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# Attitudes toward digital technology, communication, innovation skills and STEM career interest: a model test for secondary school students

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**Abstract**

This study examines the mediating role of attitudes toward digital technology in the relationship between communication and innovation skills and STEM career interest among Turkish secondary school students. The study used criterion sampling on a sample of 321 Turkish secondary school students [$Age^{ranj}$ = 10–16, $Age^{Mean}$ =12.11, $Age^{Sd}$ = 1.19] selected. Data were collected using the Communication Skills Scale, Attitude Toward Digital Technology Scale, Innovation Skills Scale, and STEM Career Interest Scale. The data were analyzed using two-stage structural equation modeling. In addition, bootstrapping analysis tested the mediation effect's significance. As a result of this study, it was determined that the mediating effect of the attitude towards digital technology was significant in the relationship between communication skills and STEM career interest. In addition, the mediation effect of the attitude towards digital technology was found to be significant in the relationship between innovation skills and STEM career interest. Finally, the STEM career interest model was obtained for secondary school students from the study results.

**Keywords** STEM career interest · Attitudes toward digital technology · Communication skills · Innovation skills

## Introduction

The 21st century has seen significant advances and changes in technology and communication. In this century, skills such as critical thinking, problem-solving, communication, cooperation, creativity, innovation, enterprise, information, and communication technologies have come to the fore. Educators believe that 21st-century skills should be present in future generations and aim to transfer 21st-century skills to students through STEM education (Bybee, 2010). STEM is an effective tool for teaching 21st-century skills. Trilling and Fadel (2009) state that STEM education prepares every child for the future.

STEM emerged at the National Science Foundation (NSF) in the 1990s and has been used as an umbrella term for any activity, policy, program, or practice that involves one or more STEM disciplines (Bybee, 2010). STEM emerges as an educational reform. STEM education is an educational model designed to develop students' skills in STEM. This educational model supports students' knowledge and skills in these fields with practical applications and prepares them for their future careers. In many countries, especially the USA, STEM education aims to increase career choice and interest in professions based on STEM disciplines (Karahan et al., 2021).

### STEM career

A career that represents a focal point in an individual's life supports the formation of an individual's identity and social status while providing them with the economic power to meet their needs (Cinel & Ogan, 2021). Countries believe it is necessary to increase interest in STEM career fields to maintain competition in the global arena. According to American Society for Quality (ASQ) studies, many students

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still need to consider STEM careers. They stated they could not perform the professions due to a lack of knowledge (Alıcı, 2018).

Regarding individuals' developmental structures, career development starts at a young age and continues in a particular order. STEM career interest should be increased early, and STEM professions should be encouraged (Gulhan & Sahin, 2016). The interest in STEM professions that begins in primary and secondary school is reciprocated by individuals being more interested in STEM fields in college (Gonzalez & Kuenzi, 2012). In their study, Wyss et al. (2012) found that secondary education is an essential age for career choice because it is at this age that students begin to make decisions about their careers. In the literature, STEM achievements support students' attitudes toward pursuing STEM careers and their interest in different occupational fields in their career choices (Ozkul & Ozden, 2020).

Considering the main goals of the US National Research Council STEM education, which are to increase the number of people with expertise and careers in STEM fields, to create a workforce with active participation in STEM fields, and to raise STEM literate individuals, it is essential to develop STEM career interest in students (NRC, 2011).

### STEM career interest

Internationally, there are growing efforts to increase student interest in STEM careers. Such efforts often aim to increase STEM career interest to stimulate economic growth and increase innovation. STEM career interest is defined as individuals' interest in choosing STEM-related careers in the future (Kier et al., 2014).

It is critical to creating STEM career interest among students to increase expertise in STEM, increase the number of STEM literate individuals, and increase the number of individuals making careers in STEM fields (NRC, 2011). To increase STEM career awareness, STEM careers should be mentioned to students from an early age (Gulhan & Sahin, 2016). When reviewing the literature, a positive relationship is observed between students' STEM interests and career choices (Christensen & Knezek, 2017; Crisp et al., 2009).

### The relationship between STEM career interest and attitude toward digital technology

Digital technology is the display and storage of data or visuals on an electronic device or transmission to another device (Cabı, 2016). The attitudes of individuals toward this technology can be called attitudes toward digital technology. Reviewing the literature shows that the research on attitudes toward digital technology and STEM career interest is indirect and limited. For example, the study conducted by Karakaya et al. (2018) concluded that STEM career interest increases with the increased use of digital technology. Based on the results of this study, the hypothesis that students' attitudes toward digital technology predict their STEM career interest was developed in the current study.

### The relationship between STEM career interest and communication skills

Communication skills are briefly defined as effective listening and responding (Bugay & Korkut-Owen, 2016). Communication skills include sensitivity to non-verbal messages and effective listening (Gibson & Mitchell, 1995). In the literature, some indirect studies indicate that communication skills are related to STEM career interests (Dabney et al., 2012; Gibson & Mitchell, 1995; Karakaya et al., 2018). The theoretical explanations of these studies state that communication skills increase STEM career interest. Based on these theoretical explanations, this study hypothesized that communication skills predict STEM career interest.

### The relationship between STEM career interest and innovation skills

Innovation skills can be expressed as applying an individual's knowledge, positive attitude, and ability (Rattanawichai et al., 2023). Individuals educated with the STEM approach are expected to be a productive and innovative workforce in the process of industrialization and industrialization in the future. Limited research in the literature suggests that STEM career interest and innovation skills are related. For example, the theoretical explanation by Rossi de Campos (2015) emphasizes that innovation skills and STEM career interests are correlated. Based on this theoretical explanation, it was hypothesized that innovation skills predict STEM career interest.

Secondary school students need accurate information about STEM careers to make career choices because students' careers in STEM depend on providing this information at an early age. Students need more information to connect science and themselves due to insufficient data and must be made aware of career options in STEM fields (Christensen & Knezek, 2017; Wyss et al., 2012). In the studies, students' attitudes toward STEM fields and academic success are parallel. Academic success provides orientation toward careers in the field. For these reasons, students' high interest in STEM leads to their career choices (Karakaya et al., 2018; Liu, 2008).

The literature review shows that students who show STEM career interest subjects at an early age, such as in secondary school, are more likely to pursue a career in STEM (Cleaves, 2005). Career development theorists and researchers suggest that career development in schools and exploring options in post-secondary career fields should begin as early as the secondary school period (Lent et al., 1994). Studies have also shown that students' career choices are shaped at the secondary school level (Kier et al., 2014; Wiebe et al., 2018). However, it is also stated that secondary school years strongly influence the education received in the following years regarding careers, as it is a critical period in which career choice is shaped (Christensen & Knezek, 2017; Wyss et al., 2012). For this reason, it is stated that informing students about STEM fields and careers in secondary school will be influential in the development of STEM career interest and the right career choice (Wyss et al., 2012). The research results emphasize that students should be directed to STEM careers starting from secondary school years (Christensen & Knezek, 2017; Wyss et al., 2012). In addition, research has shown a relationship between early career interest and career choice (Crisp et al., 2009). Considering the above reasons, this study was conducted on secondary school students.

To direct more students to STEM fields, it is essential to determine students' STEM career interests and the factors affecting these interests. However, when the studies on STEM career interests are examined, it is seen that there are a limited number of studies (Christensen & Knezek, 2017; Nariman, 2021). This study contributes to the literature in terms of being conducted in a field with limited studies. As a result of the literature review, no study examines secondary school students' attitudes toward digital technology, communication, innovation skills, and STEM career interests in Turkey. This situation reveals the originality of this research. Considering all these, this study aims to test the mediating effect of attitudes toward digital technology on the relationship between communication, innovation skills, and STEM career interest (see Fig. 1).

***Hypotheses***

**H[1]**. Innovation skills significantly and positively predict attitudes towards digital technology.

**H[2]**. Innovation skills significantly and positively predict STEM career interest.

**H[3]**. Communication skills significantly and positively predict attitude towards digital technology.

**H[4]**. Communication skills significantly and positively predict STEM career interest.

**H[5]**. Attitudes towards digital technology significantly and positively predict STEM career interest.

**H[6]**. The mediating effect of attitudes toward digital technology is significant in the relationship between innovation skills and STEM career interest.

**H[7]**. The mediating effect of attitudes toward digital technology is significant in the relationship between communication skills and STEM career interest.

# Method

## Procedure and research group

Before collecting data, the school administration was informed about the research, and necessary permissions were obtained. Subsequently, the adolescents and their families who agreed to participate were informed about the research. Then, the child consent form was obtained through their informed consent (telling about the purpose of the study, information about the content, confidentiality, and situations such as being able to leave the research at any time). The research was conducted on 321 Turkish secondary school students and was determined using a criterion sampling technique. Of these adolescents [Ageranj = 10–16, AgeMean = 12.11, AgeSd = 1.19], 162 (50.5%) were boys, and 159 (49.5%) were girls. Inclusion criteria for research: It was determined that I was a Turkish secondary school student, did not have a psychiatric diagnosis, and was a volunteer.

## Measures

### STEM career interest scale (STEM-CIS)

STEM-CIS was developed by. Kier et al. (2014). Its Turkish adaptation, validity, and reliability analyses were performed by Higde (2018). STEM-CIS consists of 44 items and four dimensions. Confirmatory factor analysis made within the scope of construct validity for the entire STEM-CIS. In this analysis finding, the goodness fit indices of STEM-CIS (x2/df = 2.48; CFI = 0.91, SRMR = 0.07, NFI = 0.85, and RMSEA = 0.08) were found to be acceptable (Higde, 2018). In addition, the Cronbach alpha value for the entire STEM-CIS was calculated as 0.93 (Higde, 2018). This research determined Cronbach's alpha value for all STEM-CIS to be 0.90.

## Innovation skills scale (ISS)

ISS was developed by Chell and Athayde (2009). Akkaya (2016) adapted it to Turkish, and its validity and reliability study was conducted. ISS contains 31 items and five dimensions. The confirmatory factor analysis method was used by Akkaya (2016) to measure the construct validity of each subdimension. For example, creativity's goodness of fit indices ($x^2$/df = 1.17, CFI = 1.00, GFI = 0.99, and RMSEA = 0.01); self-sufficiency ($x^2$/df = 2.28, CFI = 0.93, GFI = 0.98, and RMSEA = 0.04); energy ($x^2$/df = 1.30, CFI = 0.99, GFI = 0.99 and RMSEA = 0.02); risk ($x^2$/df = 0.27, CFI = 1.00, GFI = 1.00 and RMSEA = 0) and leadership ($x^2$/df = 3.35, CFI = 0.97, GFI = 0.98 and RMSEA = 0.06) were observed to be acceptable

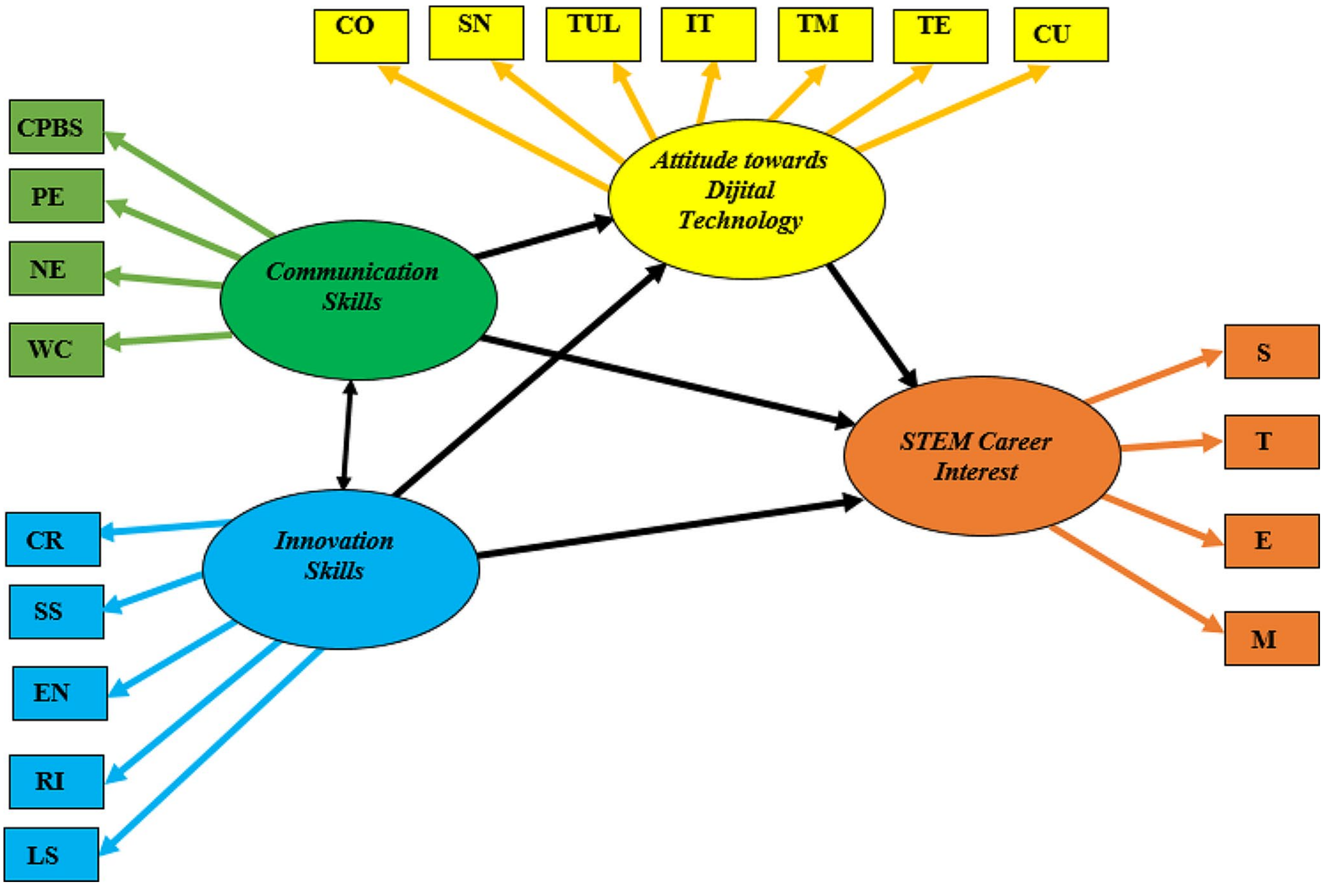


**Fig. 1** Hypothetical model. Note.CPBS: Communication Principles and Basic Skills, PE: Personal Expression, NE: Nonverbal Expression, WC: Willingness to Communicate, CR: Creativity, SS: Self-Sufficiency, EN: Energy, RI: Risk LS: Leadership, CO: Competence, SN: Social Network, TUL: Technology Use in Lesson, IT: Interest towards Technology, TM: Technology for Me, TE: Technology for Entertainment, CU: Conscious Use, S: Science, T: Technology, E: Engineering and M: Mathematics

(Akkaya, 2016). The Cronbach alpha value for the entire ISS was.86 (Akkaya, 2016). The current research calculated the Cronbach alpha value for the whole of the ISS as 0.87.

## Attitude towards digital technology scale (ATDTS)

ATDTS was developed by Cabı (2016), and the same researcher performed validity and reliability analysis. ATDTS consists of 39 items and eight dimensions (competence, social network, technology use in lessons, interest towards technology, technology for me, technology for entertainment, conscious use, and technology's negative aspects). In this research, the negative aspects of technology's sub-dimension were excluded because it does not represent the attitude towards digital technology, which is its latent variable, in a statistically significant way. Confirmatory factor analysis was performed to test the construct validity of the ATDTS. Acceptable goodness of fit indices ($X^2$/df = 3.03; RMSEA = 0.05; NFI = 0.93; CFI = 0.95; AGFI = 0.85) were reached in the analysis finding (Cabi, 2016). The Cronbach alpha value for all ATDTS was determined as 0.90 (Cabi, 2016). In this research, the Cronbach alpha value of all ATDTS was reported as 0.89, except for the technology's negative aspects.

## Communication skills scale (CSS)

CSS was developed by Owen and Bugay (2014), and the same researchers applied validity and reliability analyses. CSS includes 25 items and four dimensions. Confirmatory factor analysis was conducted to investigate the construct validity of CSS. As a result of the study, the goodness of fit indices of CSS [$\chi^2$/df = 1.40; CFI = 0.91, IFI = 0.91, RMSEA = 0.04] seem to be in the acceptable range (Owen & Bugay, 2014). The Cronbach alpha coefficient for all CSS was .88 (Owen & Bugay, 2014). The current research calculated the Cronbach alpha coefficient for all CSS as 0.81.

## Statistical analysis

This research evaluated a preliminary analysis of normality and multicollinearity (Kline, 2019). The data were analyzed using the two-stage structural equation modeling technique proposed by Anderson and Gerbing (1988). The goodness of fit indices such as ($\chi 2$/df IFI, GFI, TLI, AGFI, CFI, and RMSEA) were used to test whether these models were compatible with the data (see Table 3). This research also conducted mediation analysis (Baron & Kenny, 1986). Finally, the significance of the mediation effect was tested with bootstrapping analysis. This analysis determined the lower and upper confidence intervals by making 1000 resamples (Shrout & Bolger, 2002). According to Shrout and Bolger (2002), the mediation effect is significant if these confidence intervals do not contain zero. This research was evaluated using the maximum likelihood estimation method.

## Results

### Preliminary analysis

The kurtosis values of this research ranged from −0.554 to 0.381; skewness values were reported to vary between −0.598 and 0.021. These values prove that this research is within the limits of normality (Kline, 2019). On the other hand, it was reported that the VIF values of this research ranged between 1.08 and 1.19, and the tolerance values ranged between 0.83 and 0.92. In addition, the conditional index values of this research were found to vary between 1.00 and 21.31. Finally, this research did not find a correlation coefficient of 0.90 and above between observed and latent variables. Based on all these findings, it is proved that there is no multicollinearity problem in this research (Kline, 2019) (Table 1).

### Measurement model

This research is represented by four latent and twenty observed variables. When the measurement model was analyzed, the goodness of fit indices ($\chi 2$/df (309.004/164) = 1.88, IFI = 0.94, GFI = 0.91, TLI = 0.93, AGFI = 0.88, CFI = 0.93 and RMSEA = 0.05 (90) % CI for RMSEA = [0.04, 0.06]) was determined to be acceptable. In addition, the standardized factor loadings of the measurement model were found to vary between 0.31 and 0.82 (see Fig. 2). In addition, all t-values of the measurement model were detected to be significant. All these findings confirmed the measurement model.

### Structural model

Firstly, the measurement model was tested and verified. Secondly, the structural model was examined. According to the findings of the analysis, the structural model was validated.

Considering the diagram of the structural model in Fig. 3, a one-unit increase in communication skills increases attitude towards digital technology by 0.15 (t = 2.173, $p < .05$) and STEM career interest by 0.22 (t = 2.989; $p < .01$). Additionally, a one-unit increase in innovation skills increases attitude towards digital technology by 0.30 (t = 4.128; $p < .001$) and STEM career interest by 0.23 (t = 3.010; $p < .01$). Finally, a one-unit increase in attitude towards digital technology increases STEM career interest by 0.20 (t = 2.912 $p < .01$).

Figure 3 also includes the explained variances ($R^2$). According to Fig. 3, communication and innovation skills together were explained by about %15 of digital technology. Finally, it was found that communication, innovation skills, and attitude towards digital technology three together explained approximately %24 of STEM career interest (Tables 2 and 3).

### Mediation analysis

The aim of this research is to test the mediating effect of attitude toward digital technology in the relationship between communication and innovation skills and STEM career interest. This mediation analysis was carried out according to the steps of Baron and Kenny (1986). In the first stage, the direct impact model, which examines the direct impact of communication and innovation skills on STEM career interest, was tested. When the direct impact model is analyzed, the direct effect of communication skills on STEM career interest (β: 0.25; t = 3.351; $p < .001$) is significant. In addition, the direct effect of innovation skills on STEM career interest (β: 0.29; t = 3.905; $p < .001$) was found to be significant (see Fig. 4).

In the second stage, the partial mediation model was tested by adding the attitude towards digital technology to the path from communication and innovation skills to STEM career interest. When the partial mediation model was tested, the effect of communication skills on STEM career interest (β: 0.22; t = 2.989) decreased, but the mediation effect remained significant ($p < .01$). In addition, the effect of innovation skills on STEM career interest (β: 0.23; t = 3.010) is decreasing, but the mediation effect is still significant ($p < .01$). Based on these findings, it has been proven that attitude towards digital technology is partial of the mediating effect on the relationship between communication and innovation skills and STEM career interest.

### Bootstrapping analysis

The significance of the mediating effect of the attitude towards digital technology in the relationship between communication and innovation skills and STEM career interest

**Table 1** Correlations and normality

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.CPBS | *1* | | | | | | | | | | | | | | | | | | | |
| 2. PE | *0.591*** | *1* | | | | | | | | | | | | | | | | | | |
| 3. NE | *0.612*** | 0.542** | *1* | | | | | | | | | | | | | | | | | |
| 4. WC | *0.500*** | 0.531** | 0.512** | *1* | | | | | | | | | | | | | | | | |
| 5. CR | *0.254*** | 0.167** | 0.295** | 0.238** | *1* | | | | | | | | | | | | | | | |
| 6. SS | *0.232*** | 0.169** | 0.263** | 0.122* | 0.540** | *1* | | | | | | | | | | | | | | |
| 7. EN | *0.282*** | 0.195** | 0.322** | 0.183** | 0.643** | 0.612** | *1* | | | | | | | | | | | | | |
| 8. RI | *0.263*** | 0.187** | 0.352** | 0.195** | 0.503** | 0.397** | 0.500** | *1* | | | | | | | | | | | | |
| 9. LS | *0.178*** | 0.161** | 0.213** | 0.159** | 0.493** | 0.567** | 0.496** | 0.381** | *1* | | | | | | | | | | | |
| 10. CO | *0.165*** | 0.090 | 0.231** | 0.061 | 0.206** | 0.247** | 0.223** | 0.112* | 0.167** | *1* | | | | | | | | | | |
| 11. SN | *0.021* | 0.018 | 0.050 | 0.018 | −0.044 | 0.023 | −0.003 | −0.084 | 0.050 | 0.285** | *1* | | | | | | | | | |
| 12. TUL | *0.064* | 0.059 | 0.206** | 0.074 | 0.271** | 0.262** | 0.245** | 0.074 | 0.186** | 0.583** | 0.223** | *1* | | | | | | | | |
| 13. IT | *0.147*** | 0.174** | 0.268** | 0.117* | 0.240** | 0.215** | 0.268** | 0.080 | 0.125* | 0.581** | 0.223** | 0.613** | *1* | | | | | | | |
| 14. TM | *0.172*** | 0.163** | 0.260** | 0.165** | 0.245** | 0.255** | 0.260** | 0.123* | 0.146** | 0.614** | 0.224** | 0.517** | 0.615** | *1* | | | | | | |
| 15. TE | *−0.077* | −0.086 | 0.039 | −0.081 | 0.066 | 0.028 | 0.045 | 0.004 | 0.152** | 0.319** | 0.315** | 0.330** | 0.301** | 0.187** | *1* | | | | | |
| 16. CU | *0.268*** | 0.142* | 0.294** | 0.079 | 0.240** | 0.225** | 0.193** | 0.145** | 0.062 | 0.538** | 0.153** | 0.461** | 0.457** | 0.480** | 0.145** | *1* | | | | |
| 17. S | *0.259*** | 0.196** | 0.279** | 0.196** | 0.280** | 0.262** | 0.268** | 0.254** | 0.221** | 0.156** | −0.060 | 0.267** | 0.203** | 0.141* | −0.045 | *0.152*** | *1* | | | |
| 18. M | *0.222*** | 0.173** | 0.299** | 0.127* | 0.234** | 0.208** | 0.244** | 0.164** | 0.124* | 0.165** | −0.006 | 0.226** | 0.170** | 0.148** | −0.043 | *0.166*** | *0.551*** | *1* | | |
| 19. T | *0.204*** | 0.162** | 0.239** | 0.111* | 0.184** | 0.131* | 0.136* | 0.133* | 0.090 | 0.298** | 0.093 | 0.322** | 0.270** | 0.190** | 0.174** | *0.191*** | *0.488*** | *0.435*** | *1* | |
| 20. E | *0.125** | 0.060 | 0.206** | 0.009 | 0.184** | 0.243** | 0.169** | 0.188** | 0.150** | 0.143* | −0.064 | 0.220** | 0.096 | 0.114* | 0.057 | *0.136** | *0.498*** | *0.421*** | *0.509*** | *1* |
| Skewness | −0.22 | −0.33 | −0.40 | −0.59 | −0.55 | −0.03 | −0.41 | −0.36 | −0.12 | −0.17 | −0.24 | −0.24 | −0.52 | −0.52 | −0.13 | −0.45 | −0.01 | −0.19 | 0.02 | −0.02 |
| Kurtosis | −0.20 | −0.48 | 0.16 | −0.21 | 0.30 | −0.02 | −0.52 | 0.38 | −0.12 | −0.29 | −0.46 | −0.46 | −0.30 | 0.00 | −0.34 | −0.55 | −0.14 | −0.39 | −0.48 | −0.15 |

**$p<.01$, *$p<.05$, *CPBS,* Communication Principles and Basic Skills; *PE,* Personal Expression; *NE,* Nonverbal Expression; *WC*, Willingness to Communicate; *CR,* Creativity; *SS,* Self-Sufficiency; *EN,* Energy; *RI,* Risk; *LS,* Leadership; *CO,* Competence; *SN,* Social Network; *TUL,* Technology Use in Lesson; *IT,* Interest towards Technology; *TM,* Technology for Me; *TE,* Technology for Entertainment; *CU* Conscious Use; *S,* Science; *T,* Technology; *E,* Engineering and *M,* Mathematics was tested with bootstrapping analysis. For this, 1000 resamples were made. In addition, lower and upper limit ranges were established (Shrout & Bolger, 2002) (see Table 4).

According to Table 4, it was determined that the mediating effect of the attitude towards digital technology was significant in the relationship between communication skills and STEM career interest [β = 0.03, 95% CI (0.002, 0.093). In addition, the mediation effect of the attitude towards digital technology was found to be significant in the relationship between innovation skills and STEM career interest [β = 0.06, 95% CI (0.013, 0.140]). According to all these findings, it has been confirmed that the mediating effect of the attitude towards digital technology is significant in the relationship between communication and innovation skills and STEM career interest.

## Discussion

This study aimed to test the mediating effect of attitude toward digital technology on the relationship between communication and innovation skills and STEM career interest. Seven hypotheses were formulated in the study, and all were confirmed. In addition, STEM career interest model was obtained from the study results.

Although there are studies in the literature that examine the relationships between the dimensions of the model proposed in this study (Bugay & Korkut-Owen, 2016; Chen et al., 2023; Dabney et al., 2012; Fraile et al., 2021; Hakim et al., 2022; Karakaya et al., 2018; Kırılmaz et al., 2022; Rossi de Campos, 2015; Yucebalkan & Aksu, 2018), there are no studies that address the variables in the study together and explain the relationships between the variables. At this point, it can be said that this study has contributed to the literature by presenting the relationships between the variables from a holistic framework.

The first finding of this study is that innovation skills predict attitudes toward digital technology significantly and positively, which is also supported by the studies in the literature (Kırılmaz et al., 2022; Yucebalkan & Aksu, 2018). In the typical findings of these related studies, innovation skills and attitudes toward digital technology were observed to be correlated. Therefore, the theoretical explanations of these studies in the literature support this finding of the current study. This result can be interpreted as follows: It can be said that the secondary school students in this study brought their attitudes toward digital technology to a positive point by using their innovation skills.

The second finding is that innovation skills significantly and positively influence interest in STEM careers. There is a few research in the literature whose findings are similar to this study's (Rossi de Campos, 2015). According to Rossi de Campos (2015), innovation skills and STEM career interest are correlated variables. Therefore, this theoretical explanation confirms the finding of this study, which can be explained as follows: Individuals educated with the STEM approach have the potential to become a productive and innovative workforce in the process of industrialization and industrialization in the future (Gonzalez & Kuenzi, 2012). All kinds of innovations that emerge thanks to innovation skills are fed by the fields of science, technology, engineering, and mathematics and emerge with interest in these fields. For this reason, it can be said that innovation skills find a starting point with STEM career interest.

The third finding of this study is that communication skills are a significant and positive predictor of attitudes toward digital technology. Some studies indirectly support

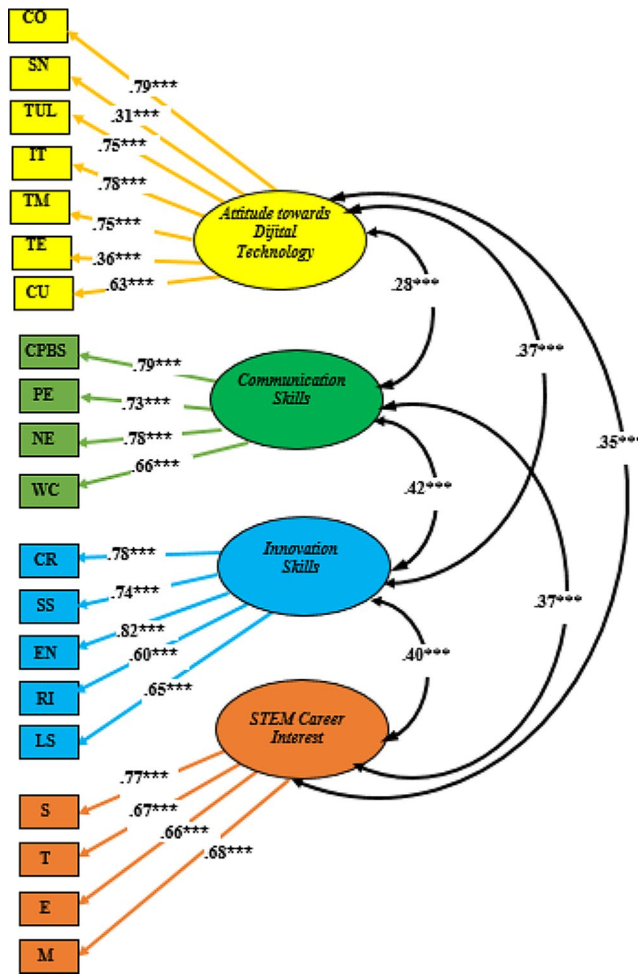


**Fig. 2** Measurement model. Note. ****p* < .001, CPBS: Communication Principles and Basic Skills, PE: Personal Expression, NE: Nonverbal Expression, WC: Willingness to Communicate, CR: Creativity, SS: Self-Sufficiency, EN: Energy, RI: Risk LS: Leadership, CO: Competence, SN: Social Network, TUL: Technology Use in Lesson, IT: Interest towards Technology, TM: Technology for Me, TE: Technology for Entertainment, CU: Conscious Use, S: Science, T: Technology, E: Engineering, and M: Mathematics

this study's finding (Bugay & Korkut-Owen, 2016; Fraile et al., 2021; Hakim et al., 2022; Hargitai & Bencsik, 2023). In the theoretical explanations of these studies, it is stated that communication skills are related to the use of technology and computer/technology-based educational practices. Therefore, the theoretical explanations of the studies in the literature support the current study's findings. It can be said that the attitudes of secondary school students who participated in this study toward digital technology were positively influenced by their use of communication skills.

The fourth finding of this study is that communication skills significantly and positively predict STEM career interest. Some studies indirectly support this finding (Dabney et al., 2012; Karakaya et al., 2018). The theoretical explanations of the above studies emphasize that students' use of communication skills improves their STEM career interests. This finding of the current study is consistent with the theoretical explanations of the above studies. This finding can be explained as follows: Students can facilitate their choice of STEM career by being active in social areas such as clubs. In addition, it can be said that participating in social clubs or technology-oriented STEM camps increases students' STEM career interests.

The fifth finding of this study is that attitude toward digital technology is a significant and positive predictor of STEM career interest. There are limited and indirect studies in the literature that support the findings of this study (Jriyasetapong et al., 2023; Karakaya et al., 2018; Subasman & Aliyyah, 2023). For example, a study by Subasman and Aliyyah (2023) aims to analyze the impact of digital transformation on career aspirations in the STEM (Science, Technology, Engineering, and Mathematics) sector. The research results show that the adoption of digital technology in STEM education increases students' interest and competence in STEM subjects, which directly affects their career aspirations. Similarly, according to the findings of Karakaya et al. (2018) on secondary school students, there is a significant positive relationship between technology use and STEM career interest. This finding is in parallel to the findings of this study. This finding can be interpreted as follows: Students' attitudes towards digital technology can shift positively after following technological developments.

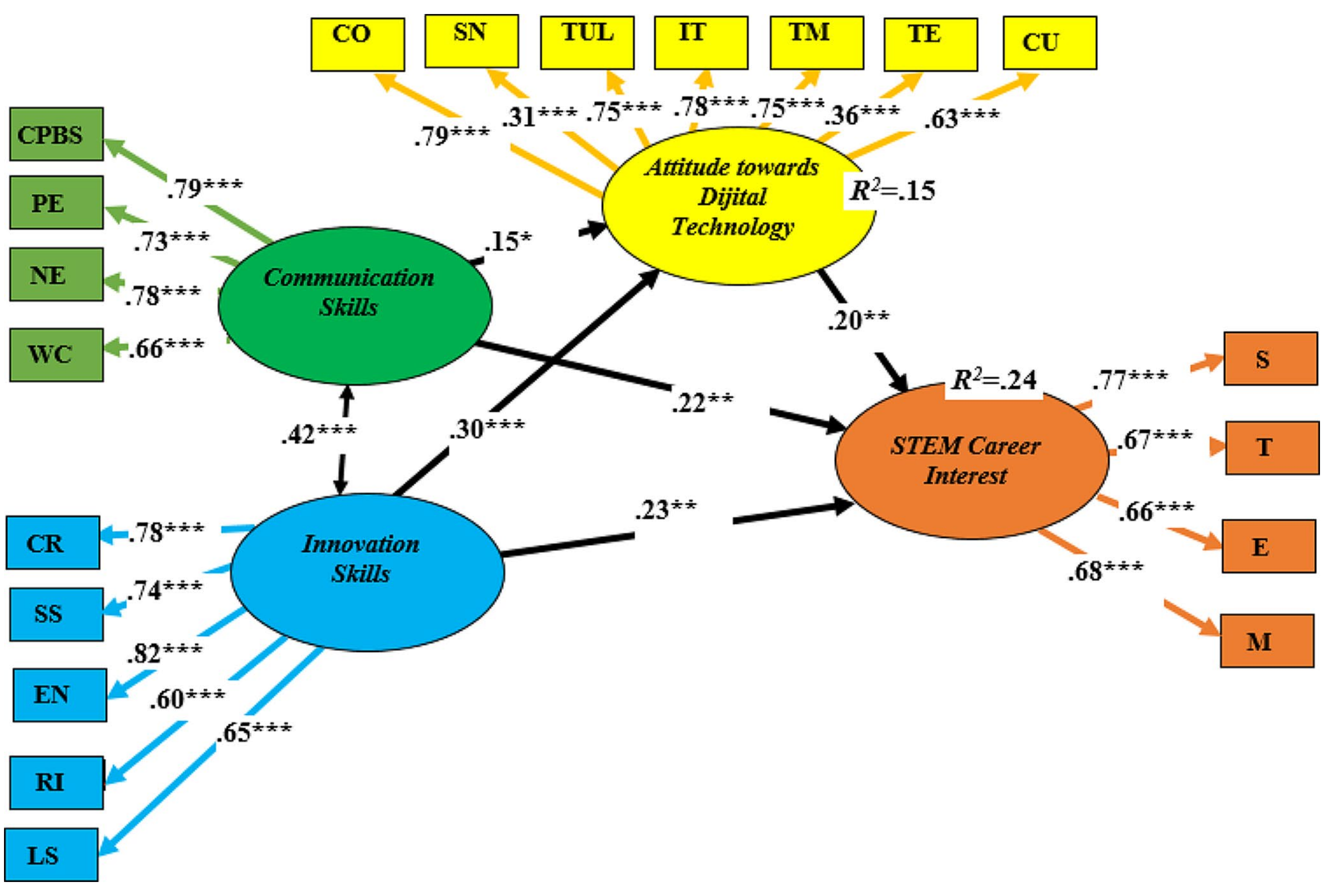


**Fig. 3** Structural model. Note. *** $p < .001$, ** $p < .01$, * $p < .05$, CPBS: Communication Principles and Basic Skills, PE: Personal Expression, NE: Nonverbal Expression, WC: Willingness to Communicate, CR: Creativity, SS: Self- Sufficiency, EN: Energy, RI: Risk LS: Leadership, CO: Competence, SN: Social Network, TUL: Technology Use in Lesson, IT: Interest towards Technology, TM: Technology for Me, TE: Technology for Entertainment, CU: Conscious Use, S: Science, T: Technology, E: Engineering and M: Mathematic

**Table 2** Results of structural model

| Predicted Variables | | Predictor Variables | Estimate | S.E. | C.R. | *p* |
|---|---|---|---|---|---|---|
| Attitude towards Digital Technology | <--- | Innovation Skills | 0.579 | 0.140 | 4.128 | *** |
| Attitude towards Digital Technology | <--- | Communication Skills | 0.365 | 0.168 | 2.173 | 0.030* |
| STEM Career Interest | <--- | Attitude towards Digital Technology | 0.196 | 0.067 | 2.912 | 0.004** |
| STEM Career Interest | <--- | Innovation Skills | 0.427 | 0.142 | 3.010 | 0.003** |
| STEM Career Interest | <--- | Communication Skills | 0.508 | 0.170 | 2.989 | 0.003** |
| S | <--- | STEM Career Interest | 1.000 | | | |
| M | <--- | STEM Career Interest | 1.006 | 0.094 | 10.678 | *** |
| T | <--- | STEM Career Interest | 0.883 | 0.084 | 10.563 | *** |
| E | <--- | STEM Career Interest | 1.019 | 0.099 | 10.343 | *** |
| CO | <--- | Attitude towards Digital Technology | 1.000 | | | |
| SN | <--- | Attitude towards Digital Technology | 0.215 | 0.041 | 5.246 | *** |
| TUL | <--- | Attitude towards Digital Technology | 0.504 | 0.037 | 13.624 | *** |
| IT | <--- | Attitude towards Digital Technology | 0.565 | 0.040 | 14.238 | *** |
| TM | <--- | Attitude towards Digital Technology | 0.456 | 0.033 | 13.685 | *** |
| TE | <--- | Attitude towards Digital Technology | 0.234 | 0.038 | 6.156 | *** |
| CU | <--- | Attitude towards Digital Technology | 0.299 | 0.027 | 11.169 | *** |
| WC | <--- | Communication Skills | 1.000 | | | |
| NE | <--- | Communication Skills | 1.368 | 0.122 | 11.188 | *** |
| PE | <--- | Communication Skills | 0.975 | 0.091 | 10.655 | *** |
| CPBS | <--- | Communication Skills | 1.969 | 0.175 | 11.224 | *** |
| LS | <--- | Innovation Skills | 1.000 | | | |
| RI | <--- | Innovation Skills | 0.621 | 0.067 | 9.267 | *** |
| EN | <--- | Innovation Skills | 1.415 | 0.121 | 11.661 | *** |
| SS | <--- | Innovation Skills | 1.276 | 0.117 | 10.925 | *** |
| CR | <--- | Innovation Skills | 1.133 | 0.100 | 11.279 | *** |

***$p<.001$, **$p<.01$, *$p<.05$, *CPBS,* Communication Principles and Basic Skills; *PE,* Personal Expression; *NE,* Nonverbal Expression; *WC,* Willingness to Communicate; *CR,* Creativity; *SS,* Self- Sufficiency; *EN,* Energy; *RI,* Risk; *LS,* Leadership; *CO,* Competence; *SN,* Social Network; *TUL,* Technology Use in Lesson; *IT,* Interest towards Technology; *TM,* Technology for Me; *TE,* Technology for Entertainment; *CU,* Conscious Use; *S,* Science; *T,* Technology; *E,* Engineering and *M,* Mathematics

This positive effect can increase their awareness about their career choices in STEM professions. This awareness may positively affect their STEM career interests.

In the sixth finding of this study, the mediating effect of attitude toward digital technology between innovation skills and STEM career interest was found to be significant. In the literature review, students' high innovation skills positively affect their attitudes toward digital technology (Kırılmaz et al., 2022; Yucebalkan & Aksu, 2018). This positive attitude toward digital technology brings individuals' STEM career interest to a positive point (Karakaya et al., 2018; Subasman & Aliyyah, 2023). It can be interpreted that the secondary

**Table 3** Goodness of fit indices of the structural model

| Goodness of Fit Indices | Fit Measure | Values of the Model | Remark of the Fit |
|---|---|---|---|
| [1]$\chi^2$/df | $0 \leq \chi 2/df \leq 2$ | 1.88 | Good fit |
| [1]RMSEA | $0 \leq RMSEA \leq 0.05$ | 0.05 | Good fit |
| [1]GFI | $0.90 \leq GFI \leq 0.95$ | 0.91 | Acceptable fit |
| [1]AGFI | $85 \leq AGFI \leq 0.90$ | 0.88 | Acceptable fit |
| [2]TLI | $0.90 \leq TLI \leq 0.95$ | 0.93 | Acceptable fit |
| [2]CFI | $0.90 \leq CFI \leq 0.95$ | 0.93 | Acceptable fit |
| [2]IFI | $0.90 \leq IFI \leq 0.95$ | 0.94 | Acceptable fit |

Source: ([1]Schermelleh-Engel et al., 2003; [2]Hu & Bentler, 1998)

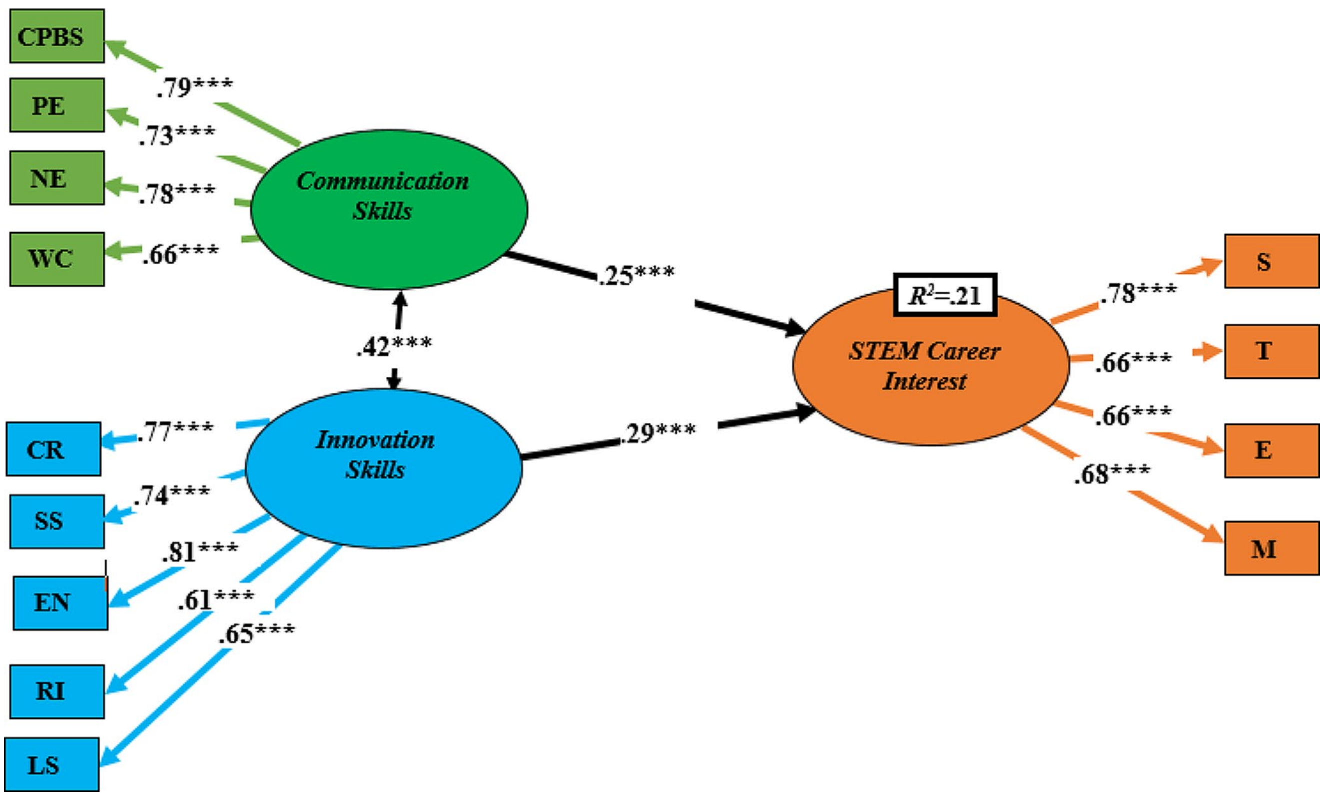


**Fig. 4** Direct effect model

school students in this study can gain positive attitudes towards digital technology by improving their innovation skills, which can positively affect their STEM career interest.

In the last finding of this study, the mediating effect of attitude toward digital technology between communication skills and STEM career interest was found to be significant. Individuals can bring their attitude toward digital technology to a positive point by using their communication skills (Bugay & Korkut-Owen, 2016; Fraile et al., 2021; Hakim et al., 2022). This positive attitude toward digital technology can contribute to their STEM career interest (Karakaya et al., 2018; Subasman & Aliyyah, 2023). In other words, digital media, communication transmitted through technology, is effective in individuals' STEM career interests (Chen et al., 2023; Shah et al., 2023).

The variables in this study can also be evaluated in terms of 21st -century skills. For example, life and career skills from the 21st-century skills correspond to STEM career interest in this research. In addition, communication and innovation variables in this study can be considered within the scope of learning and innovation skills from 21st -century skills. Finally, this study's attitude towards digital technology variable can be interpreted as related to information, media, and technology skills among 21st -century skills.

## Limitations and suggestions

This study tested the relationships between latent variables with a cross-sectional mediation model. The most important limitation of this study is that it is not longitudinal. In future studies, longitudinal mediation analyses of the variables in this study can be conducted to reveal their time interval effects. In this context, alternative longitudinal mediation models, such as cross-lagged panel and latent growth curve can be used in future studies (O'Laughlin et al., 2018). This study has revealed factors (innovation skills, communication skills, and attitudes toward digital technology) that enhance secondary school students' STEM career interests.

**Table 4** Results of bootstrapping analysis

| Exogenous Variable | Mediator Variable | Endogenous Variable | β | SE | 95%CI (Lower and Upper Bounds) | *p* |
|---|---|---|---|---|---|---|
| CS | ADT | SCI | 0.03* | 0.02 | [0.002,093] | 0.04 |
| IS | ADT | SCI | 0.06* | 0.03 | [0.013,140] | 0.01 |

*$p < .05$, *CS,* Communication Skills; *IS,* Innovation Skills; *SCI,* STEM Career Interest; *ADT,* Attitude towards Digital Technology

In the future, quasi-experimental design research on the factors that increase secondary school students' STEM career interests can be designed using the factors obtained in this study. This study examined the relationships between 21st-century skills such as innovation, communication, and digital technology and interest in STEM careers. Future studies can examine the relationships between different 21st-century skills (problem-solving, creativity, collaboration) and STEM career interest. Finally, the emphasis on digital technologies in STEM programs can be increased for educational practitioners and policymakers.

## Conclusions

This study concluded that the partial mediating role of attitude towards digital technology in the relationship between communication skills and STEM career interest was significant. Another conclusion is that the partial mediating role of attitude towards digital technology in the relationship between innovation skills and STEM career interest is significant. Finally, the STEM career interest model was obtained for secondary school students based on the study's conclusions.

**Funding** Not applicable

**Data availability** The data set is available upon request.

### Declarations

**Ethical approval** To collect the data, permissions were obtained from the relevant researchers for the measures to be used in the study, and ethical committee approval was also obtained from [Omitted] University Social and Human Sciences Ethical Committee (Meeting No: 2023-10). All stages of the study were conducted according to Helsinki Declaration.

**Informed consent** All participants provided informed consent for the data to be published and to participate in the present study.

**Competing interests** The authors declare that they have no conflict of interest.

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