*Mean*	*SD*	*F*	*df₁-df₂*	*p*
Creativity	1st Grade	74	4.08	0.440	6.747	3-296	<.001
	2nd Grade	79	4.18	0.473			
	3rd Grade	74	4.38	0.455			
	4th Grade	73	4.34	0.443			
Algorithmic thinking	1st Grade	74	3.63	0.775	4.439	3-296	<.01
	2nd Grade	79	3.73	0.787			
	3rd Grade	74	3.88	0.684			
	4th Grade	73	4.05	0.726			
Cooperativity	1st Grade	74	3.85	0.755	2.119	3-296	.098
	2nd Grade	79	3.73	0.905			
	3rd Grade	74	4.03	0.899			
	4th Grade	73	3.98	0.695			
Critical thinking	1st Grade	74	3.73	0.679	4.444	3-296	<.01
	2nd Grade	79	3.78	0.724			
	3rd Grade	74	3.95	0.609			
	4th Grade	73	4.09	0.655			
Problem-solving	1st Grade	74	3.81	0.611	1.127	3-296	.338
	2nd Grade	79	3.74	0.624			
	3rd Grade	74	3.76	0.743			
	4th Grade	73	3.92	0.727			
CT skills (total)	1st Grade	74	3.84	0.446	5.067	3-296	<.01
	2nd Grade	79	3.87	0.490			
	3rd Grade	74	4.03	0.504			
	4th Grade	73	4.10	0.491			

Table 8 shows that the CT skills (total) mean score of the first grade is 3.84, the second grade is 3.87, the third grade is 4.03, and the fourth grade is 4.10. The One-Way ANOVA results indicate a significant difference between grade levels in terms of CT skill levels ($F_{(3-296)} = 5.067$, $p < .01$). The Bonferroni test results indicate a significant difference between the first and fourth grades and between the second and fourth grades. The ANOVA results for the sub-dimensions of the scale indicate significant differences in the creativity ($F_{(3-296)} = 6.747$, $p < .001$), algorithmic thinking ($F_{(3-296)} = 4.439$, $p < .01$) and critical thinking ($F_{(3-296)} = 4.444$, $p < .01$) dimensions. The Bonferroni test indicates a significant difference between the first and third grades in the creativity dimension, between the first and fourth grades and between the second and third grades; between the first and fourth grades in the algorithmic thinking dimension; and between the first and fourth grades and the second and fourth grades in the critical thinking dimension. This result shows that the total CT skills of prospective teachers and the skill levels in the creativity, algorithmic thinking, and critical thinking sub-dimensions increase with grade level. However, this trend is not consistent across all grade levels. No significant difference was found in the cooperativity

($F_{(3\text{-}296)}$ = 2.119, p > .05) and problem-solving ($F_{(3\text{-}296)}$ = 1.127, p > .05) dimensions. The descriptive statistics and ANOVA results for the academic GPA variable of prospective teachers, obtained from the CT skills scale, are presented in Table 9.

Table 9
CT skills descriptive and ANOVA results by academic GPA

Assessment	*Academic GPA*	*N*	*Mean*	*SD*	*F*	*df1-df2*	*p*
Creativity	1.00-2.49	40	4.15	0.497	4.382	3-296	<.01
	2.50-2.99	81	4.14	0.446			
	3.00-3.49	98	4.26	0.413			
	3.50-4.00	81	4.38	0.501			
Algorithmic thinking	1.00-2.49	40	3.71	0.904	7.390	3-296	<.001
	2.50-2.99	81	3.56	0.830			
	3.00-3.49	98	3.88	0.648			
	3.50-4.00	81	4.08	0.633			
Cooperativity	1.00-2.49	40	3.78	0.813	.312	3-296	.817
	2.50-2.99	81	3.89	0.799			
	3.00-3.49	98	3.91	0.874			
	3.50-4.00	81	3.93	0.805			
Critical thinking	1.00-2.49	40	3.79	0.686	5.664	3-296	<.01
	2.50-2.99	81	3.71	0.675			
	3.00-3.49	98	3.88	0.644			
	3.50-4.00	81	4.12	0.671			
Problem-solving	1.00-2.49	40	3.69	0.652	4.447	3-296	<.01
	2.50-2.99	81	3.67	0.651			
	3.00-3.49	98	3.80	0.743			
	3.50-4.00	81	4.02	0.587			
CT skills (total)	1.00-2.49	40	3.85	0.518	7.077	3-296	<.001
	2.50-2.99	81	3.81	0.481			
	3.00-3.49	98	3.97	0.448			
	3.50-4.00	81	4.14	0.486			

Table 9 shows that prospective teachers with GPAs between 1.00 and 2.49 have a mean score of 3.85, those with GPAs between 2.50 and 2.99 have 3.81, those with GPAs between 3.00 and 3.49 have 3.97, and those with GPAs between 3.50 and 4.00 have 4.14. The ANOVA results indicate a significant difference between the academic success of prospective teachers in terms of CT skill levels ($F_{(3\text{-}296)}$ = 7.077, p < .001). Hochberg's test results indicate a significant difference between prospective teachers with GPAs between 1.00 and 2.49 and those with GPAs between 3.50 and 4.00. Also, a significant difference was found between prospective teachers with GPAs between 2.50 and 2.99 and those with GPAs between 3.50 and 4.00. The ANOVA results for the sub-dimensions of the scale indicate significant differences in the creativity ($F_{(3\text{-}296)}$ = 4.382, p < .01), algorithmic thinking ($F_{(3\text{-}296)}$ = 7.390, p < .001), critical thinking ($F_{(3\text{-}296)}$ = 5.664, p < .01) and problem-solving ($F_{(3\text{-}296)}$ = 4.447, p < .01) dimensions. Hochberg's test results indicate a significant difference between prospective teachers with a GPAs between 2.50 and 2.99 and those with a GPAs between 3.50 and 4.00 in the creativity, algorithmic thinking, critical thinking, and problem-solving dimensions. Also, a significant difference was found between prospective teachers with GPAs between 2.50 and 2.99 and those with a GPAs between 3.00 and 3.49 in the algorithmic thinking dimension. These results indicate that prospective teachers with higher academic GPAs tend to have increased CT skill levels. Also, no significant difference was found between the academic success of prospective teachers in the cooperativity ($F_{(3\text{-}296)}$ = .312, p > .05) dimension.

4.3. Correlation between Prospective Teachers' 21st Century and CT skills

In this study, Pearson correlation coefficients were calculated to test the relationship between prospective teachers' 21st-century and CT skill levels. The findings are presented in Table 10.

Table 10
The Pearson correlations between 21st century and CT skills levels

Variable(s)	*21st Century Skills (total)*	*ITLS*	*CTPSS*	*EIS*	*SRLS*	*CC*
CT skills (total)	.746***	.620***	.365***	.662***	.618***	.446***
Creativity	.720***	.651***	.301***	.601***	.540***	.496***
Algorithmic thinking	.550***	.475***	.190**	.531***	.404***	.345***
Cooperativity	.340***	.218***	.211***	.295***	.424***	.179**
Critical thinking	.681***	.608***	.217***	.692***	.526***	.313***
Problem-solving	.494***	.359***	.429***	.354***	.435***	.316***

Note. **p<.01, ***p<.001

Table 10 shows significant positive correlations between 21st-century and CT skill levels. There is a high positive correlation between 21st-century skill (total) and CT skill (total) (r = .746, p < .001). High positive correlations were found between creativity and 21st-century skill (r = .720, p < .001), critical thinking and 21st-century skill (r = .681, p < .001), ITLS and CT skill (r = .620, p < .001), EIS and CT skill (r = .662, p < .001). The highest correlation was observed between critical thinking and EIS (r = .692, p < .001). The lowest correlation was observed between cooperativity and CC (r = .179, p < .01). These results suggest that there are generally moderate to high correlations between the 21st-century skills and CT skills of prospective teachers.

4.4. Prediction of CT level and relative importance order of 21st century skills

Multiple linear regression analysis tested the predictive power of 21st-century skills for CT skills. The findings are presented in Table 11.

Table 11
Multiple linear regression analysis for the predictive effect of 21st century skills on CT skills

Variables	*B*	*Std. Error*	*β*	*t*	*p*
Constant	.952	.182	-	5.241	<.001
ITLS	.129	.057	.133	2.250	<.05
CTPSS	.149	.027	.221	5.458	<.001
EIS	.269	.043	.371	6.333	<.001
SRLS	.171	.038	.229	4.478	<.001
CC	.060	.040	.067	.150	.135
R = .762; R^2 = .573; $F_{(5\text{-}294)}$ = 81.371; p < .001; *Durbin Watson* = 1.825					

Table 11 shows a significant relationship between 21st-century skills and CT skills (R = .762, $F_{(5\text{-}294)}$ = 81.371, p < .001). The components of 21st-century skills explained approximately 57% of the variance in CT skills. The standardized beta coefficients indicate that ITLS (β =.133, p < .05), CTPSS (β = .221, p < .001), EIS (β = .371, p < .001), and SRLS (β = .229, p < .001) are significant predictors of CT skills. In terms of CT, the components of 21st-century skills are ordered by importance as follows: EIS, SRLS, CTPSS, and ITLS. As prospective teachers' EIS, SRLS, CTPSS, and ITLS skills related to 21st-century skills improve, their CT levels increase accordingly.

5. Discussion and Conclusion

5.1. Implications of the Findings in the context of 21st Century Skills

This study examined the 21st-century and CT skills of prospective teachers based on variables such as gender, department, grade level, and academic GPA. First, the 21st-century skills of prospective teachers differed significantly based on gender. Male prospective teachers have higher skill levels than female prospective teachers, especially in ITLS, EIS, and SRLS. This difference in the ITLS sub-dimension may stem from male prospective teachers' greater interest in STEM fields.

In fact, male prospective teachers may have greater interest and motivation in these fields (Wang & Degol, 2017). On the other hand, male prospective teachers showed higher skill levels than female prospective teachers in all 21st-century skill dimensions except for the CC sub-dimension. Male prospective teachers' technology accessibility and usage habits may explain their higher scores in this area. Especially due to the influence of gender roles, male prospective teachers may have been directed more towards technology. The difference in the EIS dimension may stem from male prospective teachers' tendency to take risks and cope with uncertainty.

The literature suggests that male prospective teachers tend to be more self-confident in dealing with risky situations. For example, Dyer et al. (2019) suggest that male prospective teachers may have greater motivation for innovation and entrepreneurship. Male prospective teachers are especially encouraged and supported through entrepreneurship and innovation-related activities, which positively enhance their skills. The difference in the SRLS dimension may be attributed to prospective teachers' active roles in the community and their leadership capacity. The literature frequently notes that male prospective teachers are more encouraged to take on leadership positions and better prepared for these roles (Eagly & Johannesen-Schmidt, 2001). Moreover, there are possible explanations for the lack of difference in other dimensions. For instance, the lack of difference in the CTPSS sub-dimension could be due to the absence of clear distinctions in cognitive skills (Doleck et al., 2017; Hershkovitz et al., 2019). CTPSS is generally related to individuals' education level and learning experiences, making it independent of gender differences. These findings indicate that gender roles and educational environments may lead to differences in various skill sets. These differences suggest that achieving gender equality in education and supporting female prospective teachers in these areas is essential. Restructuring educational programs and social structures to provide more opportunities and support to female prospective teachers in technology, entrepreneurship, and leadership is an essential step toward eliminating the gender gap.

When prospective teachers' 21st-century skills and components were examined by department, no significant difference was found between mathematics and science prospective teachers. Although this finding is expected, it also confirms that prospective teachers with similar curriculum contents have similar skill levels. In addition, this result suggests that 21st-century skills generally have an interdisciplinary character and that developing these skills extends beyond a single discipline. Thus, positive changes in prospective teachers' 21st-century skills are inevitable when the curriculum is well-organized. With the radical changes in today's mathematics and science curricula, new-generation skills are emphasized, and the curriculum content is designed in a spiral structure (Binkley et al., 2012; Fannakhosrow et al., 2022; ISTE, 2016; NRC, 2011; P21, 2019). 21st-century skills include critical thinking, problem-solving, information, and technology literacy skills, which are generally developed across all disciplines. Many studies show that 21st-century skills are widely adopted across disciplines and emphasized in all areas of education. The review by Voogt and Roblin (2012) reports that 21st-century skills are given similar importance and taught similarly across disciplines. Since prospective teachers in these fields have similar opportunities to use technology and access information, insignificant differences in these skills are expected. This finding supports ITLS as a cross-disciplinary skill (Erdogan & Bozeman, 2015). Both mathematics and science prospective teachers receive similar training in digital tools, information access, and technology-related skills. This likely explains the lack of a significant difference between these two groups. The literature suggests that interdisciplinary differences are minimal in developing these skills; instead, individual experiences are more influential (Binkley et al., 2012; Voogt et al., 2013).

One of the study's notable findings is that as the grade level increases, the 21st-century skills of prospective teachers also rise. Accordingly, it was determined that the 21st-century skills of prospective teachers differ significantly by grade level. The findings indicate that as grade levels increase, prospective teachers' skill levels in the ITLS and SRLS dimensions also increase significantly. ITLS is a skill that develops with progression through education. Prospective teachers learn to use more complex information and technological tools in higher grades, enhancing their skills in this area. This increase in ITLS skills may be due to prospective teachers interacting with more complex technological tools and information systems throughout their education (ISTE, 2016; P21, 2019; Tashtoush et al., 2023; Voogt & Roblin, 2012). This situation can be explained by prospective teachers learning basic technological skills in their early years and using them at a more complex level later. In upper grades, prospective teachers may need to use technology for projects and research, explaining the increase in ITLS scores. SRLS skills develop through experiences gained in education, group work, and leadership opportunities. The development of these skills is particularly evident in upper grades, where prospective teachers interact more with society and actively participate in social responsibility projects. On the other hand, no significant difference was found in prospective teachers' 21st-century skills by grade level in the CTPSS, EIS, and CC dimensions. This may result from these skills being generally related to individual differences and personal interests, rather than grade level. These skills are likely influenced by prospective teachers' personal development and individual experiences, and grade level may not be a determining factor in these areas. Paul and Elder (2006) emphasize that skills such as CTPSS, EIS, and CC develop through education but may differ individually.

When the 21st-century skills of prospective teachers are examined by academic success, it is observed that as academic success increases, their 21st-century skills also rise and differ significantly. It is observed that prospective teachers with high academic success have higher skills in the ITLS, CTPSS, EIS, and SRLS sub-dimensions of 21st-century skills. Generally, academic success is closely related to cognitive and metacognitive skills. As the academic success of prospective teachers increases, their 21st-century skills, especially ITLS, CTPSS, and EIS, are also expected to improve accordingly. For example, the positive relationship between academic success and critical thinking and problem-solving skills is well-supported by research (Halpern, 2014). Academically successful prospective teachers are considered more adept at handling complex cognitive tasks; therefore, they demonstrate higher performance levels in these skills. Prospective teachers with high academic success tend to develop better problem-solving strategies, use technology more effectively, and gain more opportunities and self-confidence in areas such as entrepreneurship. This leads prospective teachers to score higher in 21st-century skills. ITLS is closely linked to academic success. Prospective teachers with high academic success generally have more developed skills in conducting research, accessing information, and using technology effectively. This may be due to prospective teachers gaining the habit of using technology in more academic tasks (Hussein et al., 2024; ISTE, 2016).

Prospective teachers with high academic success may have more experience using technology, which may contribute to their higher ITLS scores. CTPSS is considered a key component of academic success. Facione (2011) states that these skills are critical for academic success and that prospective teachers' analytical thinking abilities enhance their academic performance. Prospective teachers with high academic success tend to solve more complex problems. This ability also explains the increase in CTPSS scores. EIS skills are closely linked to academic success. Prospective teachers are usually willing to develop new ideas and take risks. Dyer et al. (2019) state that entrepreneurial skills can be associated with academic success because successful prospective teachers tend to think innovatively. SRLS skills can develop in parallel with prospective teachers' academic success because these skills are usually acquired through group work and community projects. Blackwell et al. (2007) stated that social responsibility/leadership skills are stronger in academically successful prospective teachers. Prospective teachers with high academic success tend to solve more complex problems. Academically successful prospective teachers can assume more leadership positions and actively participate in community engagement projects. This may lead prospective teachers to achieve high scores in the SRLS dimension. CC is a skill that can grow independently from academic success. Therefore, it was found that there was no significant difference between the CC skills of prospective teachers and their academic success. The literature suggests that career awareness is more affected by personal factors unrelated to academic success (Savickas, 2005). Prospective teachers with high academic success tend to excel in skills, particularly in ITLS, CTPSS, EIS, and SRLS. These findings emphasize that educational programs should be structured to support the development of such skills and enhance prospective teachers' success.

5.2. Implications for the Findings in the context of CT Skills

It has been found that the CT skills of prospective teachers differ significantly by gender. The difference is in favor of male prospective teachers. It has been found that male prospective teachers have higher skill levels, especially in creativity and critical thinking dimensions, but there is no significant difference between male and female prospective teachers in algorithmic thinking, cooperativity, and problem-solving dimensions. Wing (2006) states that CT skills generally develop in parallel with interest in STEM fields, and male prospective teachers, who are often more inclined toward these fields, are likely to perform higher in these skills. In addition, the higher scores of male prospective teachers in CT skills may be related to their interest and exposure to technology and math-related topics. The fact that male prospective teachers are more often supported or encouraged in these areas may also explain this difference. Creativity and critical thinking are fundamental skills used in problem-solving tasks. These skills grow with more practice and experience. Male prospective teachers act with more self-confidence in problem-solving and critical thinking tasks and generally excel in these skills, as stated in the literature (Halpern, 2014). Furthermore, creative thinking requires approaching tasks from different perspectives, and male prospective teachers' tendency to take risks may lead to higher scores in this area (Cropley, 2001). Male prospective teachers score higher in creative and critical thinking dimensions, which may be explained by their greater self-confidence in problem-solving processes and greater willingness to take risks. These gender differences may also be influenced by societal gender roles. Encouraging male prospective teachers to be more creative and critical may support these findings. Algorithmic thinking, collaboration, and problem-solving skills develop in an interdisciplinary manner, regardless of gender. These skills are equally developed across genders through similar educational opportunities. The literature suggests that gender differences are minimal in developing these skills, which are primarily shaped by educational experiences (Papert, 1980).

In the study, no significant difference was found in the CT skills of prospective teachers by department. Mathematics and science are disciplines focused on developing CT skills, and these skills are similarly encouraged across both fields. CT generally includes problem-solving, analytical thinking, and algorithmic approaches, which are developed to a similar extent in both mathematics and science education (Weintrop et al., 2016). Mathematics and science prospective teachers having similar levels of CT skills indicate that these skills provide a shared foundation across these disciplines and are strongly encouraged in both fields. On the other hand, there are differences in certain sub-dimensions of CT. Prospective mathematics teachers scored higher in the algorithmic thinking dimension, while prospective science teachers scored higher in the cooperativity dimension. Algorithmic thinking is strongly related to mathematics. Solving mathematical problems generally requires algorithmic thinking; therefore, mathematics prospective teachers develop this skill more. Shute et al. (2017) emphasize that these cognitive skills are used and developed intensively during mathematics education. The higher scores of prospective mathematics teachers in the algorithmic thinking dimension might be explained by this discipline's focus on algorithmic and systematic thinking processes. Collaboration is key in science education, which enables effective teamwork (Johnson & Johnson, 1989). Thus, higher scores in collaboration for prospective science teachers may be due to a focus on group work and collaborative learning.

When the CT skills of prospective teachers were analyzed by grade level, a significant increase was observed with each advancing grade level. The skills of the prospective teachers showed substantial growth in the sub-dimensions of CT, creativity, algorithmic thinking, and critical thinking. Accordingly, it can be said that the prospective teachers developed their CT skills over time, advancing them as they acquired new competencies. These findings also support that the skills of prospective teachers can grow through their engagement with CT, as CT develops not only from mathematics but also from other branches of science (Wing, 2008b). Especially considering that prospective teachers are increasingly involved with multiple branches of science as they progress in grade level, the development of CT skills is an expected result. At the same time, these findings are consistent with statements suggesting that prospective teachers’ versatile and abstract thinking skills will improve due to CT skills (e.g., Gadanidis et al., 2017; Grover & Pea, 2013; Looi et al., 2024; Rodríguez-Martínez et al., 2020; Sneider et al., 2014; Sung et al., 2017; Yadav et al., 2022).

When the CT skill levels of prospective teachers were examined according to academic success, an increase in CT skills corresponded with a rise in academic success. In addition, the CT skills of prospective teachers improve with rising academic success, particularly in the sub-dimensions of CT creativity, algorithmic thinking, critical thinking, and problem-solving. Academically successful prospective teachers tend to be more proficient in complex problem-solving skills and analytical thinking processes. This proficiency allows them to excel in CT skills. Shute et al. (2017) state that prospective teachers with high academic success tend to demonstrate stronger CT skills. Prospective teachers with high academic success have higher CT skills due to their exposure to more complex thinking and problem-solving tasks during their education. This exposure leads them to achieve greater proficiency in these skills. Creativity is a skill commonly linked to academic success. Successful prospective teachers are likely to produce more creative solutions. Cropley (2001) emphasizes that creative thinking is closely linked to the capacity of prospective teachers to develop alternative approaches in problem-solving processes. Algorithmic thinking requires systematic problem-solving skills and the application of logical processes. Generally, prospective teachers who develop this skill at a more advanced level tend to achieve higher academic success (Wing, 2006). The high performance of prospective teachers with high academic success in algorithmic thinking skills could be attributed to their encounter with more complex algorithmic problems during their educational processes. This enhances their ability to solve such problems. Critical thinking is strongly associated with academic success. Successful prospective teachers develop their ability to analyze and solve complex problems more effectively. Halpern (2014) states that critical thinking is a fundamental skill contributing to academic success. The higher performance of prospective teachers with high academic success in critical thinking skills may result from their frequent encounter with tasks and projects that encourage critical thinking in their educational processes.

Problem-solving skills are strongly correlated with academic success. Successful prospective teachers may be more competent in solving complex problems and developing effective strategies. Research indicates that problem-solving skills are a factor that directly affects prospective teachers' academic success (Jonassen, 2011). Prospective teachers with high academic success score higher in problem-solving skills, likely due to encountering complex problems more frequently and developing more effective methods to solve them. These findings show that prospective teachers with high academic success have higher competence in CT skills, especially in sub-dimensions such as critical thinking, creativity, algorithmic thinking, and problem-solving. These findings suggest that educational processes should include strategies to increase prospective teachers' academic success while also developing these essential cognitive skills. An educational environment that provides prospective teachers with opportunities to develop these skills can enhance both their academic success and overall cognitive abilities.

5.3. Implications from the Relationships between 21st Century Skills and CT Skills

Another finding of the study concerned the relationships between the 21st century and CT skill levels of prospective teachers. Accordingly, a strong correlation was observed between the 21st century and CT skills. In addition, the strongest correlation between the 21st century and CT sub-dimensions was observed between critical thinking and EIS. These findings suggest that there are significant relationships between the 21st century and CT skills of prospective teachers and that these skills influence each other. It is strongly emphasized that 21st century skills, which include lifelong learning, are important for individuals' future careers (OECD, 2019; P21, 2019; WEF, 2016). For this reason, it is important to consider the interconnections of required 21st century skills for prospective teachers within learning environments. Considering the strengths of CT, a key 21st century skill (Tabesh, 2017), it is crucial to raise awareness of the importance of these skills and to structure the content of mathematics and science curricula to reflect future-oriented skills. One reason for this necessity is the significant relationship between 21st century skills and CT, as 21st century skills strongly predict CT skills. These findings show that there are generally moderate to high positive correlations between the 21st century skills and CT skills of prospective teachers. These strong connections between 21st century and CT skills highlight their interdependence and mutual support in modern education.

21st century skills include a range of cognitive and practical skills that prospective teachers need to thrive in the digital world. These skills encompass information literacy, critical thinking, problem-solving, and collaborative skills. CT skills are strongly related to these skills because both focus on analytical thinking, systematic problem-solving, and generating creative solutions. Wing (2006) states that CT skills are essential in modern education and that these skills are directly related to the development of 21st century skills. The strong positive correlation between 21st century skills and CT skills reflects their mutually supportive nature. As prospective teachers develop 21st century skills, such as effective use of information technologies and analytical thinking, CT skills progress alongside. Creativity is an important component of 21st century skills, encompassing prospective teachers' capacity to think innovatively, solve problems, and produce original solutions. Creativity plays a critical role in developing 21st century skills and contributes positively to other skill areas. Cropley (2001) emphasizes that creativity is a core element of modern education and enhances prospective teachers' ability to produce innovative solutions to complex problems. The high correlation between creativity and 21st century skills demonstrates how the development of these skills mutually reinforces each other. Creative thinking skills also support the development of other 21st century skills, such as problem-solving and innovation skills. Critical thinking entails analyzing, evaluating, and deriving meaning from complex information. This skill is a key element of 21st century skills and enhances prospective teachers' ability to make informed decisions and solve problems effectively. Halpern (2014) states that critical thinking plays a fundamental role in solving complex problems that prospective teachers face in the modern world. Critical thinking supports informed decision-making and complex problem solving. Information and technology literacy encompasses the effective use of digital tools and information access. This skill is closely related to CT skills because the effective use of information technologies enables prospective teachers to develop algorithmic thinking and problem-solving abilities. ISTE (2016) states that these innovative skills play a critical role in prospective teachers' CT processes.

The strong correlation between ITLS and CT skills shows how information technologies support CT processes. Prospective teachers can perform more complex CT tasks by using digital tools effectively. SRLS skills are related to prospective teachers' capacities to develop and implement innovative ideas. These new skills encourage the production of innovative solutions in the CT process. Dyer et al. (2019) state that entrepreneurship and innovation play an important role in problem-solving and innovative thinking processes. The strong correlation between EIS and CT skills shows how entrepreneurship and innovation skills contribute to prospective teachers' production of creative and innovative solutions in CT processes. These findings indicate a positive significant correlation between the 21st century and CT skills. Educational programs aimed at developing prospective teachers' 21st century and CT skills are essential to support their success in the modern world. These results show how both skill sets complement and support each other. Therefore, educational strategies should be designed with these integrated approaches in mind.

5.4. Implications for the Predictive Effect of 21st Century Skills on CT Skills

21st century skills are strongly correlated with CT and serve as important predictors of CT skills. In particular, the fact that 21st century skills account for approximately 57% of the effect on CT reveals a robust connection between these two skill sets. These skills encompass a range of competencies necessary for prospective teachers to work effectively in the digital age. The influence of 21st century skills on CT arises from their inclusion of foundational elements, such as analytical thinking, problem-solving, innovation, and collaboration. Wing (2006) states that CT skills are closely related to 21st century skills, which are essential for solving complex problems in the modern world. The significant influence of 21st century skills on CT reflects the mutually supportive nature of these skill sets.

As prospective teachers develop skills such as effectively applying ITLS, thinking critically, and creating innovative solutions, their CT skills are strengthened in this process. EIS includes the ability of prospective teachers to develop new ideas, take risks, and implement these ideas. These skills promote the production of innovative solutions in the CT process. Dyer et al. (2019) state that entrepreneurship and innovation play an important role in problem-solving and innovative thinking processes. EIS is the primary predictor of CT because innovative and creative thinking is central to the CT process. The ability to develop innovative ideas and put these ideas into practice is crucial for creating new strategies and algorithms in CT. SRLS includes prospective teachers' ability to take social responsibility and assume leadership. These skills are important in managing group work and contributing to social benefit in the CT process. Eagly and Johannesen-Schmidt (2001) emphasize that leadership and social responsibility are important in prospective teachers' effective problem-solving and decision-making processes. The substantial impact of SRLS on CT comes from leadership and social responsibility skills, which play an important role in collaborative problem-solving.

CTPSS skills encompass analyzing, evaluating, and deriving meaning from complex information. These skills are essential for developing complex algorithms in CT and applying them to problem-solving. Halpern (2014) states that critical thinking increases prospective teachers' capacity to solve complex problems. The effect of CTPSS on CT is related to the capacity of critical thinking for analytical approaches to complex problems. These skills support the systematic and logical thinking processes necessary for CT. ITLS includes prospective teachers' ability to use digital tools effectively and access information. This skill is directly related to CT skills because prospective teachers who use information technologies effectively can be more successful in algorithmic thinking and problem-solving (ISTE, 2016). The effect of ITLS on CT indicates how digital literacy supports CT processes. The findings show that 21st century skills have a notable influence on CT skills and that these skills are mutually supportive. EIS, SRLS, CTPSS, and ITLS skills play a vital role in developing CT skills. Designing educational programs to enable prospective teachers to develop these critical skills in an integrated manner may strengthen their 21st century and CT skills.

5.5. Limitations and Implications for Future Research

One of the crucial limitations of the study is the diversity in the composition of the study data set. Therefore, prospective teachers from different departments could be included in similar studies, allowing for a broader data set to be compiled. Research areas can be enriched as new competencies are defined with advancing technology. In addition, the relationships between 21st century and CT skills defined by various organizations might be tested.Another limitation of the study is that only responses from volunteer participants were included. Therefore, the results for prospective teachers who did not volunteer for this study may differ. In this study, the variables of gender, department, grade level, and academic success were examined. Apart from these, the 21st century skills of prospective teachers can be investigated using different variables (e.g., university entrance exam scores, qualifications, competencies, economic level). The findings of the study indicate that 21st century skills have a substantial impact on CT levels and that there are strong relationships between them. Therefore, the relationships between 21st century skills and affective skills (e.g., anxiety, attitude, motivation, belief, narcissism, aversion, interest, sensitivity) could also be examined. Additionally, structural models could be developed by integrating pedagogical content knowledge about technological tools into research questions.

Future research can examine the impact of prospective mathematics and science teachers' CT skills on learning and teaching basic concepts. In particular, the contributions of prospective teachers' CT skills to the preparation of teaching materials, curriculum, and classroom management can be evaluated. As technology advances, research can be conducted to evaluate the impact of CT on the professional competencies of prospective teachers and student learning outcomes. The contributions of new technologies such as artificial intelligence, data analytics, and modeling tools to the educational process of prospective teachers could be further explored. Studies can be conducted that examine interventions offered by teacher training programs to strengthen CT skills. Research could investigate how the methods used in these programs affect prospective teachers' CT skills and which applications are more effective in developing these skills.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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References

AlAli, R., & Wardat, Y. (2024). How ChatGPT will shape the teaching learning landscape in future. *Journal of Educational and Social Research, 14*(2), 336-345. https://doi.org/10.36941/jesr-2024-0047

Avcu, Y. E., & Ayverdi, L. (2020). Examination of the computer programming self-efficacy's prediction towards the computational thinking skills of the gifted and talented students. *International Journal of Educational Methodology, 6*(2), 259-270. https://doi.org/10.12973/ijem.6.2.259

Bartolini-Bussi, M., & Baccaglini-Frank, A. (2015). Geometry in early years: Sowing seeds for a mathematical definition of squares and rectangles. *ZDM Mathematics Education, 47*(3), 391-405. https://doi.org/10.1007/s11858-014-0636-5

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., & Rumble, M. (2012). Defining 21st century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17-66). Springer.

Blackwell, C., Cummins, R., Townsend, C. D., & Cummings, S. (2007). Assessing perceived student leadership skill development in an academic leadership development program. *Journal of Leadership Education, 6*(1), 39-58. https://doi.org/10.12806/V6/I1/RF1

Can, A. (2023). *Quantitative data analysis in the scientific research process with SPSS*. Pegem Academy.

Cevik, M., & Senturk C. (2019). Multidimensional 21st century skills scale: Validity and reliability study. *Cypriot Journal of Educational Sciences*, *14*(1), 11-28.

Cropley, A. J. (2001). *Creativity in education and learning: A guide for teachers and educators.* Routledge.

Curtis, E.A., Comiskey, C., & Dempsey, O. (2016). Importance and use of correlational research. *Nurse Researcher, 23*(6), 20-25. https://doi.org/10.7748/nr.2016.e1382

Çokluk, Ö., Şekercioğlu, G., & Büyüköztürk, Ş. (2021). *Multivariate statistics for social sciences: SPSS and LISREL applications*. Pegem Academy.

Doleck, T., Bazelais, P., Lemay, D. J., Saxena, A., & Basnet, R. B. (2017). Algorithmic thinking, cooperativity, creativity, critical thinking, and problem solving: Exploring the relationship between computational thinking skills and academic performance. *Journal of Computers in Education, 4*(4), 355-369. https://doi.org/10.1007/s40692-017-0090-9

Dyer, J., Gregersen, H., & Christensen, C. M. (2019). *The Innovator's DNA, updated, with a new preface: Mastering the five skills of disruptive innovators*. Harvard Business Press.

Eagly, A. H., & Johannesen-Schmidt, M. C. (2001). The leadership styles of women and men. *Journal of Social Issues, 57*(4), 781–797. https://doi.org/10.1111/0022-4537.00241

Erdogan, N., & Bozeman, T. (2015). Models of project-based learning for the 21st century. In A. Sahin (Ed.), *A practice-based model of STEM teaching* (pp. 31-42). Sense.

Esteve-Mon, F., Llopis, M., & Adell-Segura, J. (2020). Digital competence and computational thinking of student teachers. *International Journal of Emerging Technologies in Learning, 15*(2), 29-41. https://doi.org/10.3991/ijet.v15i02.11588

Facione, P. A. (2011). *Critical thinking: What it is and why it counts*. The California Academic Press.

Fannakhosrow, M., Nourabadi, S., Ngoc Huy, D. T., Dinh Trung, N., & Tashtoush, M. A. (2022). A comparative study of information and communication technology (ICT)-based and conventional methods of instruction on learners' academic enthusiasm for L2 learning. *Education Research International, 2022*(1), 1-8. https://doi.org/10.1155/2022/5478088

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. Sage.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education*. McGraw-Hill.

Gadanidis, G., Clements, E., & Yiu, C. (2018). Group theory, computational thinking, and young mathematicians. *Mathematical Thinking and Learning, 20*(1), 32-53. https://doi.org/10.1080/10986065.2018.1403542

Gadanidis, G., Hughes, J., Minniti, L., & White, B. (2017). Computational thinking, grade 1 students and the binomial theorem. *Digital Experiences in Mathematics Education, 3*(2), 77-96. https://doi.org/10.1007/s40751-016-0019-3

Grover, S., & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher, 42*(1), 38-43. http://dx.doi.org/10.3102/0013189X12463051

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). *Multivariate data analysis*. Prentice Hall.

Halpern, D. F. (2014). *Thought and knowledge: An introduction to critical thinking*. Psychology Press.

Hershkovitz, A., Sitman, R., Israel-Fishelson, R., Eguíluz, A., Garaizar, P., & Guenaga, M. (2019). Creativity in the acquisition of computational thinking. *Interactive Learning Environments, 27*(5–6), 628-644. https://doi.org/10.1080/10494820.2019.1610451

Hussein, L. A., Alqarni, K., Hilmi, M. F., Agina, M. F., Shirawia, N., Abdelreheem, K. I., Hassan, T., & Tashtoush, M. A. (2024). The mediating role of learning management system use in enhancing system effectiveness. *WSEAS Transactions on Business and Economics, 21,* 2067-2078. https://doi.org/10.37394/23207.2024.21.169

International Society for Technology in Education [ISTE]. (2016). *ISTE Standards for students.* Author. https://iste.org/standards/students

International Society for Technology in Education & Computer Science Teachers Association [ISTE & CSTA]. (2011). *Operational definition of computational thinking for K–12 education*. Author. https://cdn.iste.org

İlhan, E., & Unal, M. (2021). An investigation of the 21st century skills use of university students in Turkey. *International Journal of Curriculum and Instruction 13*(3), 2462-2481.

Jarrah, A. M., Wardat, Y., & Fidalgo, P. (2023). Using ChatGPT in academic writing is (not) a form of plagiarism: What does the literature say?. *Online Journal of Communication and Media Technologies, 13*(4), 1-20. https://doi.org/10.30935/ojcmt/13572

Johnson, D. W., & Johnson, R. (1989). *Cooperation and competition: theory and research.* Interaction Book Company.

Jonassen, D. (2011). Supporting problem solving in PBL. *Interdisciplinary Journal of Problem-Based Learning, 5,* 95-119. https://doi.org/10.7771/1541-5015.1256

Kaup, C. F., Pedersen, P. L., & Tvedebrink, T. (2023). Integrating computational thinking to enhance students' mathematical understanding. *Journal of Pedagogical Research, 7*(2), 127-142. https://doi.org/10.33902/JPR.202319187

Kline, R. B. (2011). *Principles and practice of structural equation modeling* (3rd ed.). Guilford Press.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). A validity and reliability study of the computational thinking scales (CTS). *Computers in Human Behavior, 72,* 558-569. https://doi.org/10.1016/j.chb.2017.01.005

Leopold, T. A., Ratcheva, V. S., & Saadia, Z. (2018). *The future of jobs report 2018. World Economic Forum.* Retrieved from http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf Accessed 23.04.2024

Looi, C. K., Chan, S. W., Wu, L., Huang, W., Kim, M. S., & Sun, D. (2024). Exploring computational thinking in the context of mathematics learning in secondary schools: Dispositions, engagement and learning performance. *International Journal of Science and Mathematics Education, 22*(6), 993-1011. https://doi.org/10.1007/s10763-023-10419-1

Lumley, T., Diehr, P., Emerson, S., & Chen, L. (2002). The importance of the normality assumption in large public health data sets. *Annual Review of Public Health, 23*, 151-169. https://doi.org/10.1146/annurev.publhealth.23.100901.140546

Marshall, C., & Rossman, G. (2016). *Designing qualitative research*. Sage.

Moon, P. F., Himmelsbach, J., Weintrop, D., & Walkoe, J. (2023). Developing preservice teachers' intuitions about computational thinking in a mathematics and science methods course. *Journal of Pedagogical Research, 7*(2), 5-20. https://doi.org/10.33902/JPR.202318599

Mumcu, F., Kıdıman, E., & Özdinç, F. (2023). Integrating computational thinking into mathematics education through an unplugged computer science activity. *Journal of Pedagogical Research, 7*(2), 72-92. https://doi.org/10.33902/JPR.202318528

National Research Council (NRC). (2011). *Assessing 21st-century skills: Summary of a workshop.* National Academies Press.

Organisation for Economic Cooperation and Development (OECD). (2023). *Education at a glance 2023- OECD indicators.* Author.

Organisation for Economic Cooperation and Development (OECD). (2019). *OECD future of education and skills 2030: OECD learning compass 2030.* Author.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* Basic Books.

Partnership for 21st Century Learning [P21]. (2019). *Framework for 21st century learning. A network of battelle for kids*. Author.

Paul, R., & Elder, L. (2006). *Critical thinking: learn the tools the best thinkers use.* Pearson Prentice Hall.

Rodríguez-Martínez, J. A., González-Calero, J. A., & Sáez-López, J. M. (2020). Computational thinking and mathematics using Scratch: An experiment with sixth-grade students. *Interactive Learning Environments, 28*(3), 316-327. https://doi.org/10.1080/10494820.2019.1612448

Savickas, M. L. (2005). The theory and practice of career construction. In S. D. Brown & R. W. Lent (Eds.), *Career development and counseling: Putting theory and research to work* (pp. 42–70). John Wiley & Sons.

Shute, V., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review, 22*(1), 142-158. https://doi.org/10.1016/j.edurev.2017.09.003

Sneider, C., Stephenson, C., Schafer, B., & Flick, L. (2014). Computational thinking in high school science classrooms. *The Science Teacher, 81*(5), 10-15. https://doi.org/10.2505/4/tst14_081_05_53

Sung, W., Ahn, J., & Black, J. B. (2017). Introducing computational thinking to young learners: Practicing computational perspectives through embodiment in mathematics education. *Technology, Knowledge and Learning, 22*(2), 443-463. https://doi.org/10.1007/s10758-017-9328-x

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics*. Pearson.

Tabesh, Y. (2017). Computational thinking: A 21st century skill. *Olympiads in Informatics, 11*(2), 65-70. https://doi.org/10.15388/ioi.2017.special.10

Tashtoush, M. A., AlAli, R., Wardat, Y., Alshraifin, N., & Toubat, H. (2023). The impact of information and communication technologies (ICT)-based education on the mathematics academic enthusiasm. *Journal of Educational and Social Research, 13*(3), 284-293. https://doi.org/10.36941/jesr-2023-0077

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times.* John Wiley & Sons.

Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of the 21st century. *Journal of Computer Assisted Learning, 29*(5), 403-413. https://doi.org/10.1111/jcal.12029

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299-321. https://doi.org/10.1080/00220272.2012.668938

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review, 29*(1), 119-140. https://doi.org/10.1007/s10648-015-9355-x

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*(1), 127-147. https://doi.org/10.1007/s10956-015-9581-5

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35. https://doi.org/10.1145/1118178.1118215

Wing, J. M. (2008a). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, 366*(1881), 3717-3725. https://doi.org/10.1098/rsta.2008.0118

Wing, J. M. (2008b). Five deep questions in computing. *Communications of the ACM, 51*(1), 58-60. https://doi.org/10.1145/1327452.1327479

World Economic Forum [WEF]. (2016). *New vision for education: Fostering social and emotional learning through technology.* Author.

Yadav, A., Ocak, C., & Oliver, A. (2022). Computational thinking and metacognition. *TechTrends, 66*(3), 405-411. https://doi.org/10.1007/s11528-022-00695-z

Ye, H., Liang, B., Ng, O. L., & Chai, C. S. (2023). Integration of computational thinking in K-12 mathematics education: A systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education, 10*(1), 1-26. https://doi.org/10.1186/s40594-023-00396-w

Yıldırım, A., & Şimşek, H. (2021). *Qualitative research methods in the social sciences*. Seçkin.