

Digital literacy as a buffer against technostress: Evidence from the ICT attitudes of in-service music teachers

Teknoloji stresine karşı bir tampon olarak dijital okuryazarlık: Görevdeki müzik öğretmenlerinin bilişim teknolojilerine yönelik tutumlarından elde edilen bulgular

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ABSTRACT

This study examined the relationships among technostress, attitudes toward information and communication technologies (ICT), and digital literacy, focusing on the mediating role of digital literacy among music teachers. Data were collected from 202 music teachers across different regions of Turkey and analyzed using SPSS and PROCESS Macro. The findings revealed that technostress negatively influenced ICT attitudes, while digital literacy reduced technostress and strengthened positive ICT attitudes. Furthermore, digital literacy partially mediated the relationship between technostress and ICT attitudes. Interpreted through the Job Demands–Resources (JD–R) Model, the Transactional Model of Stress, and Cognitive Load Theory, these results suggest that digital literacy functions as a key personal resource that helps teachers manage technological demands, lowers cognitive load, and enables them to perceive technology as an opportunity rather than a threat. The study highlights the critical role of enhancing digital literacy to mitigate technostress and foster positive ICT integration in music education. Practically, the findings imply that teacher education programs and in-service training should prioritize digital pedagogy and music-specific technologies. These findings also offer comparative international implications for teacher education and professional development, especially when aligning local initiatives with global digital competence standards. Policymakers should further align national standards with international frameworks such as DigCompEdu and ISTE. Overall, the study provides novel evidence by demonstrating the mediating role of digital literacy in the technostress–ICT attitude relationship specifically among music teachers.

Keywords: digital literacy, technostress, information and communication technology, technological pedagogical content knowledge (TPACK), teacher education

ÖZ

Bu çalışma, teknostres, bilgi ve iletişim teknolojilerine (BİT) yönelik tutumlar ve dijital okuryazarlık arasındaki ilişkileri incelemiştir; özellikle müzik öğretmenleri bağlamında dijital okuryazarlığın aracılık rolüne odaklanmıştır. Veriler, Türkiye'nin farklı bölgelerinden 202 müzik öğretmeninden toplanmış ve SPSS ile PROCESS Macro kullanılarak analiz edilmiştir. Bulgular, teknostresin BİT tutumlarını olumsuz yönde etkilediğini, buna karşılık dijital okuryazarlığın teknostresi azalttığını ve BİT'e yönelik olumlu tutumları güçlendirdiğini ortaya koymuştur. Ayrıca, dijital okuryazarlığın teknostres ile BİT tutumları arasındaki ilişkide kısmi aracılık rolü üstlendiği belirlenmiştir. İş Talepleri–Kaynaklar (JD–R) Modeli, Stresin İşlemsel Modeli ve Bilişsel Yük Kuramı çerçevesinde yorumlanan bu sonuçlar, dijital okuryazarlığın öğretmenlerin teknolojik taleplerle başa çıkmalarına yardımcı olan, bilişsel yükü azaltan ve teknolojiyi bir tehditten ziyade bir fırsat olarak algılamalarını sağlayan temel bir kişisel kaynak işlevi gördüğünü göstermektedir. Çalışma, müzik eğitiminde teknostresi azaltmak ve BİT entegrasyonuna yönelik olumlu tutumları geliştirmek için dijital okuryazarlığın artırılmasının kritik rolünü vurgulamaktadır.

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Telif hakkı © 2026 Yazar(lar). Açık erişimli bu makale, orijinal çalışmaya uygun şekilde atıfta bulunulması koşuluyla, herhangi bir ortamda veya formatta sınırsız kullanım, dağıtım ve çoğaltmaya izin veren Creative Commons Attribution License (CC BY) altında dağıtılmıştır.

Uygulama açısından bulgular, öğretmen yetiştirme programları ile hizmet içi eğitimlerin dijital pedagojiyi ve müziğe özgü teknolojileri önceliklendirmesi gerektiğine işaret etmektedir. Ayrıca bu bulgular, yerel girişimlerin küresel dijital yeterlik standartlarıyla uyumlaştırılması bağlamında, öğretmen eğitimi ve mesleki gelişim için karşılaştırmalı uluslararası çıkarımlar sunmaktadır. Politika yapıcılarının ise ulusal standartları DigCompEdu ve ISTE gibi uluslararası çerçevelerle daha fazla uyumlu hâle getirmesi gerekmektedir. Sonuç olarak bu çalışma, özellikle müzik öğretmenleri bağlamında dijital okuryazarlığın teknostres ile BİT tutumları arasındaki ilişkiyi aracılık rolünü ortaya koyarak alanyazına özgün katkı sunmaktadır.

Anahtar kelimeler: dijital okuryazarlık, teknostres, bilgi ve iletişim teknolojileri (BİT), teknolojik pedagojik alan bilgisi (TPAB), öğretmen eğitimi

1. INTRODUCTION

The present day is often defined as the age of information, knowledge or information processing due to the rise of information and communication technologies (ICT) (Tunç et al., 2022). The combination of these developments has resulted in this period being called the technological age, a process in which ICT has transformed all areas of society. ICT refers to the technological tools and resources used for the transmission, creation, dissemination, and management of information (Akinwale & Olafare, 2017). Rapid developments in ICT have facilitated access to and sharing of information; this has changed the ways in which societies communicate, accelerated the globalisation of information, and diversified communication environments (Almerich et al., 2016; Bağcı et al., 2020; Karaman & Karataş, 2009; Murat & Erten, 2018).

1.1. ICT and Digital Literacy in the Context of Education

Developments in technology have also profoundly affected education and teaching environments. With the spread of computer-assisted learning, ICT is seen as an important tool for developing 21st-century skills such as problem solving, creative thinking, critical thinking, and collaboration (Akgün, 2020; Voogt & Roblin, 2012). In the aftermath of the COVID-19 pandemic, music teachers globally have faced a rapidly changing digital teaching environment shaped by hybrid and online education, remote assessment, and the integration of emerging artificial intelligence tools (Feng & Liu, 2024; Martín-Gutiérrez et al., 2022). These developments have not only increased the technological demands on teachers but also heightened the need for adaptable digital literacy (Hussain et al., 2022; Redecker, 2017). The widespread use of applications such as virtual community platforms, automated accompaniment systems, and AI-powered notation software has altered the way music is taught and learned, leading to new forms of cognitive and emotional stress (Solís et al., 2023). At the same time, global discussions on digital equity and access to resources have highlighted inequalities between teachers with high and low levels of digital literacy (UNESCO, 2021). Therefore, post-pandemic music education represents a critical period in which digital literacy serves as both a professional requirement and a psychological buffer against technostress (Muslimin et al., 2023; Syvänen et al., 2016). It is acknowledged that teachers play a significant role in acquiring and imparting these skills, and therefore revisions are being made to teachers' competencies and curricula (Çapar & Vural, 2013; Martinovic & Zhang, 2012; Şad & Nalçacı, 2015; Tomei, 2005).

The International Society for Technology in Education (International Society for Technology Education [ISTE], 2020a) and the Ministry of National Education of the Republic of Turkey (2017) emphasise that the effective use of ICT by teachers is essential to increase the efficiency of the learning-teaching process, provide professional development, and spread a culture of digital literacy. In line with this, teacher training programmes in Turkey were revised in 2018, and an 'information technologies' course was added to all disciplines (Council of Higher Education, 2018).

However, ICT training provided during the teacher training process is often inadequate and not field-specific (Can & Aras, 2017). This deficiency is even more pronounced for music teachers; despite taking general technology courses during their pre-service training, they are rarely provided with quality training on music software (Yüceland, 2022). This situation leads music teachers to try to learn software on their own and increases the need for in-service training.

1.2. The Concept of Digital Literacy and Music Education

With the emergence of new technologies, the concept of literacy has acquired new meanings such as media literacy, digital literacy, and internet literacy (Lankshear & Knobel, 2004). Gilster (1997) defines digital literacy as 'the ability to understand and use information in multiple formats from various computer-mediated sources'; Martin (2006) emphasises that this process is a cognitive and critical one that also includes the

dimensions of analysis, synthesis, production, and communication. Avcı (2020) emphasises that digital literacy has acquired a new structure today as the ability to access, analyse, produce, and share information through network devices (computers, tablets, smartphones, smart watches, etc.).

In the context of music education, digital technologies have become an integral part of teaching and learning processes worldwide (Avcı, 2020; Ayhan & Gürler, 2023; Beckstead, 2001; Ho, 2004; Leong, 2012; Mills & Murray, 2000; Román-García et al., 2017). Tools such as digital instruments, music software, and MIDI technologies facilitate music learning and teaching (Babacan & Babacan, 2022). Digital literacy also provides advantages such as effective lesson planning, online instruction, and access to diverse resources (Yılmaz & Temiz, 2023). Studies indicate that technology-supported materials enhance motivation, active participation, and learning outcomes (Mert & Şen, 2019; Karaönçel & Çiftci, 2022). However, research in Turkey shows that many music teachers lack sufficient competence in music technologies and access to in-service training remains limited (Beşer, 2010; Köksal, 2019; Kürün, 2017).

1.3. The Role of Technostress in Education

The constantly changing nature of ICT can cause teachers to experience problems adapting, anxiety, fear, disappointment, and feelings of pressure (Akgün, 2019; Chiappetta, 2017; Daniel, 2020; Gökbulut, 2021; Laspinas, 2015). The concept of technostress was first defined by Brod (1984) as 'the inability to cope healthily with new computer technologies'. Technostress manifests itself through symptoms such as inadequacy, inability to adapt, psychological reluctance, and mental/physical fatigue due to intensive use (Arnetz & Wiholm, 1997; Champion, 1988; Jena, 2015; Ragu-Nathan et al., 2008; Wang et al., 2008). Teachers have experienced an increase in their levels of technostress, particularly during the pandemic, as they have been forced to use technology more intensively (Arslan et al., 2022). Research has revealed that technostress negatively affects ICT use and attitudes (Akgün, 2019; Fuglseth & Sørebo, 2014; Sami & Pangannaiah, 2006; Wang & Zhao, 2023).

1.4. Theoretical Framework

This study grounds the relationship between technostress, digital literacy, and ICT attitudes in three theoretical perspectives:

1. Job Demands–Resources (JD-R) Model: According to this model, job demands (e.g., technological complexity, overload) are sources of stress for employees. Digital literacy, as a personal resource, can mitigate the negative effects of these demands. For music teachers, technological innovations are a 'job demand,' while digital literacy acts as a protective buffer against this demand (Syvänen et al., 2016).
2. Transactional Model of Stress: According to this model, stress arises from an individual's assessment of environmental demands. When teachers perceive technology as a threat, their technostress levels increase; however, when their digital literacy skills are high, they can perceive the same technology as an opportunity and develop more positive ICT attitudes (Lazarus & Folkman, 1984).
3. Cognitive Load Theory: Teachers with low digital literacy experience high cognitive load when using technology, which increases technostress. Teachers with high digital literacy can manage their cognitive load and exhibit more positive ICT attitudes with lower stress.

Numerous studies have been conducted on teachers' technostress levels, attitudes towards ICT, and digital literacy (Aksoy et al., 2021; Çoklar & Bozyiğit, 2021; Demir, 2023; Erdem et al., 2021; Gökbulut & Dindaş, 2022). However, these studies have generally been conducted on general teacher samples, and the context specific to music teachers has not been sufficiently addressed. Music teaching, however, stands out as a more vulnerable area in terms of technostress, as it requires the combined use of both technological tools (notation software, recording technologies, digital libraries) and traditional pedagogical methods.

The aim of this study is to examine the relationships between music teachers' technostress, digital literacy, and ICT attitudes within the framework of the JD-R Model, Transactional Stress Model, and Cognitive Load Theory, and to reveal the mediating role of digital literacy.

The hypotheses developed within the scope of the research are as follows:

- H1: Technostress negatively affects ICT attitudes.

- H2: Technostress negatively affects digital literacy.
- H3: Attitudes towards ICT positively affect digital literacy.
- H4: Digital literacy plays a mediating role in the effect of technostress on attitudes towards ICT.

2. METHOD

2.1. Research Design and Procedure

The research was conducted using a quantitative research approach based on a correlational survey model to examine the relationship between music teachers' technostress, ICT attitudes, and digital literacy levels, as well as the mediating role of digital literacy in the relationship between technostress and ICT attitudes. The correlational model provides an appropriate methodological framework for defining the existing relationships between variables, revealing the direction and strength of these relationships, and testing the effects of mediating variables.

The reason for choosing the relational model in this study is to examine the experiences of music teachers through numerical data across a large sample and to determine the structural relationships (direct and indirect effects) between these variables, rather than experimentally testing the causal relationships between the variables. Collecting the data in a single session made the temporal dimension of the research practical and enabled the acquisition of a large data set.

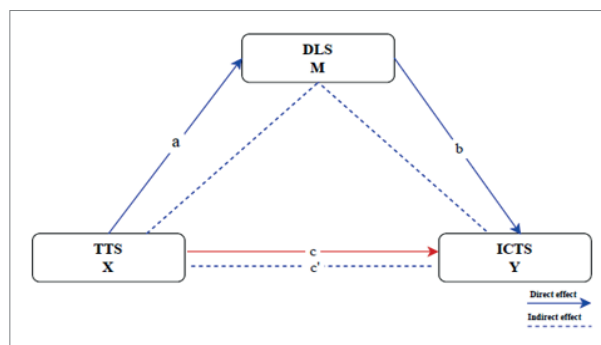
In this context, the study first examined the relationships between technostress and ICT attitude, technostress and digital literacy, and digital literacy and ICT attitude, and then tested the mediating role of digital literacy in the relationship between technostress and ICT attitude.

2.2. Conceptual Model

The conceptual model of the study is shown in Figure 1. The independent variable is technostress (X), the dependent variable is IT attitude (Y), and the mediating variable is digital literacy (M).

Figure 1

Mediation Model



2.3. Participants

In this study, a purposive sampling method was adopted to determine the study group. Accordingly, convenience sampling, one of the purposive sampling methods, was employed. Convenience sampling is based on the principle that the individuals or groups to be included in the study are easily accessible (Yıldırım & Şimşek, 2008). The study group consists of music teachers working in public and private schools across various provinces in Turkey. A total of 202 music teachers, who were reached through Google Forms during the 2023-2024 academic year, participated in the study on a voluntary basis. The demographic characteristics of the participants are presented in Table 1.

Table 1*Demographic characteristics of the participants*

Variable	Category	N	%
Gender	Female	124	61,4
	Male	78	38,6
Age	22 – 27	40	19,8
	28 – 32	59	29,2
	33 – 38	60	29,7
	39 – 44	30	14,9
	45 – +	13	6,4
Seniority	0 – 4	63	31,2
	5 – 9	69	34,2
	10 – 12	42	20,8
	15 – 19	17	8,4
	20 and +	11	5,4
School Type	Public	163	80,7
	Private	39	19,3

Of the teachers participating in the study, 61.4% were female, and 80.7% worked in state schools. In addition, 34.2% of teachers had 5–9 years of professional experience. The number of participants meets the minimum sample size recommended for testing mediation models using the Hayes Process Macro (Hair et al., 2021). However, as the regional distribution of the sample does not represent all provinces of Turkey in a balanced manner, there are limitations in the generalisability of the research findings. Therefore, the results should be interpreted taking contextual conditions into account.

2.4. Data Collection Process

Data were collected via an online survey administered to music teachers during the 2023-2024 academic year. This approach facilitated participation from different regions and was practical in terms of time and cost. However, potential limitations such as self-selection bias and limited access to technology among some participants were taken into account in interpreting the findings.

2.5. Data Collection

In order to collect the data, technostress scale, ICT teacher attitude scale and digital literacy scale were applied to music teachers on a voluntary basis during the 2023-2024 academic year.

The technostress scale (TSS) developed by Çoklar et al. (2017) consists of 28 items and 5 dimensions: "learning-teaching process-oriented", "profession-oriented", "technical subject-oriented", "personal-oriented" and "social-oriented". The Cronbach's Alpha coefficient for the 5-point Likert scale was calculated as ,917, while the Cronbach's Alpha coefficients of the factors forming the scale were found to be between ,712 and ,788. The Cronbach's alpha value calculated for the scores obtained from the sample group in the data collected in this study was determined as .96.

The ICT attitude scale was developed by Aydın & Semerci (2017) and consisted of a 5-point Likert scale, 16 items in total and 2 dimensions. The factor load values of the 11-item "Willingness to Use ICT" dimension are between .549 and .808, and the 5-item "ICT Anxiety" dimension is between .600 and .824. The Cronbach's Alpha coefficient for the "Willingness to Use ICT" dimension was calculated as .90, the Cronbach's Alpha coefficient for the "ICT Anxiety" dimension was calculated as .78, and the overall scale was calculated as .90. In the data collected in this study, the Cronbach's alpha value calculated for the scores obtained from the sample group was determined as .91.

The Digital Literacy Scale (DLS) consists of 3 dimensions and 44 items developed by Sulak (2022). The factor loading values for the "Information and Communication" dimension of the scale consisting of 15 items were calculated as .482 and .675 and Cronbach's Alpha coefficient was calculated as .900. The factor loading value for the "Instructional Technologies" dimension of the scale consisting of 18 items was found between .367 and .803 and Cronbach's Alpha coefficient was calculated as .924, while the factor loading value for the "Technical" dimension of the scale consisting of 11 items was found between .509 and .742 and Cronbach's Alpha coefficient was calculated as .919. In the data collected in this study, the Cronbach's alpha value calculated for the scores obtained from the sample group was determined as .96.

2.6. Data Analysis

The data obtained from the study were analysed using IBM SPSS 22.0 (Statistical Package for the Social Sciences) and the PROCESS Macro 4.2 add-on developed by Hayes. First, normality analyses were performed to test the distribution characteristics of the scores obtained from the scales used in the study. Skewness and kurtosis values were found to be within the ± 0.96 range, and since these values met the criteria for normal distribution (Büyüköztürk et al., 2014), the data were considered suitable for parametric analyses.

Pearson correlation analysis was performed to determine the relationships between dependent, independent, and mediating variables. Correlation analyses are a technique used to determine the direction and strength of the relationship between two or more continuous variables (Başol, 2013; Best & Khan, 2017; Büyüköztürk et al., 2014). The correlation coefficients obtained range from +1 to -1, with the absolute value of the coefficient indicating the strength of the relationship. In this study, the interpretation of correlation coefficients was based on the criteria proposed by Kalaycı (2006).

To test the effect of the mediating variable, a regression-based mediation analysis was conducted. Within this scope, Model 4 of the PROCESS Macro developed by Hayes was used. Model 4 is the standard model recommended for testing the effect of a single mediating variable in the relationship between the independent and dependent variables. The bootstrap method was used to assess the significance of the mediating effect, and bias-corrected confidence intervals based on 5,000 samples were calculated. In bootstrap analysis, if the lower confidence interval (BootLLCI) and upper confidence interval (BootULCI) values corresponding to the obtained indirect effect do not include zero (0), the mediating effect is considered statistically significant (Tibbe & Montoya, 2022).

This analytical approach was preferred because it allows testing the significance of not only direct effects but also indirect effects. Furthermore, the use of the SPSS-based PROCESS Macro was considered methodologically appropriate due to its flexibility in terms of parametric assumptions and its ability to produce reliable results in mediation models. In the analyses, not only p-values but also effect sizes (R^2 values) were reported to demonstrate the explanatory power of the model.

3. RESULTS

This section presents the results of the analysis on the relationships between technostress (TSS), ICT attitude (ICTS) and digital literacy (DLS), as well as the mediating role of digital literacy.

3.1. Descriptive Statistics and Correlations

Table 2 shows the mean and standard deviation values of the scales used in the study, along with their correlation coefficients.

Table 2

Mean, normality, correlation and reliability analysis of the measurements of tools

Variable	\bar{x}	SD	Skewness	Kurtosis	1	2	3	Cronbach's Alpha
1. TSS	64,73	22,81	,519	,216	1	-,376**	-,180*	,96
2. ICTS	65,05	10,41	-,492	-,552		1	,501**	,91
3. DLS	169,14	28,38	-,602	,505			1	,96

Abbreviations: TSS, Technostress Scale; ICTS; Information and Communication Technologies Scale; DLS, Digital Literacy Scale ; **Correlation is significant at the 0,01 level (2-tailed); * Correlation is significant at the 0,05 level (2-tailed)

The mean score for TSS was calculated as 64.73 (SD = 22.81), the mean score for ICTS was 65.05 (SD = 10.41), and the mean score for DLS was 169.14 (SD = 28.38). The skewness and kurtosis values remained within the ± 1.5 range suggested by Bayram (2010), and normality of distribution was observed.

According to the correlation analysis results:

There is a moderate, negative, and significant relationship between technostress and ICT attitude ($r = -.376, p < .01$). This result indicates that as technostress increases, teachers' positive attitudes towards ICT decrease.

A low-level, negative, and significant relationship was found between technostress and digital literacy ($r = -.180, p < .05$). This finding indicates that teachers with low digital competence experience technology as more stressful.

A strong and positive relationship was found between ICT attitude and digital literacy ($r = .501, p < .01$). This reveals that teachers with high digital literacy have a more positive approach to technology.

3.2. Direct Effects and Hypothesis Tests

Table 3 shows the regression analyses between the independent and dependent variables.

Table 3

Summary of Regression-Based Hypothesis Testing for Direct Paths

Estimated Variable	Coeff	SE	t	p	LLCI	ULCI	Hypothesis
X → Y	-,296	,027	-5,039	,000***	-,188	-,082	H1***
X → M	-,180	,087	-2,581	,011**	-,394	-,053	H2**
M → Y	,448	,022	7,627	,000***	,122	,207	H3***

Coeff. = unstandardized regression coefficient; SE = standard error; LLCI = lower limit of confidence interval; ULCI = upper limit of confidence interval; * $p < .05$, ** $p < .01$, *** $p < .001$.

H1 (Supported): Technostress was found to have a significant and negative effect on ICT attitude ($\beta = -.296, SE = .027, t = -5.039, p < .001; 95\% CI = [-.188, -.082]$). This result indicates that technostress reduces teachers' motivation towards technology. The effect size is moderate ($R^2 = .21$).

H2 (Supported): Technostress was found to negatively affect digital literacy levels ($\beta = -.180$, $SE = .087$, $t = -2.581$, $p = .01$; 95% CI = $[-.394, -.053]$). This finding reveals that teachers experiencing high stress have a reduced capacity to learn and apply digital tools.

H3 (Supported): Digital literacy was found to have a significant and positive effect on ICT attitudes ($\beta = .448$, $SE = .022$, $t = 7.621$, $p < .001$; 95% CI = $[.122, .207]$). This result indicates that teachers with strong digital skills are more willing and confident in using technology in education. The effect size is large ($R^2 = .29$).

3.3. Mediating Analysis

Table 4 presents the total, direct, and indirect effect results for the mediating model between technostress, digital literacy, and ICT attitude.

Table 4

Mediator variable effect

	Effect	SE	t	p	LLCI	ULCI
Total Effect (X → Y)	-.172	.030	-5.745	.000	-.231	-.113
Direct Effect (X → Y)	-.135	.027	-5.039	.000	-.188	-.082
	Effect	BootSE		BootLLCI	BootULCI	Hipotez
Indirect Effect via M	-.037	.019		-.078	-.005	H4***
X → M → Y						

Bootstrapping was conducted with 5,000 resamples. Std. Effect = completely standardized indirect effect; PM = proportion mediated; * $p < .05$, ** $p < .01$, *** $p < .001$.

Total effect (Eff = $-.172$, $SE = .030$, $t = -5.745$, $p < .001$; 95% CI = $[-.231, -.113]$) and the direct effect (Eff = $-.135$, $SE = .027$, $t = -5.039$, $p < .001$; 95% CI = $[-.188, -.082]$) were found to be significant.

The indirect effect was found to be significant (Eff = $-.037$, $BootSE = .019$; 95% $BootCI = [-.078, -.005]$). The completely standardized indirect effect was $-.080$, indicating a small-to-moderate mediation effect. Furthermore, the proportion mediated was approximately 21.5%, suggesting that digital literacy partially mediates the relationship between technostress and ICT attitudes.

These results indicate that digital literacy plays a partial mediating role in the relationship between technostress and IT attitude. Therefore, H4 is supported. Furthermore, the mediation rate of digital literacy in this relationship was calculated to be approximately 21.5%.

The results generally reveal that digital literacy is a critical factor in developing positive attitudes towards technology among music teachers. The fact that the negative impact of technostress on ICT attitudes can be mitigated through digital literacy supports the notion that digital literacy functions as a 'personal resource' within the Job Demands–Resources (JD-R) Model. Similarly, from the perspective of the Transactional Model of Stress, digital skills enable teachers to view technology as a manageable tool rather than a threat. Furthermore, Cognitive Load Theory explains that teachers with low digital skills experience greater cognitive load when using technology, and are therefore more stressed.

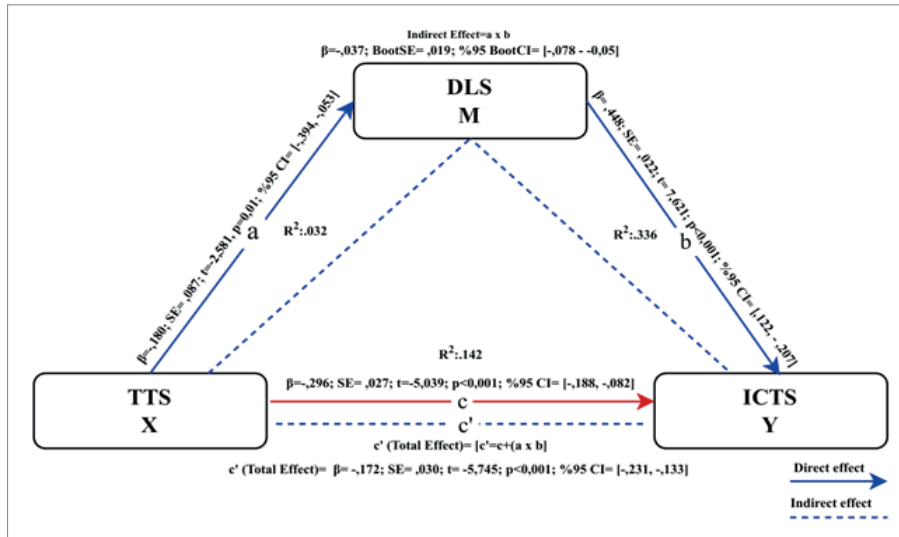
From a pedagogical perspective, these findings indicate that music teachers need digital literacy training to work more effectively with technology. From a psychological perspective, it is seen that technostress can lead to professional burnout and loss of motivation, but digital literacy buffers this negativity.

4. DISCUSSION AND CONCLUSION

This study examined the relationships between music teachers' levels of technostress, their attitudes towards ICT, and their digital literacy skills, revealing that digital literacy plays a mediating role in the relationship between technostress and attitudes towards ICT. The findings supported all hypotheses established in the study.

Figure 2

The mediating role of Digital Literacy in the relationship Technostress and Information and Communication Technology



When Figure 2 is examined, support for H1 indicates that technostress is negatively associated with attitudes towards ICT. When evaluated in terms of the Job Demands–Resources (JD-R) Model, this finding reveals that technostress functions as a 'job demand' for teachers. According to the JD-R model, high levels of job demands (e.g., technological complexity, time pressure, constant innovation) can cause employees to develop burnout and negative attitudes (Ragu-Nathan et al., 2008; Tarafdar et al., 2011). As seen in this study, music teachers' excessive exposure to technology causes them to develop a more negative attitude towards ICT if they do not have sufficient support or skills. This finding is consistent with national (Çoklar & Bozyiğit, 2021; Demir, 2023) and international (Fuglseth & Sørø, 2014; Wang & Zhao, 2023) literature.

The same finding also makes sense in the context of the Transactional Model of Stress. According to this model, developed by Lazarus & Folkman (1984), stress arises as a result of an individual's assessment of environmental demands in relation to their personal resources. In this context, when music teachers perceive technology as a 'threat' (e.g., lack of competence, technical problems), they experience stress, and this stress is associated with more negative attitudes towards ICT. This assessment process focuses on teachers' subjective experiences, and the findings obtained in our study are consistent with this theoretical framework.

Supporting H2 demonstrates that digital literacy is negatively associated with technostress. This finding reveals that personal skills (e.g., digital competencies), which can be considered 'job resources' in the JD-R model, mitigate the negative effects of job demands such as technostress. Syvänen et al. (2016) stated that ICT competencies have a direct effect on technostress, while Feng & Liu (2024) and Muslimin et al. (2023) showed that digital literacy is a factor that reduces technostress.

Furthermore, this finding can also be evaluated in the context of Cognitive Load Theory. According to this theory, developed by Sweller and colleagues, individuals have limited cognitive load capacity. Teachers with low levels of digital literacy experience greater cognitive load when interacting with technology, which increases their stress levels (LaRose et al., 1998; Tams et al., 2014). Therefore, improving digital skills both reduces cognitive load and enhances the capacity to cope with stress. This study concretely demonstrates this theoretical relationship in the context of music teachers.

Supporting H3 has revealed a strong and positive relationship between digital literacy and attitudes towards ICT. This finding indicates that teachers who develop positive attitudes towards technology find it easier to develop their digital skills and are more successful in integrating these skills into their teaching processes (Altun, 2019; Doğan, 2023; Jan, 2018; Kumari & D'Souza, 2016; Kay, 2008; Teo, 2008). This also explains how job resources (e.g., positive attitude, competence) play a protective role in managing job demands in the JD-R model.

The validation of H4 indicates that digital literacy is found to have a partial mediating role in the relationship between technostress and IT attitude. This finding explains the mediating role of job resources in the JD-R model, the importance of coping strategies in the Transactional Model of Stress, and the effect of cognitive load management on attitudes in Cognitive Load Theory. In other words, digital literacy both enables individuals to view technology as an opportunity and helps them cope with stress by reducing their cognitive load.

In light of these theoretical frameworks, the findings of this study gain meaning not only statistically but also theoretically. Music teachers need to possess personal resources such as digital literacy to cope with technological demands, as supported by the JD-R model; they need to perceive technology as an opportunity rather than a threat, as supported by the Transactional Model; and they need to be able to manage their cognitive load, as supported by Cognitive Load Theory.

The findings of this study are also consistent with the literature examining the pedagogical integration of technology in the context of music education (Ho, 2004; Mert & Şen, 2019; Karaönçel & Çiftci, 2022; Kürün, 2017; Köksal, 2019). Furthermore, the development of teachers' digital skills during the COVID-19 process (Kıymet & Çakır, 2023; Köksal, 2022) and the increase in technostress (Doğan & Birişçi, 2022) are also parallel to the findings of our study.

The rapid digitalisation and integration of artificial intelligence-based tools in global music education coincide with post-pandemic challenges for teachers, intensifying both opportunities and stress factors (Feng & Liu, 2024; Martín-Gutiérrez et al., 2022). The pandemic has reinforced hybrid and technology-mediated teaching models that reshape teachers' professional identities and workloads (Hussain et al., 2022). In this new environment, AI applications such as AI-powered notation systems, virtual accompaniment platforms, and automated feedback tools have transformed how teachers develop, deliver, and assess music learning (Solís et al., 2023). Consequently, the post-pandemic period requires teacher education programmes to move beyond basic ICT competencies towards adaptive digital literacy, integrate reflective strategies to reduce technological stress, and simultaneously support sustainable engagement with new technologies (Redecker, 2017; Muslimin et al., 2023).

In an international context, frameworks such as ISTE and DigCompEdu emphasise the need for teachers to develop their digital competencies (Hussain et al., 2022; Tor et al., 2022; Solís et al., 2023). Aligning music teacher training programmes in Turkey with these international standards will contribute to teachers adapting more healthily to technological changes and reducing the harmful effects of technostress.

4.1. Implication for Music Teacher Education Practice

The design and renewal of music teacher training programmes yield significant results. Digital literacy should be addressed not as a secondary or independent ICT course, but as an integral part of core music education, pedagogy, and methodology courses. In this context, integrating courses such as Digital Musician, Technology-Supported Ear Training, and Online Community Collaboration into music teaching programmes can bridge the gap between artistic and technological competencies by integrating digital tools with traditional music learning processes. Furthermore, the redesign of programmes should include modules that develop trainee teachers' skills in managing technological stress, time management, and collaborative learning through practical work with digital notation software (e.g., Finale, MuseScore), digital community-based learning activities, and reflective practices. These approaches will support the integration of digital literacy with pedagogical training in the process of training music teachers and the conscious, creative, and sustainable use of technology.

International research emphasises that both pre-service and in-service music teacher education must adopt a continuous and reflective approach to digital pedagogy in line with 21st-century competency frameworks (Trilling & Fadel, 2009). In Finland, the integration of creative and productive music technology into the national

curriculum (Finnish National Agency for Education [FNAE], 2014) has emphasised the role of teachers as reflective practitioners who reflect on and for action (Schön, 1987) and has promoted both musical creativity and digital resilience. However, empirical evidence shows that, despite being emphasised at the policy level, teachers' preparedness levels remain uneven and there is a persistent demand for structured, practice-oriented professional development (Ahtola et al., 2025). Similarly, Hietanen et al. (2022) demonstrated that remote co-teaching between universities not only enhances lecturers' digital literacy but also reduces technostress by promoting collaboration and contextual learning. This finding aligns with Guskey's (2002) professional development model. According to this model, changes in attitudes and teaching precede improvements in student learning.

In the United States, West (2023) found that music teachers are increasingly participating in technology-based professional development programmes, but that teachers' limited mobility and discipline-specific support constrain the long-term impact of such initiatives. In contrast, in the United Kingdom, Gall (2017) expanded the TPACK framework (Mishra & Koehler, 2006) by emphasising the concepts of Musical Technological Knowledge (MTK) and Musical Pedagogical Knowledge (MPK), thereby positioning technology as an integral part of both musicianship and pedagogy. These models collectively confirm that digital literacy serves both as a pedagogical skill and as a psychological buffer against technostress. This aligns with Fernández-Batanero et al. (2021), who define digital competence as a critical mediator of teachers' emotional and cognitive adaptation to technology.

Overall, cross-national research indicates that sustainable reform in music teacher education requires integrating pre-service and in-service training, as well as combining digital pedagogy, creativity, and reflective practice. In the Turkish context, this highlights the need to embed digital literacy into both university curricula and continuous professional development to enhance technological adaptation and reduce technostress.

In the Turkish context, empirical evidence also shows that the success of digital transformation in music education largely depends on the quality and continuity of in-service professional development. Öztürk and Öztürk (2019) found that despite an increase in the number of in-service training programmes, most remain theoretical and fragmented, offering music teachers limited opportunities to apply digital skills in real teaching environments. Similarly, Yüceland (2022) found that teachers frequently request practical training in music technology, digital notation software, and online teaching tools, but that such training opportunities are often short-term and fail to develop sustainable digital competence. These findings suggest that digital literacy should be positioned not only as a pedagogical skill but also as a psychological resource that reduces technostress and enhances resilience. Accordingly, music teacher education programmes should integrate application-oriented and collaborative training models that support the effective use of technology in music pedagogy.

Furthermore, in-service professional development should be redesigned to focus not only on technical proficiency but also on strategies for coping with technological stress, including digital self-regulation, reflective teaching, and peer mentoring (Feng & Liu, 2024; Tarafdar et al., 2011). Integrating these recommendations can strengthen teachers' digital resilience and support sustainable professional growth in rapidly evolving technological environments.

4.2. Global Perspective

Although this study was conducted in Turkey, its findings have broader implications for music teacher education in the global context. Across regions, educators face similar challenges related to technological change and adaptability. International frameworks such as ISTE (2020b), DigCompEdu (Redecker, 2017), and UNESCO (2021) emphasise that digital competence is a fundamental requirement for teaching. In this regard, digital literacy emerges as a key factor in reducing technostress, enhancing self-efficacy, and supporting professional collaboration (Feng & Liu, 2024; Muslimin et al., 2023).

From an international perspective, these findings suggest that digital literacy should be considered as part of a broader educational transformation rather than a context-specific innovation. Accordingly, integrating international collaboration, shared digital pedagogy, and comparative research into music teacher education programmes may support more effective adaptation to technology across diverse educational contexts (Valtonen et al., 2018).

4.3. Limitation and Suggestions for Future Research

This study has certain limitations, and the findings should be evaluated within this framework:

Cross-sectional Research Design: The research was conducted using a cross-sectional survey model. Therefore, the relationships between technostress, digital literacy, and ICT attitudes were only evaluated simultaneously. Longitudinal studies are recommended in the future to reveal causal relationships more strongly. This would allow for a better understanding of how teachers respond to technological demands in the long term within the JD-R model.

Self-Report Data: Data were collected using self-report scales. This carries the risk of social desirability bias or misreporting. In future research, self-report methods should be supplemented with performance-based measures (e.g., actual digital tasks) or qualitative data collection techniques (interviews, observation). This would allow for a more in-depth understanding of teachers' subjective assessments within the Transactional Model of Stress.

Limitations of the Sample: The study is limited to only 202 music teachers working in Turkey. Although this number is sufficient for statistical analysis, the generalisability of the findings to music teachers in other countries or teachers in other subjects is limited. Future research could test the international validity of the results by conducting comparative studies with teachers from different cultures and disciplines. This would provide a basis for global comparisons, particularly in the context of DigCompEdu and ISTE standards.

Limitations of the Model: The study focused only on three variables (technostress, digital literacy, ICT attitude). However, according to the JD-R model, factors such as job resources (e.g., organisational support, peer cooperation) and job demands (e.g., time pressure, workload) are also determinants of technostress. Future studies are recommended to include variables such as self-efficacy, cognitive load, organisational support, and pedagogical competence. This would allow for a more comprehensive testing of both Cognitive Load Theory and the Transactional Model.

Ethical approval

The study was approved by Kafkas University Committee on Research and Publication Ethics in the Social and Human Sciences (date: 05.05.2024, number: 58).

Author contribution

Study conception and design: ÖÜ, SK; data collection: ÖÜ, SK; analysis and interpretation of results: ÖÜ, SK; draft manuscript preparation: ÖÜ, SK. All authors reviewed the results and approved the final version of the article.

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The authors declare that there is no conflict of interest.

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