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Examining the Relationship between Computational Thinking, 21st century Skills, and Digital Literacy Levels among Students in Health Education

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ABSTRACT

Background: 21st century skills are critical for health professionals to adapt to a changing world. ***Purpose*:** This study was conducted to examine the relationship between computational thinking, digital literacy, and 21st century skills among students in health education. ***Methods*:** This descriptive and cross-sectional study was conducted with 778 students enrolled at the Faculty of Health Sciences in a province in eastern Turkey between July 2024 and December 2024. Computational thinking scale, digital literacy scale and 21st century skills scale were used in the study. ***Results*:** Correlation analyses showed that digital literacy was moderately and positively correlated with computational thinking (r =0.529, *p <0.001*) and multidimensional 21st century skills (r = 0.477, p < 0.001). Computational thinking also demonstrated a moderate positive correlation with multidimensional 21st century skills (r =0.441, *p <0.001*). Hierarchical regression analysis indicated that computational thinking and digital literacy together significantly predicted multidimensional 21st century skills, accounting for 27.7% of the variance (R^2=*0.277*). Both predictors showed significant positive standardized effects (computational thinking: β =0.262, *p <0.001*; digital literacy: β =0.338, *p <0.001*). ***Conclusion*:** The findings suggest that in order to develop 21st century skills in health education, it is necessary to support algorithmic thinking and digital literacy as a combined effort. ***Implications for Nursing*:** Nursing curricula should incorporate algorithmic thinking and the use of digital tools holistically; clinical and applied courses should provide learning opportunities in which students can apply 21st century skills in real-life contexts.

Keywords: Health education, Computational thinking, Digital literacy, 21st century skills.

What does this paper add?

1. This study provides empirical evidence that computational thinking and digital literacy both significantly and positively predict 21st century skills among health education students.
2. It shows that the combined effect of these two factors explains more variance in 21st century skills than either factor alone, highlighting their complementary and interactive nature.
3. These findings emphasise the importance of integrating digital literacy and computational thinking into the health education curriculum,

ensuring that students are prepared for the digital transformation of healthcare.

Introduction

In today's information age, digital transformation is reshaping every field at a rapid pace. The healthcare sector and health education are among the areas most profoundly affected by this change. The growing importance of software and technology at every stage of life (Nouri et al., 2020) means that individuals must be able to critically understand technological systems, produce effective solutions to complex problems, and intervene in these systems (Rehmat et al., 2020). This is of particular importance for educational programmes training future health professionals. Indeed, the evolving healthcare landscape necessitates that healthcare professionals are adaptable and embrace lifelong learning (Coumans & Wark, 2024). In this context, healthcare education students must possess 21st century competencies, such as problem solving, analytical thinking and digital skills, as well as professional competencies (Buchanan et al., 2021).

Computational thinking (CT) skills are among the most important competencies for solving complex problems, effectively utilizing technological innovations, and keeping pace with digital transformation (Palop et al., 2025). Wing (2008) defined computational thinking as a critical foundational cognitive skill for 21st century learning processes. Computational thinking is the ability to analyze and solve problems in daily life using computer-assisted approaches (Şahiner & Kert, 2016). CT is accepted as a necessary competency for problem solving (Hsu et al., 2018), and has been reported to enhance problem-solving abilities, making individuals more productive in higher education (Czerkawski & Lyman, 2015). CT significantly improves decision-making processes and the design of more effective research, particularly for healthcare professionals working with big data (Saqr & Tedre, 2019). A study in the United States emphasized that these skills affect students' collaboration, communication, and problem-solving abilities globally (Gretter & Yadav, 2016). However, while it is important to determine the level of computational thinking skills required in the digital age (Korkmaz et al., 2017), few studies have addressed this topic among health education students (Lin et al., 2024).

Another fundamental skill closely related to computational thinking is digital literacy (DL). As a 21st century skill, DL enables individuals to access accurate information in the digital age. It includes the ability to access, evaluate, and present information by effectively using different digital technologies (Hamadneh, 2023; Silik & Aydın, 2021). Health education students have the potential to adapt to rapidly changing conditions and acquire 21st century skills, such as digital literacy. These skills help students develop the ability to create electronic documentation, communicate effectively, collaborate, and search for evidence to improve patient care quality (Kaya & Üstüner Top, 2024). For instance, the active use of technology by health education students has been shown to improve clinical decision-making skills (Tarhan & Uslu, 2024).

Both computational thinking and DL are considered part of a broader set of 21st century skills. 21st century skills can generally be grouped into learning-focused skills (such as creativity, critical thinking, communication, and collaboration), digital and media literacy skills, and competencies related to life and career development (Nouri et al., 2020). One of the fundamental goals of educational institutions is to equip students with these skills, so that they can succeed in the workplace, in their social lives, and in active participation in a democratic society (Dishon & Gilead, 2021; McGunagle & Zizka, 2020). Skills are believed to facilitate students' transition into the workforce and daily life after graduation (Lauder & Mayhew, 2020). It is important to determine students' perceptions and dispositions towards these skills (Valtonen et al., 2021).

In conclusion, this study is based on the increasing impact of digital transformation in the healthcare sector and the critical importance of 21st century skills for healthcare professionals. A literature review (Nouri et al., 2020) revealed that there are very few studies examining the concepts of computational thinking (CT) and DL simultaneously in healthcare education students, and to the authors' knowledge, there are no published studies in Turkey examining the relationships between CT, DL, and 21st century skills in healthcare education students. Therefore, this study aims to determine the relationship between computational thinking, digital literacy, and 21st century skills among health education students. The research findings are expected to contribute to updating the health education curricula in line with the requirements of the digital age and to enhancing students' professional competencies.

Methods

Design and Sample

This cross-sectional and descriptive study was conducted with students studying at the Faculty of Health Sciences between July 2024 and December 2024.

Research Setting

The study population consists of 910 undergraduate students enrolled in the Nursing, Midwifery, and Physical Therapy and Rehabilitation Departments of the Faculty of Health Sciences at a university in eastern Turkey. The minimum sample size required for the known population size was calculated using the Krejcie and Morgan formula with a 95% confidence interval and a 5% margin of error (($n = N*t^2*p*q/(d^2(N-1) + t^2*p*q$); $t = 1.96$, $p = .5$, $q = 0.5$, $d = 0.05$, $N = 910$) (Krejcie & Morgan, 1970). The calculation resulted in a minimum sample size of 276 for the study. This study aims to reach the entire population. In this study, convenience sampling was used. All eligible students enrolled during the study period were invited to participate in the research. Data was collected by reaching out to students during regular classes throughout all academic years, thus ensuring that no department or grade level was systematically excluded. The study included undergraduate students from the Faculty of Health Sciences who, according to their own statements, did not have any psychiatric disorders and voluntarily agreed to participate. A total of 778 students participated, which met the minimum required sample size. Under assumptions of a medium effect size and a 95% confidence interval, the study was calculated to have 99% statistical power (Cohen, 1992).

Measures and Data Collection

Demographic Information Questionnaire: The researchers prepared a personal information form with questions about demographic characteristics.

Digital Literacy Scale (DLS): The scale was first developed by Ng (2012) and adapted into Turkish by (Ng, 2012; Üstündağ et al., 2017). The scale consists of 10 items with a single-factor structure and is answered using a 5-point Likert-type scale. In the Turkish adaptation study, the Cronbach's alpha reliability coefficient of the scale was reported as 0.86 (Üstündağ et al., 2017). In this study, we found that Cronbach's alpha value was 0.88.

Computational Thinking Scale (CTS): The CTS is a way to measure how students think about computational thinking. It was created by Tsai et al. (2021) and designed based on ideas from Selby and Woollard (2013), such as thinking in an abstract way, breaking things down, thinking like an algorithm, evaluating and generalising (Selby & Woollard, 2013; Tsai et al., 2021). The scale has 19 questions with Likert-type answers ranging from "Strongly agree (5)" to "Strongly disagree (1)". The scale produces scores ranging from 19 to 95. The scale has five smaller parts: thinking in a general way, breaking things down, using algorithms, judging things and using ideas in new situations. Gök and Karamete performed the validity and reliability tests on the scale in the Turkish population. Gök and Karamete (2023) determined the Cronbach's alpha reliability coefficient of the scale as 0.84. This study found that Cronbach's alpha value was 0.90.

Multidimensional 21st Century Skills Scale: The researchers used the Multidimensional Twenty-First Century Skills Scale that Cevik and Şentürk developed in 2019 (Cevik & Senturk, 2019). The Likert scale has five parts and 41 questions. The possible score range is between 41 and 205. Items 16, 17, 18, 19, 20, 21 and 35 are reverse items. Scale evaluation: 41-82= Low level of 21st century skills, 83-123= Medium level of 21st century skills, 124-164= Good level of 21st century skills and 165-205= High level of 21st century skills. The alpha coefficient for the overall scale was found to be 0.86. (Cevik & Senturk, 2019). This study found that Cronbach's alpha value was 0.87.

Data Collection

The data for this study was collected using face-to-face interviews during class hours. As stated in the population and sample part, students who attended classes during the study period and met the criteria for participation in the research were invited to participate in the research during regular classes. Students were informed about the purpose of the study, that participation was voluntary, and that the questionnaire would take approximately 7-10 minutes to complete. Questionnaire forms were distributed to students who verbally agreed to participate. Written consent was obtained from the participants, and informed consent forms were signed. Before starting the survey, it was clearly stated that participants could withdraw from the

study at any time or refuse to answer questions if they felt uncomfortable. Ethical principles were strictly adhered to throughout the data collection process, and no personal identification information was requested on the survey forms.

Data Analysis

This study analyzed data using the SPSS 27.0 program. The standard distribution of the information was reviewed using skewness and kurtosis values ranging from -1.5 to +1.5 (Tabachnick et al., 2007). Participants' demographic characteristics were presented using frequency and percentage distributions, and scale scores were presented using mean, standard deviation, and minimum-maximum values. Independent sample t-tests and one-way ANOVA were used for group comparisons, and Tukey HSD tests were used to identify significant differences. Pearson correlation analysis examined the relationships between variables. Parametric assumptions were verified prior to performing regression analysis. The normality of the residuals was verified using histograms and P-P plots. Multicollinearity was confirmed by ensuring that the VIF was less than 10. We verified variance homogeneity and autocorrelation by ensuring that the Durbin-Watson statistic was approximately 2 (Flatt & Jacobs, 2019). Hierarchical regression was performed to predict 21st century multidimensional skills. In the hierarchical regression analysis, CTS was included in the model in the first stage due to its established role in the theoretical literature as a fundamental cognitive component of 21st century skills; DLS was added in the second stage to determine its specific and incremental contribution beyond CTS. In regression analyses, dummy variable coding was used to ensure that demographic variables with a categorical structure could be appropriately included in the model. In this context, each variable was coded as a k-1 dummy variable and included in the hierarchical regression analysis. No missing data was identified in the dataset; therefore, all cases were included in the statistical analyses. Scale reliability was verified using Cronbach's alpha ($p \leq 0.05$, significant).

Ethical Considerations

The study received ethical approval from the University's Scientific Research and Publication Ethics Committee (Approval Date/No.: 18.07.2024-149998). Following this, institutional authorization (Approval Date/No.: 20.09.2024-583505) was secured from the respective organization where the research was to be conducted. The participants were furnished with exhaustive information regarding the objectives and methodology of the study, as well as the time commitment required for participation. It was emphasized that no harm would be caused by participation and that it would be entirely voluntary. The Helsinki Declaration of Human Rights was upheld and the protection of people's rights was made the most important thing. Written informed consent was obtained from all participants before data collection.

Results

As seen in Table 1, the mean age of the participants was 21.54±2.14 years. It was determined that 71.3% of the participants were female, 69.2% were nursing students, 31.1% were first-year students, 36.2% had one day of clinical practice and 30.3% had practice in a surgical or an internal clinic (Table 1).

Table 1. Descriptive characteristics of individuals (n=778)

Demographic Characteristics		n	%
Gender	Male	223	28.7
	Female	555	71.3
Department of Study	Nursing	538	69.2
	Midwifery	145	18.6
	Physiotherapy & Rehabilitation	95	12.2
Class of Study	Grade 1	242	31.1
	Grade 2	170	21.9
	Grade 3	216	27.8
	Grade 4	150	19.3
Number of days in clinical practice	I don't do clinical practice	278	35.7
	1 day	282	36.2
	1.5 days	28	3.6

	2 days	136	17.5
	4 days	54	6.9
Clinical practice	I don't do clinical practice	278	35.7
	Internal/Surgical Clinics	236	30.3
	Intensive Care Clinics	35	4.5
	Operating Room	15	1.9
	Other (Emergency, Outpatient Clinic, Family/Rehabilitation Health Center)	214	27.5
	M ± SD (Min. – Max.)		
Age (Years)	21.54 ± 2.14 (18 - 45)		

M: Mean. SD: Standard Deviation.

Digital literacy scores showed significant differences in terms of gender (t = 2.610; p = 0.009), field of study (F = 6.149; *p = 0.002*), grade level (F = 3.384; *p = 0.018*), number of clinical practice days (F = 3.830; *p = 0.004*), and clinical practice field (F = 2.792; *p =0.025*). Male students' digital literacy scores (M = 36.52; SD = 6.50) were found to be higher than female students' scores (M = 35.16; SD = 6.61). Subsequent analyses revealed that nursing students (M = 36.07; SD = 6.07) scored higher than physical therapy and rehabilitation students (M = 33.78; SD = 8.01). In analyses based on the number of clinical practice days, students participating in clinical practice four days per week (M = 37.03; SD = 7.41) scored higher than students participating 1.5 days per week (M = 32.89; SD = 7.60). The same analyses determined that fourth-year students scored higher than first-year students in terms of digital literacy, computational thinking, and multidimensional 21st century skills (a<d). In analyses based on clinical practice, students in "other" clinical practice settings scored higher on both the DLS and CTS compared to students who did not participate in clinical practice (a<e). CTS scores showed significant differences based on grade level (F = 5.263, *p = 0.001*), number of clinical practice days (F = 3.840, p = 0.004), and clinical practice area (F = 4.099, *p = 0.003*). Subsequent analyses revealed that students who participated in clinical practice twice a week (M = 73.44; SD = 8.49) scored higher than students who did not participate in clinical practice (M = 70.51; SD = 10.02). Significant differences were found in multidimensional 21st century skill scores based on grade level (F = 11.232; *p =0.001*) and number of clinical practice days (F = 9.602; p=0.001). Subsequent analyses regarding the number of clinical practice days revealed that students participating in clinical practice two days per week (M = 156.06; SD = 15.16) and four days per week (M = 162.12; SD = 13.26) scored higher than those not participating in clinical practice (M = 150.31; SD = 17.35), those who participated one day per week (M = 149.84; SD = 16.40), and those who participated 1.5 days per week (M = 149.39; SD = 11.24) (Table 2).

Table 2. Comparison of total DLS, CTS, and 21st century skill scores according to students' socio-demographic characteristics (n=778)

Demographic Characteristics		DLS M ± SD	Testing and p	CTS M ± SD	Testing and p	Multidimensional 21st century Skills Scale M ± SD	Testing and p
Gender	Male	36.52 ± 6.50	t= 2.610	72.42 ± 9.78	t= 1.913	151.78 ± 18.38	t= -0.155
	Female	35.16 ± 6.61	*p=**0.009***	70.97 ± 9.40	*p=0.056*	151.99 ± 15.77	*p=0.877*
Department of Study	Nursing[a]	36.07 ± 6.07	F= 6.149	71.63 ± 9.32	F= 0.676	151.49 ± 16.85	F= 0.621
	Midwifery[b]	34.77 ± 7.24	*p=**0.002***	70.62 ± 8.93	*p=0.509*	152.82 ± 14.85	*p=0.538*
	Physiotherapy[c] and rehabilitation	33.78 ± 8.01	c<a	71.15 ± 11.42		153.07 ± 17.32	
Class of Study	Grade 1[a]	34.66 ± 6.93	F= 3.384	70.26 ± 9.95	F= 5.263	150.13 ± 17.46	F=
	Grade 2[b]	35.50 ± 6.58	*p=**0.018***	71.67 ± 9.42	*p=0.001*	149.87 ± 15.93	11.232
	Grade 3[c]	35.68 ± 6.18	a<d	70.66 ± 9.14	a<d	150.80 ± 16.39	*p=0.001*
	Grade 4[d]	36.83 ± 6.53		73.94 ± 9.08		158.81 ± 14.15	a<d

Number of days in clinical practice	I don't do clinical practice[a]	34.74 ± 6.91	F= 3.830 *p=**0.004***	70.51 ± 10.02	F= 3.840 *p=**0.004***	150.31 ± 17.35	F= 9.602 *p=0.001*
	1 day[b]	35.83 ± 6.11	c<e	70.91± 9.48	a<d	149.84 ± 16.40	a,b,c<d,e
	1.5 days[c]	32.89 ± 7.60		69.50 ± 6.84		149.39 ± 11.24	
	2 days[d]	36.56 ± 6.12		73.44 ± 8.49		156.06 ± 15.16	
	4 days[e]	37.03 ± 7.41		74.20 ± 9.77		162.12 ± 13.26	
Clinical practice	I don't do clinical practice[a]	34.74 ± 6.91	F= 2.792 *p=**0.025***	70.51 ± 10.02	F= 4.099 *p=**0.003***	150.31 ± 17.35	F= 1.677 *p=0.153*
	Internal/Surgical Clinics[b]	35.81 ± 6.43	a<e	71.56 ± 9.22	a<e	152.58 ± 15.06	
	Intensive Care Clinics[c]	36.28 ± 5.95		70.22 ± 9.16		149.17 ± 21.59	
	Operating Room[d]	32.73 ± 7.98		64.80 ± 9.59		151.80 ± 15.44	
	Other (emergency, outpatient clinic, Family/rehabilitation Health Center)[e]	36.38 ± 6.27		72.99 ± 8.96		153.78 ± 16.09	

[a]*t: Independent Sampde T-test;* [b]*F: One-way ANOVA; M: Mean; SD: Standard Deviation; *p<0.05; post hoc analysis: Tukey HSD;* DLS: Digital Literacy Scale; CTS: Computational Thinking Scale.

Table 3 presents the findings of the correlation analysis regarding the mean, minimum-maximum values of students' DLS, CTS, and multidimensional 21st century skill scores. The skewness and kurtosis values of the variables indicate that the data is normally distributed. According to the correlation analysis results, a moderate and positive significant relationship was found between DLS and CTS ($r = 0.529$; $p < 0.001$). Additionally, it was determined that multidimensional 21st century skills showed moderate, positive, and statistically significant correlations with both DLS ($r = 0.477$; $p < 0.001$) and CTS ($r = 0.441$; $p< 0.001$) (Table 3).

Table 3. Descriptive statistics and correlation analysis results regarding DLS, CTS, and 21st century skills scores (n = 778)

Variables	M ± SD	Min - Max	Skewness	Kurtosis	1	2	3
DLS	35.55 ± 6.60	10 - 50	-0.200	0.272	1		
CTS	71.39 ± 9.52	45 - 95	-0.137	0.292	*r= 0.529* *p=0.001*	1	
Multidimensional 21st Century Skills	151.93 ± 16.55	96 - 201	0.040	0.071	*r= 0.477* ***p=0.001***	*r= 0.441* *p=0.001*	1

r: Pearson correlation; M: Mean; SD: Standard Deviation; DLS: Digital Literacy Scale; CTS: Computational Thinking Scale; (r = 0.00-0.19 very weak, r = 0.20-0.39 weak, r = 0.40-0.59 moderate, r = 0.60-0.79 strong, and r = 0.80-1.00 very strong).

The results of the statistical analysis of Model 1 show that it is both significant and usable (F = 187.813, $p = 0.001$). The degree to which computational thinking is employed accounts for 19.5% of the total variance in the multidimensional 21st century skill level ($R^2=0.195$). When the t-test findings concerning the importance of the regression coefficient in the regression model were reviewed, it was established that the rise in the CTS level of the subjects (t= 13.704, $p<0.001$) resulted in a substantial rise in the multidimensional 21st century skill score (Table 4).

The numbers in Model 2 also show that the model is important and can be used (F= 88.403, $p =0.001$). CTS and DLS levels account for 27.7% of the total variance in multidimensional 21st century skills. In the regression model, an analysis of the t-test results regarding the significance of the regression coefficient revealed that an enhancement in the CTS (t= 7.292, $p<0.001$) and DLS (t= 9.402, $p< 0.001$) levels of the participants gave rise to a substantial augmentation in the multidimensional 21st century skill score (Table 4).

The results of the statistical analysis conducted for Model 3 indicate that the model is meaningful and suitable for use (F = 3.076, $p<0.001$). When computational thinking, digital literacy, and sociodemographic variables were included simultaneously as dummy variables, the model explained 31.3% of the variance in multidimensional 21st century skills ($R^2 =0.313$), which corresponds to a 3.6% increase compared to Model 2. Both

computational thinking (t = 6.992, *p<0.001*) and digital literacy (t = 9.719, *p<0.001*) remained statistically significant predictive factors, while among the sociodemographic variables, only the "other" clinical practice setting showed a significant effect (t = −2.312, *p =0.021*) (Table 4).

Table 4. The effects of CTS and DLS on multidimensional 21st century skills (n=778)

Model	Predictive Variables	Multidimensional 21st Century Skills (Dependent variable)										
		B	*SD*	*β*	*t*	*p**	95.0% Confidence Interval for B					
							Lower Bound	Upper Bound	VIF	Durbin-Watson	R^2	R^2 Change
Model 1	**CTS**	.767	.056	.441	13.704	***.001***	.657	.877	1.000	0.804	*.195*	0.195
Model 2	**CTS**	.456	.063	.262	7.292	***.001***	.333	.579	1.389	0.854	*.277*	0.082
	DLS	.848	.090	.338	9.402	***.001***	.671	1.025	1.389			
Model 3	**CTS**	.436	.062	.251	6.992	*.001*	.314	.558	1.430			
	DLS	.876	.090	.350	9.719	*.001*	.699	1.053	1.437			
Gender	**"Male"**	-	-	-	-	-	-	-	-			
	Female	1.196	1.189	.033	1.006	*.315*	-1.138	3.531	1.172			
Department of study	**"Midwifery"**	-	-	-	-	-	-	-	-			
	Nursing	-.839	2.020	-.023	-.415	*.678*	-4.805	3.128	3.531			
	Physiotherapy and Rehabilitation	3.386	2.361	.067	1.434	*.152*	-1.248	8.019	2.422			
Class of study	**"Grade 1"**	-	-	-	-	-	-	-	-			
	Grade 2	-4.899	3.180	-.122	-1.541	*.124*	-11.142	1.343	7.002			
	Grade 3	-2.311	3.159	-.063	-.732	*.465*	-8.512	3.889	8.114			
	Grade 4	.566	4.257	.013	.133	*.894*	-7.792	8.924	11.438	0.890	*0.313*	0.036
Number of days in clinical practice	**"1 day"**	-	-	-	-	-	-	-	-			
	I don't do clinical practice	-4.102	3.406	-.119	-1.204	*.229*	-10.789	2.585	10.804			
	2 days	1.546	2.941	.035	.526	*.599*	-4.228	7.320	5.059			
	1.5 days	3.116	3.524	.035	.884	*.377*	-3.802	10.035	1.747			
	4 days	4.859	4.767	.075	1.019	*.308*	-4.499	14.218	5.952			
Clinical practice	**"Internal/Surgical Clinics"**	-	-	-	-	-	-	-	-			
	I don't do clinical practice	-4.102	3.406	-.119	-1.204	*.229*	-10.789	2.585	10.804			
	Intensive Care Clinics	-3.017	2.596	-.038	-1.162	*.246*	-8.114	2.080	1.174			
	Operating Room	1.814	3.779	.015	.480	*.631*	-5.605	9.232	1.095			
	Other	-3.392	1.467	-.092	-2.312	*.021*	-6.273	-.511	1.741			

Hierarchical Regression Analysis*. *p < 0.001; DLS: Digital Literacy Scale; CTS: Computational Thinking Scale; In regression analyses. the effect size is small when $R^2 \approx 0.02$. medium when $R^2 \approx 0.13$. and large when $R^2 \geq 0.26$.

Discussion

This study found significant differences in scale total scores for certain sociodemographic variables. The correlation analysis revealed a positive and significant relationship between DLS, CTS, and 21st century skills. Furthermore, the hierarchical regression analysis showed that DLS and CTS together explained a significant portion of the variance in 21st century skills and that this relationship persisted even when sociodemographic variables were controlled for. Within this framework, the findings of the study were discussed in light of the relevant literature.

This study has revealed that students with a high level of digital literacy tend to demonstrate 21st century skills at a higher level. This relationship between digital literacy and 21st century skills can be explained by the nature of digital literacy, which involves processes, such as information management, online communication, and digital collaboration. Research shows that the development of digital literacy skills positively contributes to students' processes of acquiring and applying 21st century skills. One study shows that individuals with a high level of digital literacy may also have higher levels of 21st century skills (Kuloğlu, 2022). This relationship is supported by studies showing that digital literacy is linked to developments in critical thinking (Alakrash & Abdul Razak, 2021), and may be related to increased learning motivation (Abdul Rahman et al., 2023). Digital literacy is considered a fundamental requirement for cognitive learning outcomes (Kivunja,

2015), and its integration with 21st century skills is emphasized as potentially helping students achieve their learning goals (Ufondu et al., 2024). Therefore, increasing students' interaction with technology is recommended to support the development of both skill sets (Özer & Kuloğlu, 2023). The diversity and interaction offered by digital learning environments can support learners' motivation and participation levels. This situation can be considered a possible explanation for the observed relationship between digital literacy and 21st century skills.

Another finding of this study is that students with a high level of computational thinking tend to demonstrate 21st century skills at a higher level. This correlation between computational thinking and 21st century skills can be explained by the cognitive orientations underlying computational thinking. Processes, such as breaking problems down into parts, recognizing patterns, abstracting, and algorithmic reasoning, are closely related to 21st century competencies, such as problem solving, critical thinking, and adaptability. It can be said that students with a high level of computational thinking approach learning tasks more systematically and strategically. This approach also aligns with skills, such as decision-making and creative problem-solving. This finding is consistent with various studies in the literature. For example, frameworks developed to analyze computational thinking in game design workshops suggest that the development of this skill can support the development of 21st century skills (de Souza et al., 2019). Similarly, assessing computational thinking in reasoning and programming contexts has the potential to reveal learning processes associated with these broader competencies (Li et al., 2020). Furthermore, students with higher computational thinking skills tend to exhibit more advanced 21st century skills (Ghanizadeh, 2017).

Another key finding of this study is that computational thinking and digital literacy are jointly related to 21st century skills and exhibit a synergistic predictive model beyond the variance explained by each variable individually. Hierarchical regression analysis showed that computational thinking alone explained approximately 20% of the variance in 21st century skills. With the addition of the digital literacy variable to the model, the explained variance increased significantly, and the two variables together explained approximately 28% of the total variance. These results suggest that, as proposed in theoretical frameworks, the two concepts may be closely related and their explanatory pathways may overlap. It can be argued that digital literacy can provide contextual support for the application of computational thinking in learning environments. The critical importance of this synergy is becoming even more apparent with the proliferation of advanced technologies, such as artificial intelligence, in fields, such as healthcare. For example, a study conducted by Algunmeeyn and Mrayyan (2025) on nursing students revealed that fundamental competencies, such as data literacy, critical thinking, and digital tool proficiency, are necessary for the ethical and effective use of artificial intelligence. These findings indicate that advanced AI applications are built upon the foundations of computational thinking (e.g., algorithmic reasoning) and digital literacy (e.g., using digital tools and data) measured in this study. Therefore, this observed interaction constitutes a fundamental skill set that prepares students in the field of health education, not only academically, but also to adapt to new generation technologies, such as artificial intelligence and use them in their professional practice (Algunmeeyn & Mrayyan, 2025). The literature shows that computational thinking improves problem solving and cognitive productivity (Czerkawski & Lyman, 2015; Hsu et al., 2018), while digital literacy supports communication, information management, and collaboration skills (Kuloğlu, 2022; Silik & Aydın, 2021). The findings of this study reveal that the intersection of these two skills is a critical mechanism in the development of 21st century skills.

Study Limitations

This study has certain limitations. Since the research was conducted among students of a university's Faculty of Health Sciences, the findings cannot be generalized to the entire health education population. Furthermore, since participation was voluntary, potential selection bias cannot be ignored, as students with a greater interest in technology or learning were more likely to participate. The cross-sectional research design does not allow for the interpretation of causal relationships between variables. Therefore, the findings should be interpreted as reflecting relationships rather than causal effects. The use of self-report scales as a data collection method raises the possibility of social desirability bias. Furthermore, the study did not control for potential confounding variables, such as prior technology

experience, socioeconomic status, and educational background, which could influence digital literacy and computational thinking.

Implications for Nursing

The results of this study indicate that health education must adapt to digital transformation by comprehensively integrating digital literacy and computational thinking skills into educational programs. To enable students to develop 21st century skills, such as the effective use of digital tools, data-driven decision-making, problem-solving, and collaboration. These skills must be supported in both theoretical and practical courses. Effectively using digital platforms and simulations in clinical practice can strengthen students' technological proficiency, critical thinking, and decision-making skills. Restructuring health education curricula to include innovative learning strategies focused on digital literacy and computational thinking will help students become competent and adaptable professionals in digital health environments. Furthermore, considering that the sample consisted of nursing students, the findings suggest that digital literacy and computational thinking are closely related to the development of 21st century skills, particularly in nursing education.

Conclusion

The findings of this study indicate that computational thinking and digital literacy are meaningfully associated with multidimensional 21st century skills among health sciences students, predominantly nursing students, and that these two competencies demonstrate stronger explanatory value when considered together rather than in isolation. Importantly, this relationship remained robust even after sociodemographic characteristics were incorporated into the regression model through dummy variables, suggesting that digital literacy and computational thinking are central competencies beyond basic demographic differences. Differences observed across class level and clinical practice experience further highlight the role of educational progression and practice-based learning in shaping digital and cognitive skill development. From a nursing education perspective, these findings underscore the importance of integrating computational thinking and digital literacy in a complementary manner within both classroom instruction and clinical training. Such an approach may support the preparation of nursing students for professional practice in increasingly digital and technology-intensive healthcare environments. Future nursing research may benefit from longitudinal, multi-center, or intervention-based designs to better understand how these competencies develop over time and how targeted educational strategies can effectively support them.

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Data Availability

The data is available upon reasonable request from the corresponding author.

Conflıct of Interests

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Ethics Approval and Consent to Participate

The study was approved by Muş Alparslan University Scientific Research and Publication Ethics Committee (Date and Number: 18.07.2024-149998). After ethical approval, institutional permission (Date and Number: 20.09.2024-584505) was obtained from the institution where the study would be conducted. Participants were given detailed information about the purpose and method of the study and the time required for participation. It was also emphasized that participation would not cause any harm and was entirely voluntary. The Helsinki Declaration of Human Rights was adhered to and the protection of individual rights was prioritized. Participants gave their written consent based on this information.

Authors' Contributions

Study Design: **YS, MFY, NÇ**. Data Collection: **YS, MFY, GA**. Data Analysis: **YS, MY**. Study Supervision: **YS, MAA**. Manuscript Writing: **YS, MY, MFY, MAA, GA, NÇ**. Critical Revisions for Important Intellectual Content: **YS, MY, MFY, MAA, GA, NÇ**.

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