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Original Article

The Effect of Using Technology in Music Education and Training on Academic Achievement: A Meta-Analysis Study

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Abstract

The objective of this study is to examine the impact of technology use on academic achievement in music education and training through meta-analysis. To this end, a comprehensive literature review was conducted to examine the effects of technology use and music education and training on academic achievement. Keywords were used for these reviews (music education, music teaching ICT, technology, etc.). A comprehensive literature review was conducted to examine the effects of technology use and music education and training on academic achievement. The following databases were used for these searches: ERIC, Scopus, Web of Science, Springer Link, Taylor & Francis, Scopus, ProQuest Dissertations and Theses Global, Sage Journals, and Google Scholar. The data obtained from the studies were first placed on an Excel sheet by creating a coding form. A meta-analysis software was used for a comprehensive meta-analysis study. The study method employed was meta-analysis, which was used to calculate the effects on academic achievement. The purpose of meta-analysis is to re-examine the findings of the studies by evaluating the studies on the same subject together. In the literature review process, 31 studies (articles and doctoral dissertations) published between 2013 and 2023 were included. The results of the meta-analysis indicated that the incorporation of technology in music education and training has a positive impact on academic achievement. The average effect size of the studies was found to be d=0.525, according to the random effects model. Additionally, the analysis revealed that the effect size varies depending on several factors, including year, publication type, participant, technology type, and sample. The evaluations yielded the highest effect size values in 2021 (0.375), articles (0.561), students (0.946), Others (0.497), and between 1-75 people (0.911). Based on these findings, recommendations were made to expand the number of studies on pre-service teachers and to conduct meta-analysis studies across various categories of related studies.

Keywords

Music education
Music teaching
Technology
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Introduction

The pace of technological development has led to significant changes in the way people work and the nature of the work they undertake. Technology use is vital to ensuring that people have the right skills to sustain long-term economic prosperity and competitive advantage in the global economy (Leitch, 2006). Technology, which has become a necessity of our age, enables countries to progress and make a name for themselves in social, economic, and cultural fields. Technology offers significant contributions with its use in all fields.

At the same time, technology affects many areas from people's daily life to education, work, economy, social and cultural life (Karataş, 2024). In this context, technology makes important contributions with its use in every field.

One of these areas is the use of technology in education. Education and instructional technology have developed considerably by integrating technology into education. The rapid advances in educational technology bring new perspectives to the modern education framework on a daily basis. It is therefore imperative to keep up with the requirements of this so-called digital age.

Today, integrating technology into lessons is becoming essential for students, who are commonly referred to as the digital generation. In the current era, technology is regarded as a fundamental aspect of enriching teaching and utilising tools (Önal, 2022). Educational technology encompasses a diverse range of fields, including technological devices, technology-based activities, and applications. Additionally, educational technology encompasses the utilisation of internet-connected computing devices, such as laptops, tablets, and smartphones, which are integral components of digital technology. These technological devices are employed in the education system to facilitate a range of educational approaches, from early childhood education to work-based learning (Selwyn, 2013). Educational technology can be categorised into three main areas of use. These are:

- Technology as a teacher (the computer provides instructions and guides the user)
- Technology as a teaching tool
- Technology as a learning tool (Stošić, 2015)

The advent of technology has opened up new avenues for learning and information transmission (Williams & Webster, 2006). In order to ensure that these innovations are employed in an optimal manner within the context of education, it is essential that both the infrastructure be made suitable and that teachers receive in-service training on technology usage skills.

It is estimated that pre-service teachers and teachers may encounter a range of challenges related to the use of technology. These challenges are outlined below: First-order barriers include a lack of software and hardware, inadequate training for teachers and pre-service teachers, a lack of support from administrators on technology, overcrowded classrooms, economic constraints, time constraints, an inadequacy of classroom and school infrastructure, and a lack of technical support (Ertmer, Adisson, Lane, Ross, & Woods, 1999). Diem (2000) emphasised that teacher education is vital in enabling teachers to use technology in schools. Concurrently, he underscored the necessity of substantial investment in teacher training to facilitate the integration of information and communication technologies (ICTs) in the classroom and enhance ICT infrastructures in schools on a global scale.

The Use of Technology in Music Education

It is evident that the incorporation of technological materials in creativity-based music education will positively impact students' motivation, music-oriented thinking, musical practices, and musicality. It is crucial to capture students' attention and engage them effectively in the educational process through the provision of novel experiences. In this context, it is imperative that teachers possess the requisite competence to utilise diverse applications in the contemporary technological landscape. Nevertheless, it is widely acknowledged that it is essential to identify suitable methodologies for the subject matter, with a clear and structured plan of action, and to integrate different applications at various stages of the educational process. It is therefore recommended that teachers should be provided with in-service training in order to improve their competencies, to be aware of technological changes and developments, and to use technological materials in a planned and active way in the lesson process (Gül, 2023).

Composition in music education serves as an important tool for the affirmation of self and identity. It is notable that music technology is becoming an increasingly central aspect of music-making practices in educational settings across all educational sectors, from primary to tertiary education (Armstrong, 2011). Digital technology offers a more straightforward method for music students to disseminate their music work, as audio-formatted music can be rapidly transmitted over the network to any destination chosen by the student. Secondly, digital technology also provides students with live music and performances. Students are able to express music through the use of computers and synthesizers (Song & Chen, 2017).

In the field of music education, music teachers utilise computers for a variety of purposes, including listening to music, watching videos, and presenting visual materials. Additionally, they employ computers for the purposes of notation and sound recording. There exists a plethora of software programs designed for the aforementioned purposes. However, it is often the case that teachers are unable to learn and utilise software that requires a certain degree of detailed knowledge (Nart, 2016).

The advent of new methods that enable teachers to reach students offers the potential to expose future music educators to new teaching methods in music education that will influence future educational practices (Lin, 2005). Consequently, it is imperative that music educators receive training in the specific technology utilisation (Cremata, 2010).

Bannerman and O'Leary (2021) sought to ascertain the personal use of technology by music teacher candidates, their views on the use of technology in music teaching, and their experiences with music technology. The study concluded that pre-service music teachers utilise technology for various purposes on a daily basis and perceive themselves to be lacking in knowledge regarding technology for music teaching.

A review of the literature reveals a plethora of methods related to the use of technology in music education lessons. Notation software is one such method, which helps students to enhance their creativity in the lessons and to facilitate visual and auditory development in the field of music theory. Another method of use is mobile devices, which are frequently employed in music technology. The ability to play multiple instruments with mobile software such as GarageBand facilitates performance at different levels. Furthermore, in secondary and high school music classes, form and harmonic structures can be analysed through works with this method (Dammers, 2019).

Web-based videoconferencing is another method used in music education. With this method, it becomes easy to receive or give training from long distances. This approach can be useful for almost every subject in the music curriculum (Dammers, 2009).

A Meta-Analysis Study on The Effects of Technology Use on Academic Achievement

A number of meta-analysis studies in the literature have been conducted on the effect of technology use on academic achievement. Ayaz, Şekerci, and Oral (2016) conducted a meta-analysis study to determine the effect of technology use in education on the academic achievement of primary school students. A total of 19 studies on the effect of the use of instructional technologies on the academic achievement of primary school students were included in the meta-analysis. The study determined effect size differences related to courses, implementation period, study type, and grade level. It was found that the use of instructional technologies positively affected the academic achievement of primary school students.

Ayaz and Söylemez (2015) conducted a meta-analysis study to determine the effect on students' academic achievement in science courses. The total number of studies included in the meta-analysis was 41. As a result of the analysis, 42 effect size values were obtained. As a result of the meta-analysis, it was determined that the project-based learning approach had a positive effect on students' academic achievement in science courses.

Kates, Wu, and Coryn (2018) conducted a meta-analysis to investigate the relationship between cell phone use and educational achievement. The overall analysis revealed that the average effect of cell phone use on student outcomes was $r = -0.162$, with a 95% confidence interval of -0.196 to -0.128. The effect sizes of moderator variables (level of education, region, type of study, and whether the effect size was derived from the Beta coefficient and the nature of mobile phone use) were analysed.

Akar (2020) examined the effect of smart board use on academic achievement. Forty-seven experimental studies examining the effect of smart board use on academic achievement that met the inclusion criteria were analysed according to the random effects model using the meta-analysis method. The analysis revealed that the effect size of smart board use on academic achievement was positive, large, and significant (ES(d) = .94, $p < .05$).

In their 2022 meta-analysis, Di and Zheng (2022) synthesised findings on the overall effects of virtual-based spatial ability development. They identified 36 empirical peer-reviewed journal articles from 2010-2020 that met the inclusion criteria. The results demonstrated that virtual technologies moderately improved spatial ability, with an overall effect size of 0.617.

Chen and Yang (2019) conducted a meta-analysis to synthesize existing research comparing the effects of project-based learning and traditional teaching on student academic achievement. The analysis included 46 effect sizes (comparisons) from 30 eligible journal articles published between 1998 and 2017. These represented 12,585 students from 189 schools in nine countries. The results demonstrated that the overall average weighted effect size (d+) was 0.71, indicating that project-based learning had a moderate to large positive effect on students' academic achievement compared to traditional teaching.

In a recent study, Lynch, An, and Mancenido (2023) conducted a meta-analysis of 37 experimental and quasi-experimental studies of mathematics summer programs for pre-K-12 children. The results indicated that children who participated in summer programs that included mathematics activities exhibited significantly better mathematics achievement outcomes than their counterparts in the control group. The objective of the study by Kazu and Kurtoğlu Yalçın (2022) was to ascertain the overall impact of hybrid learning on students' academic achievement. To this end, five research findings were analysed. The relevant studies were identified from the databases of academic publications. The sample was examined using the Comprehensive Meta-Analysis CMA program. The type of publication, level of education, discipline, and duration of intervention were identified as moderator variables. The results indicated that the effect of hybrid learning on students' achievement was statistically higher ($d = 1.032$) in the random effects model.

In general, when the studies are examined, indicators such as publication type, participants, education level, etc. are determined as moderator variables. When the reasons for their selection are considered, it is important to understand the relationship between variables. The variables selected as moderators are to reveal how they affect the strength of the relationship between the dependent and independent variables (Baron & Kenny, 1986). In summary, the strength of the relationship between music education and technology use may increase or decrease with variables such as participant, year, type, etc.

In his study, Ulum (2022) analysed the impact of online education on student achievement. He conducted a meta-analysis of relevant studies focusing on the impact of online education on students' academic achievement in various countries between 2010 and 2021. This meta-analysis consisted of a total of 27 studies. The study results demonstrated that the effect size of online education on academic achievement was moderate.

Although numerous studies have been conducted to determine the effects of technology on students' academic achievement, particularly in the context of music education, there are few that examine the results holistically. Consequently, there is a need for studies that are analysed in more comprehensive and reliable ways in order to interpret the accumulation of knowledge formed by existing studies and to shed light on new studies. It is acknowledged that meta-analysis studies that can integrate the disparate results of these studies in a holistic manner and contribute to more robust interpretations by synthesising their findings are crucial. Consequently, this study is of significant value in terms of synthesising the experimental studies that examine the utilisation of technology in music education with regard to academic achievement. It seeks to ascertain whether there is an effect, to determine the extent of this effect, and to provide a general perspective on these studies.

Rationale and Importance of the Study

When meta-analysis studies in music education are examined, Standley, J. M. (1996) "A meta-analysis on the effects of music as reinforcement for education/therapy objectives"; Cooper (2019) states that "It's all in your head: A meta-analysis on the effects of music training on cognitive measures in schoolchildren"; Blackwell, Matherne, and McPherson (2023) "A PRISMA review of research on feedback in music education and music psychology"; Mishra (2014) "The Criterion Validity of Gordon's Music Aptitude Tests in Published Music Education Research"; Jaschke, Eggermont, Honing, and Scherder (2013) "Music education and its effect on intellectual abilities in children: A systematic review"; Hanson (2019) "Meta-Analytic Evidence of the Criterion Validity of Gordon's Music Aptitude Tests in Published Music Education Research"; Folkestad (2004) "A meta-analytic approach to qualitative studies in music education: a new model applied to creativity and composition"; Gordon, Fehd, and McCandliss (2015) "Does music training enhance literacy skills? A meta-analysis", only these studies could be accessed. It can be seen from this that the number of meta-analysis studies on music education is relatively low. Furthermore, it has been established that there is no focus on how the use of technology affects the academic achievement of music education and training. Consequently, the present study aims to address this important gap in the relevant literature.

The Purpose and Research Questions of the Study

The study aims to investigate the effectiveness of technology use in increasing academic achievement through meta-analysis. To this end, the research question was formulated as follows: "What is the overall effect of technology use on academic achievement in music education and training?" In the course of the research, the variables that were identified as affecting the use of technology in music education and became apparent due to the coding of the data were determined. The sub-problems created for this purpose are as follows:

1. What are the descriptive statistics of the studies examining academic achievement according to variables?
2. What is the overall effect size of academic achievement?
3. What is the moderator analysis of technology use in music education on academic achievement?
   a. What is the effect on academic achievement according to publication year?
   b. What is the effect on academic achievement according to publication types?
   c. What is the effect on academic achievement according to the participants?
   d. What is the effect on academic achievement according to the type of technology?
   e. Does the number of sample group have an effect on evaluations?

Method

In this study, meta-analysis was employed as a research methodology to assess the impact of technology use on academic achievement. The objective of meta-analysis is to re-examine the findings of previous studies by evaluating the studies on the same subject collectively. In the process of conducting a literature review, 31 doctoral dissertations and articles published between 2013 and 2023 were included in the study. The Comprehensive Meta-Analysis (CMA) V4 software and Microsoft Excel were employed for effect size calculations. In the significance process of the analyses, it was accepted that there was a statistically significant difference when $p < 0.05$, and when $p > 0.05$, statistically significant differences were considered insignificant.

The total number of samples in the studies was 4,853. Given that it was determined that the studies included in the study had a heterogeneous structure, the random effects model was employed. The random effects model yielded an average effect size value of 0.525 for the studies. This value indicates that the results have a moderate effect size (0.40 and above), as classified by Thalheimer and Cook (2002). It also indicates that the treatment effect favors the experimental group, with a positive mean magnitude value of +0.700.

A meta-analysis is a form of analysis that is employed in order to obtain a general result by combining the results obtained from individual studies. While meta-analysis was initially used only in the field of health science, it was later used in other branches of science. The process of meta-analysis allows researchers to combine quantitative data by combining a similar method or study in different regions. This is because it can interpret many studies under a single study (Dinçer, 2021). This study was created in accordance with the guidelines set forth in the PRISMA method (Moher, Liberati, Tetzlaff, & Altman, 2009). The PRISMA method was employed to systematically analyse studies on the use of technology in music education and training between 2013 and 2023.

Data Collection

Sampling and Selection Criteria

In the search for studies on the use of technology in music education and training, a number of keyword phrases were used from abstracts in well-known databases, including ERIC, Springer Link, Taylor & Francis, Web of Science (WoS), Scopus, and ProQuest. Dissertations and Theses Global, Sage Journals, Google Scholar. The following keywords were used to identify relevant articles: "Music" AND "Education" AND "Technology," "Technology in Music Education," AND "Music Education and Technology," "Music Education" AND "Technology."

The journals and theses were manually screened in order to facilitate the meta-analysis and to ensure the inclusion of all relevant studies. In addition, care was taken to avoid duplication, as some articles were indexed in more than one database, or some theses were published as research articles in journals. Consequently, 15 studies were excluded due to duplication, and 22 research articles were excluded.

All studies were then read in order to apply the inclusion criteria. The inclusion criteria were as follows:

The following criteria were applied to the selection of studies for inclusion in the meta-analysis:

- Publication language: English
- Articles and theses
- Experimental studies
- The use of technology in music education
- General music education
- Studies published between 2013-2023

A meta-analysis study requires sufficient data, including mean, standard deviation, sample size, and paired p-value or t-values. Descriptive statistical results for meta-analysis, such as those reported by Montgomery, Mousavi, Carbonaro, Hayward, and Dunn (2019), Kardeş (2022), and ANOVA and ANCOVA findings, are insufficient. Therefore, 11 studies were excluded. Four studies were excluded due to the inclusion of different dependent variables. These included perception, awareness, motivation and skills, collaborative skills, science process skills, and social skills (Crawford & Southcott, 2017; Hillier, Greher, Queenan, Marshall, & Kopec, 2016; Jiang, 2023; Stevens, 2018).

The statistical values (mean, standard deviation, and sample size for each experimental and control group) from the included studies were entered into the comprehensive meta-analysis (CMA) statistical software.

The PRISMA flowchart, translated into Turkish for the purpose of systematic review and meta-analysis, is presented in Figure 1. This figure outlines the selection process of the 31 articles included in the study, which examined the impact of technology use in music education and training on academic achievement (Aşık & Özen, 2019).

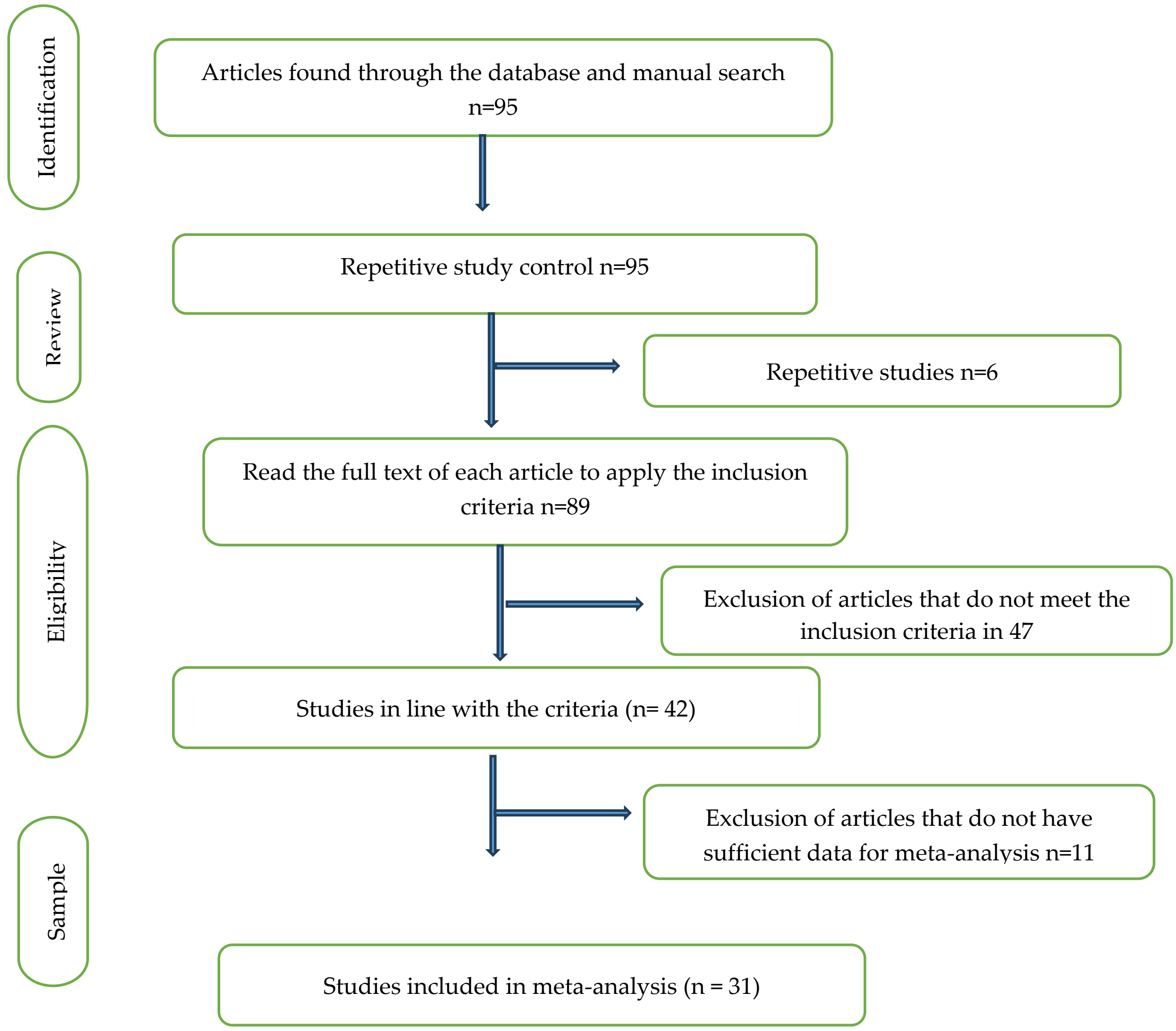

Figure 1. PRISMA Flowchart for Meta-analysis

Coding Procedure

Coding is the procedure by which data is extracted from a given set of data sources, with the objective of creating a formatted set of data that is suitable for the purposes of the research project in question (Karadağ, 2020). A coding form has been prepared for this study, with the intention of ensuring that the data extracted from the sources is accurate and complete. The main headings in the coding form are as follows:

1. Research reference (Author name, year, etc.)
2. Information about the sample
3. The data collection tools employed in the study are as follows:
4. Quantitative values
5. The type of technology involved in the studies

Calculating Effect Sizes

The Comprehensive Meta-Analysis (CMA) programme was employed to calculate the individual effect sizes and the overall effect size of the studies. The Cohen's d formula (Cohen, 1988) is the most commonly used for the calculation of effect size in statistical methods (single group t-test, t-test for related samples, t-test for unrelated samples, etc.) in which the difference between the two group means is calculated. Consequently, the preferred method for calculating effect sizes in this study was that of Cohen's d. The classification of effect levels was handled as follows during the calculation of these effect sizes: $-0.15 \leq$ Cohen d < 0.15: insignificant, $0.15 \leq$ Cohen d < 0.40: small, $0.40 \leq$ Cohen d < 0.75: moderate, $0.75 \leq$ Cohen d < 1.10 large, $1.10 \leq$ Cohen d < 1.45 very large, $1.45 \leq$ Cohen d excellent (Dinçer, 2021; Ay Emanet & Kezer, 2021).

Statistical Model Selection

Meta-Analysis Model

In meta-analysis studies, statistical models should be employed to integrate the results. Despite the similarity in the analytical techniques employed, the specifics and interpretation of the statistical outcomes differ (Çarkungöz & Ediz, 2009). The selection of the model to be utilised represents the most contentious and complex issue in meta-analysis, yet is arguably the most straightforward issue for educational sciences. The most significant challenge in combining numerous individual studies is the disparate sample sizes. It is therefore predicted that the population sizes of the studies may differ from one another (Dinçer, 2021).

The method was selected according to the p and Q values obtained in the heterogeneity tests performed to select the statistical method. In cases where $p > 0.05$ or $Q < df$, it is said that the studies included in the meta-analysis are similar and homogeneous. In this case, the fixed effects model is used. If $p > 0.05$ or $Q < df$, it can be concluded that the studies included in the meta-analysis are not homogeneous. In this case, the random effects model should be used as a choice of statistical method. Based on the data obtained, the random effects model was selected.

In all meta-analysis studies, the fixed effect model provides an exact representation of the effect size, whereas the random effects model indicates that the actual effect size may vary across studies. In the analysis studies, while the fixed effect model is conducted on the assumption of a summary effect and a common effect size, the summary effect in the random effects model is subject to the distribution rate of these effects. In this model, the study rates are more similar to the fixed effect model. Consequently, the weight of large-volume studies is diminished, while that of small-volume studies is enhanced. In the random effects model, confidence intervals and the error of the summary effect are more extensive than in the fixed effects model (Bakioğlu & Göktaş, 2017).

Reliability and Validity of the Study

Publication Bias and Calculation of Effect Sizes

The results of the funnel plot graph, Rosenthal's secure N method, and Orwin's error protection number analysis are shown below to demonstrate the reliability of the meta-analysis study and to determine the bias.

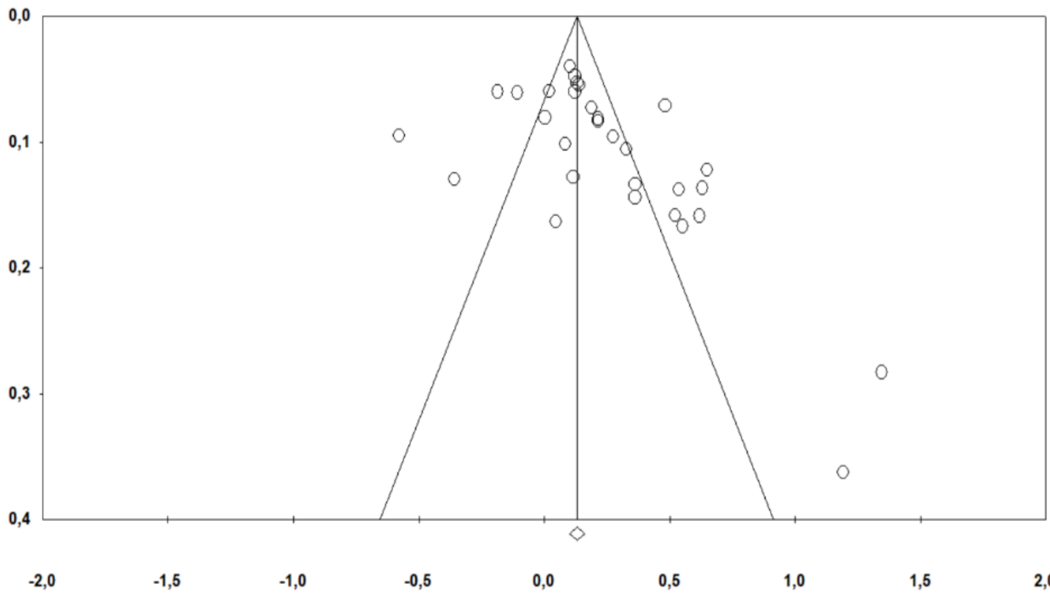

Figure 2. Funnel scatter plot of effect sizes of included studies

In this plot, if the effect sizes of individual studies are distributed symmetrically within the funnel lines, it indicates that publication bias is not a concern. Conversely, if the effect sizes of individual studies are distributed asymmetrically outside the funnel lines, it suggests that publication bias may be a factor. In accordance with this information, an examination of Figure 2 reveals that the effect sizes of the studies examining the achievement variable are distributed in the graph in a manner that is close to a symmetrical shape. A distribution that is close to symmetry indicates that the publication bias is low. Consequently, the Begg-Mazumdar and Egger tests for bias indicators in the funnel plot yielded the following results: Begg-Mazumdar Kendall's tau = 0.41, p = 0.001 and Egger: bias = 3.0841 (95% CI = 0.851 to 5.316), p = 0.028. In this case, it is expected that the p-value should be greater than 0.05 for there to be no significant difference. However, the observed value is 0.001, indicating that the bias is indeed very low.

Table 1. Rosenthal's fault protection number data

The z value for the analyzed studies	11.31541
The P-value for the analyzed studies	0.000
Alpha	0.050
Direction	2.000
Z-value for Alpha	1.95996
The number of studies analyzed	31
Fail-Safe Number	1003

Upon analysis of Table 1, the fail-safe number obtained from this meta-analysis study is 1003, according to the Rosenthal method. In order for the statistical significance value of p=0.000 to be p>0.05, that is, for the significance of the meta-analysis result to disappear, it is necessary for 1003 studies with an effect size value of zero to be conducted. Consequently, for the findings of this meta-analysis, comprising data from 31 studies, to be deemed invalid, there should be at least 1003 studies in the literature with values contrary to those observed in the present study.

Table 2. Orwin's analysis of the number of fault protection cases

Hedges'g in the analyzed studies	0.430
The benchmark for a trivial Hedges'g	0.000
Average Hedges'g for missing studies	0.050
Number of Missing Studies (FSN) required to reduce Hedges's g below 0.1	542

In table 2 the average effect size obtained from this meta-analysis, as determined by Orwin's method, was found to be 0.430. Additionally, the number of studies that should be included in the meta-analysis was determined to be 542. In order for the average effect size of 0.430 to decrease to 0.000 and for the general effect size values to be evaluated as insignificant, it is necessary to conduct 542 studies with an effect size value of zero.

Findings

This section of the study presents the results of the analyses conducted to determine the impact of technology use in music education on students' academic achievement. Firstly, the findings of the descriptive statistics of the studies included in the research are presented. Then, the results of the meta-analytic effect analyses of the studies on the effect of technology use in music education on academic achievement are given.

Furthermore, the effect size values calculated by creating subgroups were examined for academic achievement, and moderator analyses of these variables were conducted. The results of these analyses are presented in another finding title. Consequently, the findings of the study are presented in three main headings and their subheadings.

Descriptive Statistics Findings of the Study

This section presents the descriptive statistical values of the studies included in the research for each categorical variable. Additionally, frequency and percentage distribution tables of the studies subject to the research are created and interpreted according to various criteria. The frequency and percentage distribution tables of the studies included in the research according to years, publication type, sample size and education level of the studies are presented in this section.

Descriptive statistics of studies examining academic achievement according to various variables

Table 3 presents the descriptive statistics resulting from the classification of the studies on the academic achievement variable according to years and publication types. It can be observed that the majority of studies were conducted in 2022 (32.3%). With regard to the distribution of publication types, four of the 31 studies are doctoral theses, while 27 are articles. In 2015, no studies were conducted as doctoral theses or articles.

Table 3. Frequency and percentage distributions of studies according to years and publication types

	Doctoral Dissertation		**Article**		**Total**	
Years	**f**	**%**	**f**	**%**	**f**	**%**
2013	0	0,0	1	3,7	1	3,2
2014	1	25,0	0	0,0	1	3,2
2015	0	0,0	0	0,0	0	0,0
2016	0	0,0	1	3,7	1	3,2
2017	0	0,0	2	7,4	2	6,5
2018	0	0,0	5	18,5	5	16,1
2019	0	0,0	1	3,7	1	3,2
2020	0	0,0	2	7,4	2	6,5
2021	1	25,0	4	14,8	5	16,1
2022	2	50,0	8	29,6	10	32,3
2023	0	0,0	3	11,1	3	9,7
Total	4	100,0	27	100,0	31	100,0

The analysis revealed that the highest effect size in the effects on academic achievement was observed in the publications of 2021 (0.375), while the lowest was in the publications of 2022 (0.115). When considering the total value, it can be concluded that the years have a low effect size (0.364).

The results of the classification of the studies on the academic achievement variable included in the research according to the participants are presented in Table 4.

Table 4. Frequency and percentage distributions of study participants according to their types

Participant	**n**	**%**
Student	16	51,6
Teacher Candidate	4	12,9
Teacher	11	35,5

Upon examination of the distribution of participants in the studies included in the meta-analysis, it becomes evident that the majority of samples in the research studies are comprised of students (51.6%), with 16 studies falling under this category. Of the participants in the studies, 11 were teachers (35.5%) and 4 were pre-service teachers (12.9%).

Table 5 presents the descriptive statistics resulting from the classification of the studies on the academic achievement variable according to technology types.

Table 5. Frequency and percentage distributions according to technology types

Types of Technology	**n**	**%**
ICT	15	48,4
Digital Technology	3	9,7
Others	13	41,9

A total of 15 ICT technology types (48.4%) were identified when the technology types were analysed. While three studies (9.7%) focused on digital technologies, the remaining 13 (41.9%) examined other options.

Table 6 presents the descriptive statistics resulting from the classification of the studies on the academic achievement variable according to the sample size.

Table 6. Frequency and percentage distributions of the studies according to sample size

Sample Size	**n**	**%**
1-75	13	41,9
76-150	6	19,4
151-225	4	12,9
226-300	4	12,9
301+	4	12,9

Upon examination of the sample sizes employed in the analysed studies, it was found that the majority (41.9%) utilised a sample size of between 1 and 75. The number of studies in the 76-150 person range was 6 (19.4%), while the number of studies in the 151-225, 226-300, 301 and above ranges was 4 (12.9%).

General Effect Size Findings Regarding Academic Achievement

The findings obtained by analysing the effect size of the studies are presented in this section. The sample size, standard deviations, arithmetic averages, p-values and F-values were used to calculate the overall effect sizes of the studies that met the criteria.

Mean effect size, confidence intervals and heterogeneous distribution value according to the effect model of the studies included in the meta-analysis

When conducting a meta-analysis study, the studies included in the research give different effect sizes. These differences are statistically necessary for the study to be carried out. Heterogeneity tests are applied to find out whether the effect sizes are suitable for normal distribution. These tests can be calculated numerically and can also be presented graphically, which facilitates examination. In this study, both heterogeneity tests and graphs were employed to ascertain whether the effect sizes conform to the normal distribution.

The findings of the fixed effects model and the general effect size of the studies related to the academic achievement variable are presented in Table 7.

Table 7. Fixed effects model

Model	Hedges'g	chi squared	Homogeneity Value	%95 Confidence Interval		p
				Lower Limit	Upper Limit	
Fixed effects model	0.430	88.370	257.949	0.102	0.159	0.000

The results of the fixed effects model analysis indicate that the homogeneity value (257.949) exceeds the critical value of the chi-square distribution (88.370) with 30 degrees of freedom at a 95% significance level. This indicates that the distribution of effect sizes is heterogeneous. Furthermore, the Z value was found to be 8.693. As the p-value is less than 0.05, it can be concluded that the analysis is statistically significant. The positive average effect size (0.430) indicates that the procedures favoured the experimental group. Consequently, it can be stated that any potential errors arising from the heterogeneity of the sample can be eliminated by using the random effects model, given that the heterogeneity of the effect size values is greater than that of the fixed effects model.

Table 8. Random effects model

Model	k	Hedges'g	Standard Error	%95 Confidence Interval		p
				Lower Limit	Upper Limit	
Random effects model	31	0.525	0.046	0.136	0.315	0,000

Upon analysis of Table 8, it is observed that the average effect size value is calculated as 0.525 with a standard error of 0.046. The lower limit of the 95% confidence interval is 0.136, while the upper limit is 0.315, according to the random effects model. The Z-test calculations performed for statistical significance yielded a value of Z=9.933. Consequently, it can be stated that the obtained result is statistically significant with p=0.000 (Z=9.933; p=0.000).

Table 9. Effect Size Values and Ranges of the Studies

Study	Effect Size	Standard Error	Variance	Lower Limit	Upper Limit	Z	p
Leong & Cheng, 2013	0,563	0.170	0.029	0.229	0.896	3.306	0,001
Atabek & Burak, 2020	0.102	0.040	0.002	0.024	0.180	2.577	0.010
Liu, Wan, Tu, Chen, & Wang, 2021	0.532	0.161	0.026	0.217	0.848	3.305	0.001
Macrides & Angeli, 2018	0.138	0.055	0.003	0.030	0.246	2.514	0.012
Bannerman & O'Leary, 2021	0.132	0.053	0.003	0.028	0.235	2.485	0.013
Shahab et al., 2022	1.281	0.389	0.152	0.517	2.044	3.289	0.001
Candel & Colmenero, 2022	-0.362	0.131	0.017	-0.619	-0.105	-2.759	0.006
Kılıç, 2017	0.124	0.060	0.004	0.006	0.242	2.056	0.040
Eyles, 2018	0.020	0.060	0.004	-0.097	0.137	0.332	0.740
Calderón-Garrido, Carrera, & Gustems-Carnicer, 2021	0.278	0.096	0.009	0.089	0.466	2.884	0.004
Arici, 2018	0.629	0.161	0.026	0.313	0.946	3.900	0.000
Aikins & Akuffo, 2022	0.118	0.130	0.017	-0.136	0.372	0.910	0.363
Gül, 2023	0.544	0.139	0.019	0.271	0.817	3.900	0.000
Haning, 2016	0.629	0.161	0.026	0.313	0.946	3.900	0.000
Guillén-Gámez, Álvarez-García, & Rodríguez, 2018	0.369	0.146	0.021	0.083	0.655	2.525	0.012
Çakan Uzunkavak & Gül, 2022	0.485	0.071	0.005	0.345	0.625	6.803	0.000
Innocenti et al., 2019	0.047	0.167	0.028	-0.280	0.374	0.281	0.778
Colás-Bravo & Hernández-Portero, 2023	0.004	0.081	0.007	0.154	0.163	0.050	0.960
Sai, 2022	0.084	0.102	0.010	-0.116	0.264	0.823	0.411
Palazón-Herrera, 2021	0.217	0.084	0.007	0.052	0.381	2.580	0.010
Bačlija Sušić, & Mičija Palić, 2022	0.189	0.073	0.005	0.045	0.332	2.579	0.009
Magalhães, Magalhães, Carvalho, Monteiro, & de Castro Monteiro, 2018	-0.186	0.060	0.004	-0.305	-0.068	-3.093	0.025
Eyles, 2018	-0.186	0.060	0.004	-0.305	-0.068	-3.093	0.025
Crawford, 2016	0.123	0.048	0.002	0.030	0.217	2.577	0.010
Cuervo, Bonastre, Camilli, Arroyo, & García, 2023	1.395	0.293	0.086	0.821	1.969	4.763	0.000
Zhao, 2022	0.656	0.123	0.015	0.414	0.897	5.320	0.000
Portero & Bravo, 2022	0.217	0.092	0.007	0.057	0.378	2.656	0.008
Noor, 2014	-0.107	0.061	0.004	-0.227	0.012	-1.764	0.078
Bell, 2022	-0.583	0.095	0.009	-0.769	-0.396	-6.119	0.000
Holliman, 2021	0.367	0.136	0.018	0.102	0.633	2.708	0.007
Haynes Gibbs, 2022	0.637	0.138	0.19	0.367	0.908	4.613	0.000

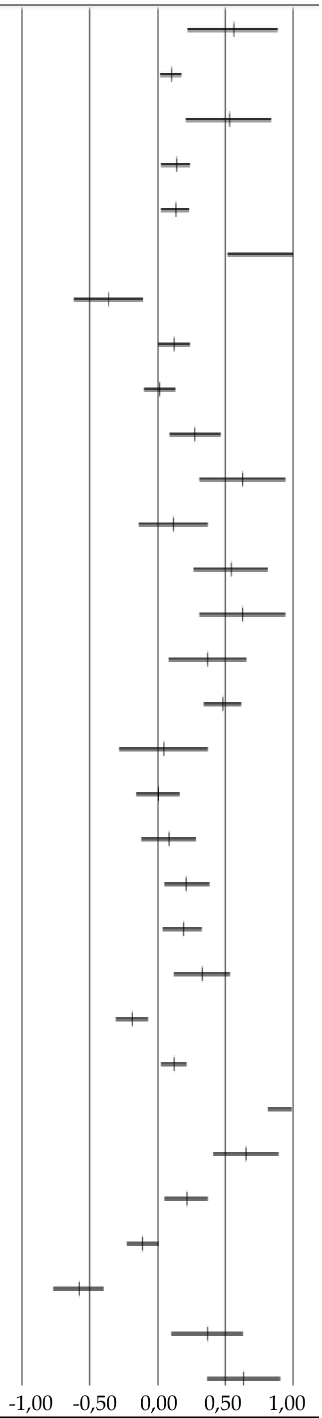

Table 9 the middle points indicated on the lines in the figure represent the effect sizes of the studies included in the research. The lines next to the points show the lower and upper limits of the effect sizes according to the 95% confidence interval. Upon analysis of these effect sizes, it was determined that the highest effect size was 1.395, while the smallest effect size was 0.583. Twenty-seven studies exhibited a positive effect size, while four studies exhibited a negative effect size.

Moderator Analysis Findings Related to Academic Achievement

Due to the heterogeneity of the distribution in the study, the type of publication, class level, sample size and the year of the study were used as moderator variables in the studies included in the research. In order to ascertain the effectiveness of teaching using research-based learning strategies and teaching with the other curriculum (teaching applied in control groups), subgroup analyses were performed for the moderator variables that had been determined.

a) Publications on the Use of Technology in Music Education; Findings Regarding the Effect on Academic Achievement According to Publication Year

Table 10. Effectiveness of the studies on academic achievement according to the years of the studies

Publication Year	k	Hedges'g	%95 Confidence Interval		Value of homogeneity between groups	χ^2 critical value range	p
			Lower Limit	Upper Limit			
2013	1	-	-	-			
2014	1	-	-	-			
2016	1	-	-	-			
2017	2	-					
2018	5	-					
2019	1	-	-	-	2,479	18.989	0.798
2020	2	-					
2021	5	0.375	,1597	4,2403			
2022	10	0.115	1,2736	2,5264			
2023	3	-					
Total	31	0.364	1,8145	2,8952			

The effect size could not be calculated in cases with only one data in the sample size distribution.

In table 10 the intergroup homogeneity value of the research was found to be 2.479, with the critical value of the chi-square table at the 95% significance level and degree of freedom being 18.989. Calculations revealed that the homogeneity value between groups was smaller than the critical value, indicating that the effect sizes were homogeneously distributed. Given that the homogeneity value between groups according to the years of publication of the studies included in the meta-analysis is smaller than the critical value, it can be concluded that there is no statistically significant difference between the groups formed according to years (p>.05). Although the distribution has a homogenous structure, there is no statistical difference between the difference in effect sizes between the groups formed according to the years of publication. The results indicate that the years of publication of the studies have a similar effect size on academic achievement.

b) Publications on the Use of Technology in Music Education; Findings Regarding the Effect on Academic Success According to Publication Types

Table 11. Effectiveness of the studies on academic achievement according to the type of publication

Publication Type	k	Hedges'g	%95 Confidence Interval		Value of homogeneity between groups	χ^2 critical value range	p
			Lower Limit	Upper Limit			
Article	27	0.561	1.8139	3.0009			
Doctoral Dissertation	4	0.364	-,2503	4,2503	1.014	20,207	0,614
Total	31	0.712	1.8145	2.8952			

Table 11 shows that the analysis revealed that the highest effect size was observed in articles with an effect size of 0.561, while the lowest effect size was observed in doctoral theses with an effect size of 0.364. When considering the total value, it can be concluded that publication types have a moderate effect size (0.712).

The results of the analyses indicated that the homogeneity value between the research groups was 1.014, while the critical value of the chi-square table at the 95% significance level and degree of freedom was 20,207. The calculations demonstrated that the homogeneity value between groups was smaller than the chi-square critical value, indicating that the effect sizes were homogeneously distributed. Given that the homogeneity value between groups, as determined by the sample sizes of the included studies in the meta-analysis, is smaller than the critical value, there is no statistically significant difference between the groups formed according to publication types (p>.05). Although the distribution is homogeneous, there is no statistical difference between the effect sizes of the groups formed according to publication types. The results indicate that publication types have a similar effect size on academic achievement.

c) Publications on the Use of Technology in Music Education; Findings on the Effect on Academic Achievement According to the Participants

Table 12. Effectiveness of the studies on academic achievement according to the participants

Participant	k	Hedges'g	%95 Confidence Interval		Value of homogeneity between groups	χ^2 critical value range	p
			Lower Limit	Upper Limit			
Student	16	0.946	,9430	1,3070	2,207	24,299	0.672
Teacher Candidate	4	It could not be calculated because there was equal distribution in the groups.					
Teacher	11	0.916	,9101	1,4536			
Total	31	0.801	1,0040	1,2540			

In table 12 in terms of the impact on academic achievement, the highest effect size was 0.946 for students, while the lowest effect size was 0.916 for teachers. When considering the total value, it can be stated that the participants exhibited a large and large effect size (0.801).

The inter-group homogeneity value of the research was found to be 2,207, while the critical value of the chi-square table at a 95% significance level and 2 degrees of freedom was found to be 24,299. Calculations revealed that the homogeneity value between groups is smaller than the critical value, indicating that the effect sizes are homogeneously distributed. Given that the homogeneity value between groups, as determined by the sample size of the studies included in the meta-analysis, is smaller than the critical value, it can be concluded that there is no statistically significant difference between the groups formed according to the participants (p>.05). Despite the observed homogeneous distribution, there is no statistical difference between the effect sizes of the groups formed according to the participants. The results indicate that class levels have a similar effect size on academic achievement.

d) Publications on the Use of Technology in Music Education; Findings Regarding the Effect on Academic Achievement According to Technology Type

Table 13. Effectiveness on academic achievement according to technology type

Type of Technology	k	Hedges'g	%95 Confidence Interval		Value of homogeneity between groups	χ^2 critical value range	p
			Lower Limit	Upper Limit			
ICT	15	0.488	1,7680	3,4320	,491	18.842	0.727
Digital Technology	3	-	-	-			
Others	13	0.497	1,1818	2,8182			
Total	31	0.730	,26784	1,8062			

In table 13 the analysis revealed that the highest effect size in the effects on academic achievement was 0.497 for others, while the lowest effect size was 0.488 for ICT. When considering the total value, it can be stated that technology types have a moderate effect size (0.730).

The intergroup homogeneity value of the research was found to be 491, while the critical value of the chi-square table at a 95% significance level and degree of freedom was found to be 18.842. Calculations revealed that the homogeneity value between groups is smaller than the critical value, indicating that the effect sizes are homogeneously distributed. Given that the homogeneity value between groups according to the technology types of the studies included in the meta-analysis is smaller than the critical value, it can be concluded that there is no statistically significant difference between the groups formed according to the types (p>.05). Although the distribution has a homogeneous structure, there is no statistical difference between the effect sizes between the groups formed according to types.

e) Publications on the Use of Technology in Music Education; Findings Regarding the Effect on Academic Achievement According to Sample Size

Table 14. Effectiveness on academic achievement according to sample size

Sample Size	k	Hedges'g	%95 Confidence Interval		Value of homogeneity between groups	χ^2 critical value range	p
			Lower Limit	Upper Limit			
1-75	13	0.911	,9269	1,3808	2,187	19.457	0.797
76-150	6	0.907	,16667	,7382			
151-225	4	-	-	-			
226-300	4	0.893	,4544	2,0456			
301+	4	-	1,0040	1,2540			
Total	31	0.905	,9520	1,3060			

In table 14 the highest effect size for the effects on academic achievement was 0.911 in studies conducted with 1-75 participants, while the lowest effect size was 0.893 in studies conducted with 226-300 participants. When considering the total value, it can be stated that the sample sizes have a high level of effect size (0.905).

The intergroup homogeneity value of the research was found to be 2.187, while the critical value of the chi-square table at the 95% significance level and degree of freedom was found to be 19.457. Calculations revealed that the homogeneity value between groups is smaller than the critical value, indicating that the effect sizes are homogeneously distributed. Given that the homogeneity value between groups, as determined by the sample sizes of the studies included in the meta-analysis, is smaller than the critical value, it can be concluded that there is no statistically significant difference between the groups formed according to the sample (p>.05). Despite the observed homogeneous distribution, there is no statistical difference between the effect sizes between the groups formed according to the sample.

Conclusion, Discussion, and Implications

The studies conducted for the main problem of the research, which aimed to determine the effect of technology use on academic achievement in music education and training, were combined in a meta-analysis study. The total number of samples in the studies was 4853. Since the studies included in the study had a heterogeneous structure, the random effects model was used. The effect size value indicates that the results have a moderate effect size (0.40 and above) according to Thalheimer and Cook's (2002) effect level classification. Furthermore, it indicates that the results are statistically significant. The treatment effect favours the experimental group if the mean magnitude value is positive. Therefore, it can be concluded that the effect of using technology in music teaching on academic achievement is more effective in a positive way than traditional teaching methods (control group).

In this study, the effect of technology use on academic achievement in music education and training was investigated by meta-analysis method. Subgroup analyses were performed for moderator variables to determine whether there is a significant difference according to the factors determined to affect the effect size values. These factors included participants, publication type, publication year, technology type and sample size. The results indicated that the majority of the studies included in the research were conducted on students, with 16 studies representing the highest effect size. Given that the homogeneity value between the groups formed according to the sample numbers of the studies included in the meta-analysis was smaller than the critical value, it was evident that there was no statistically significant difference between the groups. It can be concluded from this point that the effect size of the use of technology in music education and training on the academic achievement of students in primary and secondary education is higher than the findings of the meta-analysis studies on this subject. Mert and Şen (2019) concluded that using technology-supported materials has a more positive effect on students and is more effective than the traditional teaching method. It can be concluded from the aforementioned studies that although there is no significant difference in effect sizes, the use of technology in music education at the primary and secondary education levels is more effective. Furthermore, students' learning is highly effective. In their studies, Çakan Uzunkavak and Gül (2022) conducted studies on sound formation with Web 2.0 technologies for high school students. The findings of this study indicate that students can readily learn about phonetics, voice preservation, voice change, and theoretical information. Similarly, Innocenti et al. (2019) conducted a study on the use of VR technology to teach music genres to students. The results of this study demonstrated that the use of technology enhanced the learning outcomes of the students.

A review of the literature reveals that the incorporation of technology in music education has a profound and positive impact on students' academic performance. In other words, numerous studies have demonstrated that the incorporation of technology in music education has a positive impact on academic achievement (Cheng & Xiao, 2022; Haning, 2016; Palazón-Herrera, 2021; Sai, 2022; Zhang, 2022). In a study by Calderón-Garrido et al. (2020), it was found that the experimental group, which utilized technology in music education, exhibited a greater increase in academic achievement. In this case, the results of the study are consistent with those of previous research and the aforementioned learning strategy has been shown to enhance academic success in students.

According to the conclusions on the effect on academic achievement according to the year of publication, in this research, which covers the studies conducted between 2013 and 2023, there are 1 study in 2013, 2014, and 2016. The number of studies conducted in each year is as follows: 6, 2019, 2 in 2017, 2020, 5 in 2018, 2021, 10 in 2022, and 3 in 2023. A comparison of the average effect sizes across the years revealed that the highest value was 0.375 in 2021, while the lowest was 0.115 in 2022. This analysis indicated that, despite the highest number of studies being conducted in 2022, the effect size observed in 2021 was higher. Upon analysis of the homogeneous value between the groups, the critical value was found to be 18.989, with a 95% significance level in Table 10 Consequently, no significant difference was identified between the groups formed according to years. This indicates that years do not influence the effect size on the use of technology in music education in a manner that results in a significant difference. In this meta-analysis study, the distribution according to years revealed that the majority of studies were conducted in 2022. The conclusion section was organised in a similar manner to the findings section. Furthermore, an increase in the number of studies on the academic achievement variable was observed since 2018.

The fact that there are nine studies between 2016 and 2019 and 20 studies between 2020 and 2023 lends support to this situation. An examination of the effect sizes of the years in which the studies were conducted reveals that the studies conducted in 2021 have the highest effect size. It is postulated that this phenomenon is attributable to the surge in studies initiated in 2021, influenced by the rise in technology usage concomitant with the transition to online education during the pandemic in 2020. Furthermore, the lowest effect size was observed in the studies conducted in 2022, with a value of 0.115. Upon examination of the results, it can be observed that the years in which the studies were published exhibit a similar effect size in terms of the year of study and the use of technology on academic achievement.

In regard to the effect of publication types on academic achievement, it can be concluded that there are 27 articles and four doctoral theses. The average effect size of the publication types was found to be 0.461, with the highest effect size observed in articles (0.561) and the lowest in doctoral theses (0.364). The critical value was determined to be 20.207 with a 95% significance level from the χ^2 table for publication types. The homogeneity value between the groups formed according to the publication types was found to be 1.014. As the homogeneity value between the groups was smaller than the critical value, no significant difference was found between the groups formed according to the type of publication. Upon analysis of the findings of the studies subject to the research according to the type of publication, it can be observed that articles are more common than doctoral thesis studies. However, upon analysis of the studies themselves, it can be understood that there has been an increase in doctoral theses in recent years. A review of the studies subject to the research according to the type of publication reveals that 27 of the 31 studies included in the study consisted of articles, which accounted for a significant proportion, with a value of 32.3% in 2022. This leads to the conclusion that the subject is studied more in articles than theses because technology use in music education has become more widespread, especially in recent years with the pandemic. Furthermore, more effective results have been obtained in a shorter time.

Upon analysis of the effect sizes of the study types, it can be observed that articles have the highest average. The effect size of doctoral thesis studies is at a medium level. When the total value is considered, it can be stated that the publication types have a moderate effect size. Given that the homogeneity value between the groups according to the sample numbers of the studies included in the meta-analysis was smaller than the critical value, it was determined that there was no statistically significant difference between the groups formed according to the publication types. While it is evident that publication types do not alter the effect sizes in the context of technology use in music education on academic achievement, it is understood that the effect sizes of articles are larger than these. One potential explanation for this discrepancy is that the gains to be measured in academic achievement and the subject content of the studies may differ. Another reason may be that the measurement tools used in the studies vary. A third reason may be that the measurement tools used in the studies vary. According to İnal (2013), the characteristics of the tests used in the studies are of great importance. Consequently, it can be posited that disparate outcomes may be yielded contingent upon the nature of the studies conducted.

The conclusions drawn from the studies indicate that the participants' academic achievement was affected to varying degrees. Of the total number of participants, 16 were students, 11 were teachers, and 4 were pre-service teachers. The average effect sizes of the participant types were then considered. It was found that the highest effect size in the effects on academic achievement was in students, with 0.946, and the lowest in teachers, with 0.916. In consideration of the total value, it can be stated that the participants exhibited a considerable and statistically significant effect size. The critical value was determined to be 24.299 with a 95% significance level, and the homogeneity value between the groups formed according to the participant types was found to be 2.207. Given that the homogeneity value between the groups was smaller than the critical value, no significant difference was identified between the groups formed according to the participant type. The results of similar studies by Adanaş, Çetin, and Güler (2018) indicate that the use of technology enhances academic success among students. The participants reported that a rich learning environment with multiple stimuli supports the holistic development of children.

The effect of technology on academic achievement was analysed according to the technology type. The studies included 15 ICT, 13 others, and 3 digital technologies. The average effect size of technology types was calculated, and it was found that the highest effect size on academic achievement was in others (0.497), followed by ICT (0.488). When the total value is considered, it can be stated that the technology types have a moderate effect size. The critical value was found to be 18.842 with a 95% significance level from the χ^2 table, and the homogeneity value between the groups formed according to the participant types was found to be. Given that the homogeneity value between the groups was smaller than the critical value, no significant difference was found between the groups formed according to the technology type.

The lack of a significant continuity of the genre may be a contributing factor to the absence of a significant difference in the use of ICT, digital technologies and other technologies (VR, AR, artificial intelligence, etc.) in music education studies. In fact, the use of technology is supportive and instructive in every way in music education. In their 2017 study, Ayhan and Ertekin (2017) found that videos designed to support music education help learners to understand the correct rhythm and melody of songs.

The conclusions regarding the effect on academic achievement according to sample size indicate that when the findings are analysed according to the sample size in the studies, there are 13 studies in the sub-dimension (1-75 people), six studies between 76-150 people, four studies between 151-225, 226-300 and 301+ people. A further analysis of the average effect sizes of the studies according to the sample size revealed that the highest effect size in the effects on academic achievement was 0.911 in the studies conducted with 1-75 participants, while the lowest effect size was 0.893 in the studies conducted with 226-300 participants. When considering the total value, it can be stated that the sample sizes have an effect size of 0.905 at a high level. The critical value was found to be 19.457 with a 95% significance level from the table for these studies. The homogeneity value between the groups formed according to the sample size was 2.187. The calculations indicate that, given the homogeneity value between the groups is smaller than the x2 critical value, it can be concluded that the effect sizes are homogeneously distributed. Furthermore, given that the homogeneity value between groups is smaller than the critical value, it can be stated that no significant difference exists between the groups formed according to the sample size.

It is postulated that the reason why studies conducted with a sample size of 1 to 75 individuals are more effective is because the use of technology in music education is inadequate in the areas where the application is carried out, the class size is small, and people who generally participate voluntarily can be reached. According to Kaya (2019), the number of technology devices in music education units can be increased. Further studies could be conducted in different institutions to reach more generalisable results, since studies supporting the conscious and rational use of technology to eliminate disadvantages are limited to the participant group.

Upon evaluation of the research results, it becomes evident that the majority of studies included in the meta-analysis on the effect of technology use on academic achievement in music education and training consist of articles. It is recommended that further studies be conducted to address the paucity of master's theses and the limited number of doctoral theses. It is also possible to conduct studies on the use of technology in music education at different levels of education, with effect sizes being analysed.

It was also observed that the majority of the samples of the studies included in the research were carried out with the participation of students. This scarcity of studies conducted for pre-service teachers is worthy of attention. It would be beneficial to increase the number of studies on this subject for pre-service teachers.

Studies on academic achievement, attitudes, skills, and functioning of technology use in music education were generally found in the literature. In light of the above, it seems appropriate to propose an examination of the effectiveness of technology use in music education in relation to the aforementioned variables.

With regard to the limitations of the study, it should be noted that the period covered is only 10 years. Furthermore, some of the methods employed are relatively more recent than others. However, it is anticipated that relevant studies will emerge over the next 10 years. Consequently, it is important to disseminate the study prospectively over time.

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