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Investigating the Relationship between Primary School Teachers' Computational Thinking Skills, STEM Implementation Self-Efficacy, and 21st Century Skills Self-Efficacy Perception Levels

Sınıf Öğretmenlerinin Bilgi İşlemsel Düşünme Beceri, STEM Uygulama Öz Yeterlik ve 21. Yüzyıl Becerileri Öz Yeterlik Algı Düzeyleri Arasındaki İlişkinin İncelenmesi

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Abstract: The aim of this study is to examine the relationship between primary school teachers' 21st century skills self-efficacy levels and their computational thinking skills and STEM implementations self-efficacy levels. The sample of the study consists of 440 primary school teachers. While determining the sample of the research, convenience sampling technique, one of the purposeful sampling methods, was used. In order to collect data within the scope of the research, "Personal Information Form", "STEM Implementations Teacher Self-Efficacy Scale", "Computational Thinking Skill Scale" and "21st Century Skills Self-Efficacy Perception Scale" were applied. SPSS 22 package program was used to analyze the data obtained in the study. Since the data of the research showed normal distribution, Pearson correlation and multiple regression were analyzed. According to the results of Pearson correlation analysis conducted in this study, it was determined that there was a weak positive relationship between STEM implementations self-efficacy variable and 21st century skills self-efficacy computational thinking skills variables. In addition, it was determined that the relationship between the 21st century skills self-efficacy variable and the computational thinking skills variable was positive and moderate. According to the results of multiple regression, it was determined that primary school teachers' computational thinking and 21st century skills self-efficacy levels significantly predicted STEM implementations teacher self-efficacy level. As a result, it was determined that 21st century skills self-efficacy and computational thinking skills affect STEM implementation self-efficacy levels.

Key Words: Primary school teachers, STEM implementation self-efficacy, 21st century skills, computational thinking skills

Öz: Bu araştırmanın amacı, sınıf öğretmenlerinin 21. yüzyıl becerileri öz yeterlik düzeyleri ve bilgi işlemsel düşünme becerileri ile STEM uygulamaları öz yeterlik düzeyleri arasındaki ilişkiyi incelemektir. Araştırmanın örneklemini 440 sınıf öğretmeni oluşturmaktadır. Araştırmanın örneklemi belirlenirken amaçlı örnekleme yöntemlerinden uygun örnekleme tekniği kullanılmıştır. Araştırma kapsamında verilerin toplanması maksadıyla öğretmenlere ait "Kişisel Bilgi Formu" ile "STEM Uygulamaları Öğretmen Özyeterlik Ölçeği", "Bilgi İşlemsel Düşünme Beceri Ölçeği" ve "21. Yüzyıl Becerileri Özyeterlik Algı Ölçeği" uygulanmıştır. Araştırmada elde edilen verilerini analiz etmek amacı ile SPSS 22 paket programı kullanılmıştır. Araştırmanın verileri normal dağılım gösterdiği için Pearson korelasyon ve çoklu regresyon uygulanarak analiz edilmiştir. Bu çalışma da yapılan Pearson korelasyon analiz sonuçlarına göre STEM uygulamaları öz yeterlik değişkeni ile 21. yüzyıl becerileri öz yeterlik bilgi işlemsel düşünme becerileri değişkenleri arasında pozitif yönlü zayıf bir ilişkinin olduğu belirlenmiştir. Ayrıca 21. yüzyıl becerileri öz yeterlik değişkeni ile bilgi işlemsel düşünme becerisi değişkeni arasındaki ilişkinin ise pozitif yönlü orta düzeyde olduğu tespit edilmiştir. Çoklu regresyon sonuçlarına göre ise sınıf öğretmenlerinin bilgi işlemsel düşünme ve 21. yüzyıl becerileri öz yeterlik düzeyleri, STEM uygulamaları öğretmen öz yeterlik düzeyini anlamlı düzeyde yordadığı tespit edilmiştir. Sonuç olarak 21. yüzyıl becerileri öz yeterlik ve bilgi işlemsel düşünme becerileri STEM uygulama öz yeterlik düzeylerini etkilediği belirlenmiştir.

Anahtar Kelimeler: Sınıf öğretmenleri, STEM uygulama öz yeterlik, 21. yüzyıl becerileri, bilgi işlemsel düşünme becerisi

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Introduction

Science, technology, engineering, and mathematics (STEM) education is important for social, cultural, and economic development and sustainability in the 21st century (Sun et al., 2021). Indeed, the United Nations Educational, Scientific, and Cultural Organization (2022) recommended teaching STEM subjects to ensure sustainability (Citaristi, 2022). STEM education is also critical for the development of 21st century skills (Tytler, 2020). Its connections with computational thinking, which include algorithmic thinking, collaborative learning, critical thinking, creative thinking, and communication skills, are also noteworthy (Korkmaz et al., 2015; Sırakaya et al., 2020; H.-H. Wang et al., 2011). These skills also overlap with the basic skills expected in individuals of the modern age (Günüç et al., 2013). Therefore, international interest in these skills has increased, and the role of STEM education has become an important research topic (Ching et al., 2019; Sisman et al., 2021).

Effective teaching practices are essential for successful STEM education (Breiner et al., 2012; Kelley & Knowles, 2016; H.-H. Wang et al., 2011). A large proportion of teachers experience problems in implementing STEM education (Uğraş & Genç, 2018), and according to the National Research Council (2013), students' success in STEM fields depends on a quality education that actively involves them in the science, mathematics, and engineering practices they receive in schools and increases their awareness of STEM careers. In this way, students deepen their understanding of both the core ideas in STEM fields and the shared concepts in science, mathematics, and engineering (Roehrig et al., 2021).

In order to stimulate and motivate interest in math and science, it is important to relate these disciplines to the real world and to demonstrate links to future careers. This requires enhanced teaching strategies and opportunities inside and outside the classroom (Archer et al., 2012; Dare et al., 2021; Hartmann & Schukajlow, 2021). Therefore, to prepare students for success in STEM education, we need teachers with a focus on STEM and high self-efficacy (Kelley et al., 2020).

Policymakers, researchers, and teachers emphasize that there is a close alignment between STEM standards and 21st century skills, and that students need to draw attention to STEM education in order to develop these skills (National Research Council, 2013). Students' motivation and interest in STEM careers are associated with their persistence in STEM learning and future career choices (LaForce et al., 2017). Students need 21st century skills for STEM learning and STEM career development (Dare et al., 2021). Therefore, developing students' STEM motivation, interest in STEM careers, and 21st century skills together is important to increase and strengthen students' engagement in STEM disciplines and the future STEM workforce.

There are many studies showing the relationship between STEM education and 21st century skills (Küçükaydın et al., 2024; Lin et al., 2023; Tytler, 2020). For example, in the study of González-Pérez and Ramírez-Montoya (2022), it is emphasized that STEM education is important in terms of developing future skills, and it is concluded that active learning strategies are effective in gaining these skills (González-Pérez & Ramírez-Montoya, 2022). Similarly, Rusydiyah et al. (2021) stated that STEM activities can support the development of 21st century skills (Rusydiyah et al., 2021). Küçükaydın et al. (2024) revealed that 21st century skills mediate the relationship between STEM learning attitudes and information technology skills. These studies show that having 21st-century skills can improve the quality of STEM education practices. This situation reveals that 21st century skills can enable students to develop their knowledge and skills more effectively through STEM education and support success in these fields.

Computational thinking skills like abstraction, problem solving, and algorithmic thinking are closely associated with STEM education (Hava & Koyunlu Ünlü, 2021; Li, Wang, et al., 2020; Sun et al., 2021). Research shows that developing computational thinking skills in teachers positively affects their ability to integrate STEM into teaching practices (Huang et al., 2022; Tripon, 2022; Yildiz Durak et al., 2023). Computational thinking enables teachers to structure complex problems required in STEM fields and equips them with methods to develop similar skills in students (Tripon, 2022; S. Wang et al., 2024). Scholars have identified this connection between computational thinking and STEM as a valuable asset in preparing students for future STEM careers and challenges in a technology-driven society (Li, Schoenfeld, et al., 2020; Tripon, 2022).

It is stated that STEM education actually has the greatest impact in early childhood (Uğraş, 2017; Uğraş & Genç, 2018). According to related research, children's aspirations in STEM fields are largely shaped in early childhood and show little change after this age (Archer et al., 2012; Babarović, 2022). Therefore, identifying teachers' self-efficacy in STEM practices and the associated variables has become a crucial endeavor (Sun et al., 2021). Examining the correlation between primary school teachers' computational thinking abilities, self-efficacy in STEM strategies, and 21st-century competencies helps elucidate possibilities for improving pedagogical approaches to meet contemporary educational objectives. In this context, the aim of this study is to determine the relationship between primary school teachers' self-efficacy in STEM implementation, their perception of computational thinking skills, and their perception of 21st century skills.

The research objectives determined in line with the general purpose of the study:

1. What is the relationship between STEM implementation self-efficacy, computational thinking, and the 21st century skills of primary school teachers?
2. Do primary school teachers' computational thinking and 21st century skills predict their STEM implementation self-efficacy score?

Research Methodology

This study, which aims to examine the relationship between STEM implementation self-efficacy, computational thinking skills, and 21st century skills self-efficacy perception levels of primary school teachers, is descriptive research within the scope of quantitative research. The study was conducted using the relational survey model, one of the survey models. This model is a research approach designed to assess the current situation and provide information about the population. (Creswell, 2013). This model conducts research on either the entire population or a small group that represents the population, known as a sample (Creswell, 2013). The research uses relational survey models to determine changes in two or more variables. These relationships are not considered direct cause-and-effect relationships. However, by providing ideas within the context of a cause-and-effect relationship, we can comment on the status of other variables by understanding their current state (Creswell, 2013). This study groups the variables under examination into dependent and independent categories. In this context, the dependent and predictor variable of the research is STEM self-implementation self-efficacy, and the independent and predictor variables are computational thinking skills and 21st century skills self-efficacy.

Participants

The participants of the study consists of primary school teachers teaching in primary schools in Elazığ province in the 2021–2022 academic year. Given that the research took place during the COVID-19 pandemic and the challenges associated with conducting scientific studies, we determined the sample using the convenience sampling method. This sampling method is one of the most preferred sampling methods in the field of social sciences. It is the collection of data from participants who facilitate access to data under conditions where there are limitations in terms of time, finance, and labor force (Büyüköztürk, 2018). The convenience sampling method was used because the sampling can be easily accessed due to the fact that the research was conducted during the pandemic process, and it can provide quality and practicality to the research (Yıldırım & Simsek, 1999). Table 1 presents information on the characteristics of the research group.

Table 1. Demographic characteristics of participants

Demographic Variable	Groups	*N*	*(%)*
Gender	Female	229	52,05
	Male	211	47,95
School Location	Province	190	43,18
	District	121	27,50
	Town	65	14,77
	Village	64	14,55
Teaching Experience	1-5 years	99	22,50
	6-10 years	74	16,82
	11-15 years	92	20,91
	16-20 years	53	12,05
	21 years and above	122	27,73
Education Status	Undergraduate Degree	225	51,14
	Postgraduate	215	48,86
Total		440	100

Table 1 shows the demographic characteristics of the 440 primary school teachers who participated in the study.

Data Collection Tools

In this study, data were collected using “STEM Implementations Teacher Self-Efficacy Scale” was developed by Özdemir et al. (2018). The scale consists of 18 items in 5-point Likert type. Model fit values were $\chi2$=301.25, $\chi2$/df=2.74, p<.001, CFI=0.96, RMSEA=0.09, IFI=0.96, TLI =0.94, SRMR=0.04, which are acceptable. Cronbach alpha reliability coefficient of the scale was calculated as 0.92. Korkmaz et al. (2015) developed the “Computational Thinking Skill Scale” to determine the level of computational thinking skills of primary school teachers (Korkmaz et al., 2015). This scale is a 5-point Likert and consists of 29 items. The reliability coefficient of the scale was calculated as .82. Anagün et al. (2016) developed the '21st Century Skills Self-Efficacy Perception Scale' as another variable in the study (Anagün et al., 2016). The scale is a 5-point Likert scale with three subdimensions and a total of 42 items. The reliability coefficient of the scale was calculated as .92. After applying to the Ethics Committee of Fırat University and obtaining the necessary approval, permission was granted by the Provincial Directorate of MoNE to conduct this research with primary school teachers.

Data Analysis

Before the distribution analysis of the data obtained as a result of the research, the extreme values of the data were examined. "Leverage Values" were examined to check the extreme values obtained from the data. Seçer (2013) removes values of .05 and above from the data set for use. This analysis identified 23 observations as outliers and removed them from the data set for use. In addition, the missing values in the frequency values of the data were filled with the method of assigning arithmetic averages. Seçer (2013) asserted that this technique will not impact the analysis and normality distributions derived from the data. With the data set consisting of 440 observations, normality analysis was performed, and as a result, it was decided to use parametric tests. Table 2 displays the normality values of the data included in the study, along with the skewness and kurtosis values of the scale dimensions. The data set, consisting of 440 observations, did not include the results of 23 observations used to control outliers.

Table 2. Skewness and kurtosis coefficients of the variables used in the study

Variable			**Skewness**		**Kurtosis**	
	$\bar{X}$	*Sd*	**Value**	**Standard Error**	**Value**	**Standard Error**
STEM Implementation Self-efficacy	3.3677	.77447	-.425	.116	.854	.232
Computational Thinking	3.7002	.45545	.066	.116	.743	.232
21st Century Skills	3.8298	.40485	.395	.116	.044	.232

Upon examining Table 2, we found that the variables' skewness and kurtosis coefficients ranged from -.425 to .854 for STEM self-efficacy, .066 to .743 for computational thinking, and .395 to .044 for 21st century skills. Skewness and kurtosis values between -1 and +1 can be considered sufficient for a normal distribution of data (Büyüköztürk, 2018). Thus, it was decided to utilize parametric tests to determine the relationships between groups by accepting that the distribution of the variables to be used within the scope of the research was normal. We used an independent sample t-test in this context to identify significant differences in attitudes towards STEM self-efficacy, computational thinking, and 21st century skills, taking into account gender and educational status variables. In addition, a one-way analysis of variance (ANOVA) was used to determine the region and length of service ($p<.05$). ANOVA is used to compare the averages of dependent variables obtained in more than two independent groups (Büyüköztürk, 2018). If there is a significant difference between the groups, ANOVA uses multiple comparison tests known as post-hoc tests to determine the significance (Can, 2017). In multiple comparisons between normally distributed groups, the Bonferroni test from the Post Hoc Tests group was used because it does not require an equal sample size (Kayri, 2009; Miller et al., 2009). Effect sizes were calculated to determine the significance levels in the groups that were found to have a significant difference, and evaluations were made according to the ranges of 0.01 = small effect, 0.06 = medium effect, and 0.14 = large effect (Büyüköztürk, 2018).

Findings

The findings obtained in this study, which was conducted to determine the relationships between STEM implementation self-efficacy, computational thinking skill scores and 21st century skills perceptions of primary school teachers, are presented below. The relationships between primary school teachers' STEM implementations teacher self-efficacy, computational thinking skills and attitudes towards 21st century skills self-efficacy were analyzed by Pearson Correlation Analysis and the results are presented in Table 3.

Table 3. Pearson correlation analysis results regarding the ınvestigation of the relationships between primary school teachers' attitudes towards stem ımplementations teacher self-efficacy, computational thinking skills and 21st century skills self-efficacy

Variables	STEM Implementation Self-efficacy	Computational Thinking	21st Century Skills
STEM Implementation Self-efficacy	1		
Computational Thinking	.297	1	
21st Century Skills	.385	.470	1

Table 3 shows a weak positive correlation between STEM implementation self-efficacy and computational thinking skills ($r = .297$, $p < .01$) and between STEM implementation self-efficacy and 21st-century skills ($r = .385$, $p < .01$). Additionally, a moderate positive correlation was observed between computational thinking skills and 21st-century skills ($r = .470$, $p < .01$).

Multiple regression analysis was conducted for the prediction of primary school teachers' attitudes towards STEM implementations, teacher self-efficacy, computational thinking skills, and 21st century skills self-efficacy, and the results are presented in Table 4.

Table 4. Multiple regression analysis results on the prediction of primary school teachers' attitudes towards stem implementations teacher self-efficacy, computational thinking skills and 21st century skills self-efficacy

Predicted Variable	Predictor Variable	*B*	Standard Error	*β*	*t*	*P*
STEM Implementation Self-efficacy	Stable	.123	.351		.349	.737
	Computational Thinking	.252	.084	.148	2.995	.003
	21st century skills	.604	.095	.316	6.375	.000

$R=.407$ $R^2=.166$ $F_{(2-437)}= 43.355$ $p=0.000$

According to Table 4, multiple regression analysis was applied to determine the extent to which primary school teachers' computational thinking and 21st century skills self-efficacy levels predict STEM implementation teacher self-efficacy. The regression analysis revealed that both computational thinking skills (β = .148, p = .003) and 21st-century skills self-efficacy (β = .316, $p < .001$) significantly predicted STEM implementation self-efficacy. Together, these predictors explained 16% of the variance in STEM self-efficacy ($R = .407$, $R^2 = .166$, $F(2, 437) = 43.355$, $p < .001$).

Discussion and Conclusion

This study was conducted to examine the relationship between primary school teachers' 21st century skills self-efficacy levels, computational thinking skills, and STEM practice self-efficacy levels.

The relationships between primary school teachers' 21st century skills, computational thinking skills, and their self-efficacy levels in STEM implementation were examined. The study revealed a weak positive correlation between STEM implementation self-efficacy and computational thinking skills, as well as a weak positive correlation between self-efficacy in STEM implementation and 21st century skills. In addition, the relationship between computational thinking skills and 21st century self-efficacy levels was found to be positively moderate. Multiple regression analysis was applied to determine the extent to which primary school teachers' computational thinking and 21st century skills self-efficacy levels predict STEM implementation teacher self-efficacy. This analysis revealed a significant relationship between the variables. Together, these variables explain 16% of the self-efficacy of STEM implementation teachers.

The study found a positive relationship between STEM implementation self-efficacy levels and computational thinking skills. This finding demonstrates a relationship between teachers' self-confidence in STEM implementations and their computational thinking skills. This situation reveals that self-efficacy perceptions towards STEM education can develop in parallel with computational thinking skills. STEM education is an approach that has recently attracted attention in education and training processes, and this situation requires addressing its integration with computational thinking in a common context (Fessakis & Prantsoudi, 2019; Sun et al., 2021). According to Dede et al. (2013), the computational thinking skill significantly supports STEM education (Dede et al., 2013). The literature views computational thinking as a method for addressing complex problems and a cognitive approach applicable across various disciplines (Hsu et al., 2018; Zhao et al., 2022). Computational thinking, one of today's fundamental skills, plays a crucial role in problem-solving across various disciplines (Hsu et al., 2018; Yildiz & Yildiz, 2021; Yildiz Durak, 2021). Computational thinking processes and problem-solving steps are also interrelated (Kale et al., 2018; Polat et al., 2021; Yildiz Durak, 2021). At the same time, computational thinking is important for real-world problems, which is an important component of STEM education (Israel et al., 2015). Therefore, computational thinking skill levels can positively affect self-efficacy levels in STEM fields by providing a foundation for teaching how to solve problems. Educational policies and teacher education programs can benefit greatly from these findings. Professional development programs aimed at enhancing teachers' computational thinking skills are believed to significantly contribute to their success in STEM education. In particular, teacher education programs should integrate practical modules covering both computational thinking and STEM implementation strategies to enable teachers to effectively apply these skills in real classroom scenarios. Policymakers can also develop structured frameworks that incentivise schools to devote dedicated time to STEM and computational thinking exercises in all subjects. Professional development programs aimed at improving teachers' computational thinking skills are considered to contribute significantly to their success in STEM education. Furthermore, the implementation of certification programs for teachers who complete these training modules could establish a standardised approach, ensuring that all educators have the necessary skills to foster computational thinking in students. Future research should delve deeper into the interactions between computational thinking and STEM education, and devise strategies applicable to various educational contexts.

The study found a positive relationship between the self-efficacy levels of STEM practices and those of 21st century skills. This finding demonstrates a relationship between teachers' self-confidence in STEM practices and 21st-century skills. Early childhood STEM education develops children's creativity (Üret & Ceylan, 2021), improves school readiness and concept acquisition (Toran et al., 2020), and increases children's future social and academic success (Tippett & Milford, 2018). The relationship between STEM education and 21st century skills has been emphasised in previous studies pointing to interdependencies (Çiftçi et al., 2022). Akcanca (2020) and Thibaut et al. (2018) found a significant relationship between teachers' and pre-service teachers' perceptions of STEM education and 21st century skills (Akcanca, 2020; Thibaut et al., 2018). These findings suggest that 21st century skills can improve primary school teachers' STEM implementation self-efficacy levels. Teachers' inclusion of teaching practices that will develop 21st century skills requires them to have self-efficacy towards these skills (Beswick & Fraser, 2019). Dare et al., (2021) concluded that STEM education improves 21st century skills by using real world problems to motivate students. As a result of the meta-analysis study conducted by Ichsan et al., (2023), it was shown that STEM-based learning practices are effective in developing 21st century skills. STEM implementations have the potential to enhance their self-efficacy levels. Therefore, increasing teachers' self-efficacy levels for both STEM education implementation and 21st century skills is critical for achieving successful outcomes in education. These findings suggest that education programs and teacher education strategies should focus on developing 21st-century skills. Future research should examine the interactions between 21st-century skills and STEM education in more detail and reveal effective methods for developing these skills.

These findings show that there are important relationships between STEM education, computational thinking, and 21st century skills. Increasing teachers' self-efficacy levels in these areas may positively affect their success in STEM education. In this context, teacher training programs should include special modules to develop computational thinking skills, increase opportunities to practice STEM implementations, and encourage the integration of 21st century skills into daily classroom practices. Additionally, we can organize workshops and activities to enhance teachers' skills through in-service trainings. Future research should delve deeper into these relationships and devise strategies applicable across various educational levels and regions.

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