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THE EFFECT OF TECHNOLOGY-BASED MATHEMATICS TEACHING ON MATHEMATICS PERFORMANCE: A SECOND-ORDER META-ANALYSIS

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Abstract

It is mentioned that all types of technological supports used in the mathematics instruction process have positive impacts on student mathematics performance without analyzing their educational dimension of them. In this context, the purpose of this research is to analyze the impact of technology-based mathematics instruction on the mathematics performance of students. 22 meta-analyses about the effects of technology-based mathematics instruction on student performance were carried out between 2017 and 2022; 27 impact sizes collected from these researches are combined with second-order meta-analyses. It is found that technology-based instruction's impact on mathematics performance is medium-level. On the other hand, in studies about technology-based instruction, it is determined that the location and quality of the article caused important improvements in the mathematics performance of students. On the other hand, technology-based instruction, performance type, grade level, bias status, report type, and year range moderator variables didn't cause statistical differences. It is determined that technology-based instruction methods increase the mathematics performance of students; however, Digital Tools Based Instruction and Software Based Instruction models are more efficient when compared to the other learning methods. Suggestions based on the research results are presented in the study.

Keywords: teaching method; technology-based instruction; mathematics performance; meta-analysis.

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TEKNOLOJİ DESTEKLİ MATEMATİK ÖĞRETİMİNİN ÖĞRENCİLERİN MATEMATİK PERFORMANSINA ETKİSİ: İKİNCİ DERECEDEN BİR META-ANALİZ

Öz

Matematik öğretiminde kullanılan tüm teknolojik desteklerin öğretimsel yönüne bakılmaksızın öğrencilerin matematik performanslarını olumlu düzeyde etkileme gücüne sahip olduğu ifade edilmektedir. Bu bağlamda bu araştırmada teknoloji destekli matematik öğretiminin öğrencinin matematik performansına etkisini incelemek amaçlanmıştır. 2017-2022 yılları arasında teknoloji destekli matematik öğretiminin öğrencilerin matematik performansı üzerindeki etkisini inceleyen 22 meta analiz araştırması ve bu araştırmalardan gelen 27 etki büyüklüğü second-order meta analiz yöntemiyle birleştirilmiştir. Teknoloji destekli öğretimin matematik performansına etkisinin orta düzeyde olduğu sonucuna ulaşılmıştır. Ayrıca teknoloji destekli öğretim ile ilgili çalışmalarda lokasyon ve yayın kalitesinin öğrencilerin matematik performansı üzerinde anlamlı bir farklılık oluşturduğu tespit edilmiştir. Öte yandan teknoloji destekli öğretim, performans çeşidi, öğretim kademesi, yanlılık durumu, araştırma türü ve yıl aralığı moderatör değişkenlerine göre istatistiksel olarak bir farklılık oluşturmadığı belirlenmiştir. Teknoloji destekli tüm öğrenme modellerinin öğrencilerinin matematik performansını artırdığı ancak Digital Tools Based Instruction ve Software Based Instruction modellerinin öğretim sürecinde kullanımının öğrencilerin matematik performansına etkisi bakımından diğer öğrenme modellerine göre daha etkili olduğu ortaya çıkmıştır. Ayrıca araştırma sonuçları doğrultusunda önerilere yer verilmiştir.

Anahtar Kelimeler: matematik performansı; teknoloji tabanlı öğretim; öğretim yöntemleri; meta-analiz.

Yasal İzinler: Bu araştırma kapsamında insan(lar)dan veri toplanmadığı için etik kurul iznine tabi değildir.

Geniş Özet

Günümüz öğrencileri, internet kültürünün etkisi altında doğmuş ve dijital yerliler olarak tanımlanan bir grup olarak, genellikle dizüstü bilgisayar, tablet bilgisayar ve cep telefonu gibi en az bir bilgisayar tabanlı teknolojik araca erişim sağlamaktadır. Ayrıca, internet tabanlı birçok matematik eğitimi içerikli yazılımın, oyunun ve uygulamanın geliştirildiği bir ortamda, öğrencilere zenginleştirilmiş matematiksel deneyimlerin sunulmasının çağdaş eğitim anlayışının bir gereği olduğunu belirtmek mümkündür. Teknolojinin eğitim-öğretim süreçlerinde kullanılması, araştırmacıların dikkatini teknolojinin matematik öğretiminde kullanımı üzerine çekmiş ve matematik öğretiminde teknoloji kullanımı sıklıkla araştırılan bir konu haline gelmiştir. Teknoloji destekli öğretimin öğrencilerin matematik performansı üzerinde olumlu bir etkisi olduğu ve öğrenci başarısını artırdığı bildirilmektedir (Ran vd., 2022). Matematik performansı, hem bilişsel (zihinsel) hem de duyuşsal (duygusal ve motivasyonel) boyutlardan oluşan karmaşık bir kavramdır (Fazlı & Avcı, 2022). Bilişsel boyut kapsamında problem çözme becerisi, analitik düşünme yeteneği, matematiksel bilgi ve bilgiyi anlama yer alırken; duyuşsal boyutta tutum, ilgi, motivasyon ve kaygı gibi kavramlar yer almaktadır.

Araştırmalarda, teknoloji destekli matematik öğretiminin öğrencilerin matematik performansları üzerindeki etkilerini inceleyen bir dizi meta-analiz bulunmaktadır. Bu çalışmalar, bilgisayar destekli matematik öğretimi (Akçay vd., 2021; Baki & Gürsoy, 2020;

Higgins vd., 2017; Kaur, 2013; Özdemir vd., 2020; Ran vd., 2022; Taşpınar-Şener, 2023; Helsa vd., 2023), akıllı tahta kullanımı (Akar, 2020; Gündüz & Kutluca, 2019), mobil teknolojiler (Güler vd., 2021; Öztop, 2022; Sung vd., 2016), dijital eğitsel oyunlar (Byun & Joung, 2018; Lei vd., 2022; Turgut & Temur, 2017), dijital manipülatifler (Gui vd., 2023; Hillmayr vd., 2020; Kul vd., 2018), web tabanlı yazılımlar (Akın, 2022; Güzeller & Akin, 2012) ve dinamik geometri yazılımları (Chan & Leung, 2014; Juandi vd., 2021; Kaya & Öçal, 2018; Zhang vd., 2023) gibi çeşitli teknoloji içerikli araçların matematik derslerindeki akademik başarı üzerindeki etkilerini araştırmaktadır. Yapılan farklı meta analiz araştırmalarından farklı sonuçların elde edilmesi muhtemeldir. Bu bakımdan teknoloji destekli matematik öğretiminin öğrenci performansı üzerindeki etkileri ile ilgili bu bilgi birikiminin daha sistematik ve anlamlı hale getirilebilmesi adına meta analiz araştırmalarından elde edilen bulgularının birleştirilmesi oldukça önemli görülmektedir. Alanyazın taramaları sonucunda, teknoloji destekli matematik öğretiminin öğrencilerin matematik performansına etkisi ile ilgili son beş yılda yapılan meta analiz araştırmalarının bulgularının birleştirildiği bir çalışmaya rastlanmamıştır. Bu bakımdan bu araştırmadan elde edilecek bulguların ilgili alanyazına katkıda bulunacağı düşünülmektedir. Bu araştırmada, teknoloji destekli matematik öğretiminin öğrencinin matematik performansına etkisi incelenmiştir. Bu amaç doğrultusunda aşağıdaki sorulara yanıt aranmıştır.

1. Teknoloji destekli öğretimin matematik performansına etkisi var mıdır?

2.Teknoloji destekli öğretimin matematik performansına etkisi moderatör değişkenlere göre farklılaşmakta mıdır?

Teknoloji destekli matematik öğretimi kapsamında, çeşitli öğretim araçları kullanılmaktadır. Matematik öğretimi sürecinde çeşitli teknolojilerin sıklıkla kullanıldığı ve bu alandaki araştırmaların fazlalığı göz önüne alındığında, bu çalışmada matematik öğretiminde teknoloji kullanımıyla ilgili bilgi birikiminin derlenmesi ve özetlenmesi amacıyla ikincil düzeyde bir meta-analiz yöntemi tercih edilmiştir. İkinci dereceden meta-analiz yöntemi, meta-analiz araştırmalarının meta-analizidir (Schmidt & Oh, 2013). Bu yöntemde, birinci dereceden meta-analiz araştırmalarının istatistiksel bulguları birleştirilmektedir (Oh, 2020; Schmidt & Hunter, 2015). Araştırmanın verileri Web of Science, Scopus ve ERIC veri tabanları kullanılarak toplanmıştır. Yıl aralığı olarak 2017-2022 tercih edilmiştir. Belirlenen elektronik veri tabanları üzerinden derinlemesine bir tarama yapılmıştır. Elektronik tarama için veri tabanlarının gelişmiş arama özelliklerinden faydalanılmıştır. Tarama yapılırken belirlenen anahtar kelimeler kullanılmıştır. İlk satırda, "mathematics", "technology", "mathematics performance", "mathematics achievement", "mathematics attitudes" anahtar kelimeleri; ikinci satırda "computer assisted", "computer based", "web-based", "computer aided", "video games", "digital games", "mobile learning", "e-learning", "distance education", "mobile devices", "applications" ve "educational games"; üçüncü satırda ise "meta analysis" ve "systematic review" anahtar kelimeleri yer almıştır. Taramalar sonucunda, ilk arama sonuçlarına göre toplamda 934 çalışmaya ulaşılmıştır. Ulaşılan çalışmalardan araştırma konusuyla ilgisi olmayan ve birbirini tekrar eden çalışmalar kapsam dışında tutulmuştur (n=897). Bir sonraki aşamada, veri kapsamına dâhil edilen çalışmalar, özet kısımları dikkate alınarak incelenmiş ve konuyla ilgisi olmayan çalışmalar hariç tutulmuştur (n=3). Uygunluk açısından değerlendirilen tam metin makaleler dâhil edilme ve hariç tutulma kriterleri dikkate alınarak incelenmiştir (n=31). Uygun istatistiksel veri içermeyen (n=7) ve örtüşen çalışmalar (n=2) hariç tutulmuştur. Ölçütleri karşılayan tam metin makaleler (n=22) ikinci dereceden analize dâhil edilmiştir. Verilerin analizinde örtüşme problemi, istatistiksel bağımsızlık, istatistiksel model, etki büyüklüğü seçimi, yayın yanlılık analizleri, moderatör ve heterojenlik analizi kriterlerine dikkate alınmıştır.

Bu araştırma 22 meta analiz araştırması 953 temel araştırmayı kapsamaktadır. Bu araştırma 22 meta analiz araştırmasından gelen k=27 etki büyüklüğünü içermektedir. Etki büyüklükleri ES=.13 ile ES=1.14 arasında yayılmaktadır. Ortalama etki büyüklüğü ve toplam heterojenlik: Teknoloji destekli öğrenmenin matematik performansına etkisinin ortalama etki büyüklüğü ES=.60 (LL=.48 UL=.71) olarak hesaplanmıştır. Başka bir ifade ile teknoloji destekli öğrenmenin matematik performansına etkisi orta düzeydedir. Yine veri setinin toplam heterojenlik miktarı Q (26) =439,42 olarak hesaplanmıştır. Veri setinin yüksek düzeyde heterojen olduğu tespit edilmiştir (I^2=94.74). Yayın yanlılığı analizleri: Begg and Mazumdar rank correlation test sonucu yayın yanlığı bulgulanmamıştır (tau=.21 z=1.54 p=.12). Egger's regression testi sonucu ise yayın yanlılığı tespit edilmiştir (t=4.7 p=.00). Duval & Tweedie trim and fill analysis sonucu ise yayın yanlığı tespit edilmemiştir. Etki büyüklüklerinin standart hatalarına göre dağılımı için oluşturulan Funnel Plot Şekil 1'de gösterilmiştir. Şekil 1 incelendiğinde etki büyüklüklerinin standart hatalarına göre dağılımlarının yaklaşık simetrik olduğu gözlenmiştir. Yukarıdaki bulgular dikkate alındığında önemsiz düzeyde (trivial) yayın yanlılığı olduğu kabul edilebilir. Meta analiz araştırmalarının kalite düzeylerine göre ortalama etki büyüklüklerinin istatistiksel olarak farklılaştığı bulgulanmıştır (Q (1) = 6.86 p=.01). Kalitesi yüksek meta analiz araştırmaları daha düşük düzeyde etki büyüklüğü üretirken (ES=.49 LL=.37 UL=.61) kalitesi orta düzeyde olan meta analiz araştırmaları daha yüksek düzeyde (ES=.76 LL=.60 UL=.91) etki büyüklüğü üretmiştirler. Yine Meta analiz araştırmaların kapsadığı lokasyona göre ortama etki büyüklüklerinin istatistiksel olarak farklılaştığı gözlenmiştir (Q (3) = 14.87 p<.01). Karma ülkeleri (farklı ülkeleri) kapsayan meta analiz araştırmaları daha düşük düzeyde etki büyüklüğü üretirken Türkiye ve Endonezya'yı kapsayan araştırmalar ise daha yüksek etki büyüklüğü üretmiştirler. Karma ülkeleri kapsayan meta analiz araştırmaları (ES=.51 LL=.40 UL=.62) orta düzeyde bir etki büyüklüğü üretirken Türkiye (ES=.97 LL=.69 UL=1.26) ve Endonezya'yı (ES=.98 LL=.63 UL=1.32) kapsayan araştırmalar yüksek düzeyde etki büyüklüğü üretmiştirler. Bunun yanında Çin'den tek bir araştırma gelmektedir ve zayıf düzeyde bir etki büyüklüğü raporlanmıştır (ES=.38 LL=-.08 UL=.84). Öte yandan teknoloji destekli öğretim, performans çeşidi, öğretim kademesi, yanlılık durumu, araştırma türü ve yıl aralığı moderatör değişkenlerine göre istatistiksel bir fark bulgulanmamıştır. Yine de bazı dikkat çekici durumlardan söz edilebilir. DBI ve SBI modellerinin matematik performansına etkisini yüksek düzeyde olduğu söylenebilir (sırasıyla ES=.80 LL=.50UL=1.10; ES=.94LL=.63 UL=1,25). GBI ise matematik performansına etkisinin zayıf düzeyde olduğu gözlenmiştir (ES=.38 LL=.13 UL=.63).

Teknoloji destekli matematik öğretimi öğrencilerin matematik performanslarını daha iyi hale getirmektedir (Cohen, 1998 p.2 akt Young, 2017). Gelişen teknolojiler ve bu teknolojilerin matematik öğretiminde kullanımı son yıllarda artış göstermektedir. Bu bakımdan bu araştırmada teknoloji destekli öğretimin öğrencilerin matematik performansına etkisini inceleyen birincil meta analizlerden elde edilen etki büyüklükleri birleştirilmiştir. Bu araştırma sonucunda, teknoloji ile desteklenen matematik öğretiminin, öğrencilerin matematik performansları üzerinde orta düzeyde bir etkiye sahip olduğu tespit edilmiştir. Young (2017), 30 yıllık meta-analiz çalışmalarını birleştirerek yaptığı araştırmada, teknoloji destekli matematik öğretiminin öğrencinin matematik başarısını orta düzeyde artırdığını belirlemiş ve matematik sınıflarında teknolojinin didaktik işlevselliğine vurgu yapmıştır. Benzer şekilde Taşpınar-Şener (2023) 2019-2023 yılları arasında yayınlanan çalışmaları incelediği meta analiz çalışmasında teknoloji kullanımının matematik başarısına genel etkisini orta düzey olarak saptamıştır. Bu bakımdan teknoloji destekli matematik öğretiminin öğrencinin matematik performansı üzerinde etkili olduğu görülmektedir. Matematik öğretiminde kullanılan tüm teknolojik desteklerin öğretimsel yönüne bakılmaksızın öğrencilerin matematik performanslarını olumlu düzeyde etkileme gücüne sahip olduğu ifade edilmektedir (Young, 2017). Bu araştırmada matematik öğretiminde teknoloji kullanımı ile ilgili yapılan araştırmalar teknoloji destekli öğretim modellerine göre kategorize edilmiştir. Yapılan sınıflandırma sayesinde matematik öğretiminde kullanılan bu modellerin moderatör olarak karşılaştırılmasına da olanak sağlamıştır. Ayrıca bu araştırmada performans çeşitleri, öğretim kademesi, yayın kalitesi, yayın yanlılık durumları, rapor çeşitleri, yıl aralığı ve araştırmanın yapıldığı bölge diğer moderatör değişkenler olarak ele alınmıştır. Bu araştırma sonucunda meta analiz çalışmalarında ele alınan teknoloji destekli öğretim modellerinin moderatör değişkenler olduğu sonucuna ulaşılmıştır. Elde edilen bulgular doğrultusunda bilgisayar destekli öğretim, oyun temelli öğretim ve mobil teknoloji destekli öğretim modellerinin düşük etki büyüklüğü ürettiği ortaya çıkmıştır. Web temelli öğretim ve karma olarak incelenen araştırmaların da orta düzey bir etki büyüklüğü ürettiği belirlenmiştir. Dijital araçlarla desteklenmiş öğretim ve yazılım temelli öğretim modellerinin ise yapılan araştırma sonucunda yüksek etki büyüklüğü ürettiği ortaya çıkmıştır. Bu araştırmanın sonucunda teknoloji destekli öğretimin öğrencilerin matematik performansı üzerindeki etkisi meta analiz araştırmalarının kalitesi bakımından moderatör bir değişken olduğu sonucuna ulaşılmıştır. Araştırma sonucunda yüksek kalitedeki meta analiz araştırmalarının daha düşük etki büyüklüğü üretirken orta düzey kalitedeki meta analiz araştırmalarının daha yüksek düzeyde etki büyüklükleri ürettiği ortaya çıkmıştır. Feeley (2020), meta analiz araştırması yürüten araştırmacıların dâhil ettikleri araştırmalar için kalite değerlendirmesi yapmalarının gerekli olduğunu belirtmektedir. Meta analiz araştırmaların kapsadığı lokasyonun teknoloji destekli öğretimin öğrencilerin matematik performansı üzerindeki etkisi bakımından moderatör bir değişken olduğu sonucuna ulaşılmıştır. Meta analiz araştırmalarında lokasyon yanlılığı önemli bir sorundur. Higgins & Green (2011) göre lokasyon yanlılığının (location bias) iki formundan söz edilmektedirler. Birincisi araştırmaların yer aldığı veri tabanı; ikincisi ise araştırmaların veri toplandığı ülkelerdir. Vickers vd. (1998) ülkelere göre klinik uygulamada etki büyüklüklerinin istatistiksel olarak farklılaştığını ortaya koymuştur. Klinik uygulamaları için tespit edilen bu durum eğitim ortamı uygulamaları içinde söz konusu olabilir.

Bu araştırma 2017-2022 yılları arasında teknoloji destekli öğretimin öğrencilerin matematik performansı üzerindeki etkilerini ortaya çıkaran birincil meta analizlerin birleştirildiği ikinci dereceden bir meta-analiz çalışmasıdır. Teknoloji destekli öğretimin öğrencilerin matematik performansları üzerindeki etkisini ortaya çıkarmayı amaçlayan bu araştırma sonucunda dört önemli sonuç ortaya çıkmıştır. İlk olarak, matematik öğretiminin teknoloji ile desteklenmesi öğrencinin matematik performansı üzerinde olumlu bir etki oluşturmaktadır. İkinci olarak, teknoloji destekli tüm öğrenme modellerinin öğrencilerinin matematik performansını artırdığı ancak dijital araçlarla desteklenmiş öğretim ve yazılım temelli öğretim modellerinin öğretim sürecinde kullanımının öğrencilerin matematik performansına etkisi bakımından diğer öğrenme modellerine göre daha etkili olduğu ortaya çıkmıştır. Üçüncü olarak, ikinci dereceden meta-analiz araştırmalarına dâhil edilen birincil meta analiz çalışmalarının kalitelerinin, araştırma sonucunda elde edilen etki büyüklüğü üzerinde etkili olduğu belirlenmiştir. Son olarak, meta analiz araştırmaları açısından araştırmanın verilerinin dâhil edildiği konumun da etki büyüklüğü üzerinde bir etkisinin olduğu ortaya çıkmıştır. Araştırma sonucunda teknoloji destekli matematik öğretiminin öğrencilerin matematik performansları üzerinde etkili olduğu görülmektedir. Bu bakımdan öğretmenler öğrencilerinin matematik performanslarına olumlu etkisi olması adına derslerinde bu teknoloji destekli öğrenme modellerini kullanabilirler. Ayrıca karar vericilerin bu teknolojilerin kullanılması adına öğrenme ortamlarına gerekli donanımları sağlamaları da önerilmektedir. Araştırmada Digital Tools Based Instruction ve Software Based Instruction modellerinin öğrencilerin matematik performansını artırmada daha etkili yöntemler olduğu görülmektedir. Bu bakımdan öğretmenler öğretim tasarımlarında bu modellere ağırlık verebilirler. Yapılan araştırma sonucunda meta analiz araştırmalarının kalitesinin etki büyüklüğü üzerinde etkili olduğu belirlenmiştir. Bu bakımdan meta analiz çalışmalarının birleştirildiği ikinci dereceden meta analiz çalışmalarında kalite değerlendirmeleri yapılmalıdır.

Introduction

Social systems become more digitalized along with the developments in computer and internet technology. This digitalization ensures presenting quality service in the health, education, industry, and communication sectors (Demirci & Kıratlı, 2019). Technologies developed according to the necessities of societies in the digital age increase the comfort of individuals besides globalization (Kavak, 2023). On the other hand, they direct social experiences, affect cultural structures, and change individual habits. For instance, transportable smart tools such as cell phones and tablets, reflections of this digitalization encompassing living spaces and directing the world, have become inseparable pieces of daily life. These instruments change the habits of individuals, ease access to information and ensure flexible learning.

The education system, which prepares new generations for the future, is affected by cultural changes and technological developments (Zinchenko et al., 2023). For instance, the development of internet technologies has eased access to information without the limitation of time or space. This development also made it possible to have sustainable teacher-student communication and led to the questioning of traditional methods. As a result of these questions distant-learning and e-learning models, which are out-of-school methods, are developed (Hamidi & Chavoshi, 2018; Kilit & Güner, 2021). Technology has positive effects on teacher motivation and job satisfaction besides supporting efficient and permanent learning (Morris, 2021). Technology-based instruction contributes to ensuring equality of opportunity by easing access to information and presenting flexible learning environments. On the other hand, it gives individuals the chance to learn at their speed (Hamidi & Chavoshi, 2018; Yalçın et al., 2023). It also enables the designing of new activities and the creation of rich learning-teaching environments.

It is observed that students have difficulties in mathematics as it is a lesson that requires intense mental activities such as reasoning, association, and problem-solving. The abstract conceptual structure that the lesson requires is another important problem for students (Ran et al., 2022; Sokolowski & Ansari, 2017). International organizations emphasize the importance of supporting mathematics instruction with technology; they state that enriched learning environments are indispensable and should be used in math instruction processes (IEA, 2019; NCTM, 2008; OECD, 2018). It is possible to decrease the hesitations and fears of students, improve their sense of sufficiency and competencies, and support conceptual learning and meta-cognitive skills by using technology in mathematics lessons (Lin, 2009; Koyuncu et al., 2015). Studies in the literature indicate that mathematics instruction based on technological instruments has an important impact on student success (Byun & Joung, 2018; Ran et al., 2022). On the other hand, it is determined that technology-based mathematics instruction is highly effective in cognitive features such as self-sufficiency (Peters, 2013), motivation, and attitude (Higgins et al., 2017). Trainers living in the modern era, using technological tools in education can produce content in cooperation with their colleagues; they also have the chance to present different conceptual and practical construction of thematic presentations with multiple representations (Helsa et al., 2023; Uwineza et al., 2023; Yorganci, 2018). Today’s students, born into the internet culture and named digital nomads have computer-based technological instruments such as laptops, tablets, and telephones. Internet-based content software, games, and application for mathematics education have been constantly developed and students get the chance to witness different mathematical experiences. It is possible to say that these experiences have become necessities of the modern understanding of education.

The utilization of technology within educational contexts, particularly in mathematics instruction, has garnered significant attention from researchers worldwide. Consequently, numerous scholars have investigated this subject, resulting in a plethora of meta-analysis studies within the literature examining the impact of technology-enhanced mathematics instruction on students' mathematical performance, indicative of their achievements in mathematics classes. This research theme encompasses various meta-analytic investigations, including those focused on computer-based mathematics teaching (Akçay et al., 2021; Baki & Gürsoy, 2020; Higgins et al., 2017; Kaur, 2013; Özdemir et al., 2020; Ran et al., 2022; Taşpınar-Şener, 2023; Helsa et al., 2023), mobile technologies (Güler et al., 2021; Öztop, 2022; Sung et al., 2016), digital educational games (Byun & Joung, 2018; Lei et al., 2022; Turgut & Temur, 2017), digital manipulatives (Gui et al., 2023; Hillmayr et al., 2020; Kul et al., 2018), web-based software (Akın, 2022; Güzeller & Akin, 2012), and dynamic geometry software (Chan & Leung, 2014; Juandi et al., 2021; Zhang et al., 2023).

In addition, Young (2017) combined meta-analysis studies on technology-based instruction conducted between 1985 and 2015. Considering that technology has been used more in recent years, combining the results of studies conducted after 2015 and comparing them with previous studies is important in terms of the use of technology in education and its integration into classrooms. In this respect, it is considered very important to combine the findings obtained from meta-analysis studies in order to make this knowledge about the effects of technology-supported mathematics teaching on student performance more systematic and meaningful.

Computer-based instruction

Computer-based instruction can be defined as practicing education by benefiting from software and application opportunities of computers in the learning-teaching process (Xie et al., 2020). Computer’s support increasing the interest of students through voice, animation, presentation, graphics, and simulations. Interactions and instant feedback enable students to evaluate their performance and control the self-learning process (Baki, 2002; Özdemir et al., 2020). Students get the chance to learn at his/her own pace, make research, test information, and make evaluations (Baki, 2002; Xie et al., 2020). Computer-based instruction ensures academic improvements; it additionally eases learning and carries out the role of leading the process (Atay, 2023). Computers ease the teaching process by presenting mathematical concepts through graphics, systems of algebra, and simulations; they thus ease transmitting information and learning (Özdemir et al., 2020). According to Atay (2023), the significance of computer-assisted instruction in mathematics education lies in its ability to enhance students' understanding of mathematical concepts, improve problem-solving skills, and foster positive attitudes towards mathematics. Additionally, computer-assisted instruction enriches the teaching process for educators and increases students' motivation for learning.

Digital tools-based instruction

Digital tools-based instruction includes the process of education based on technological instruments such as computers, tablets, projections, smart boards, and calculators. These processes present programs, websites, and other training platforms through which training is carried out (Ahsan et al., 2023; Greefrath et al., 2018; Hillmayr et al., 2020).

Digital tools contribute to carrying out learning and teaching activities in cognitive, affective, and social dimensions. They on the other hand allow students to reach information easily, deeply understand multiple displays and improve themselves. Digital tools are grouped under 5 categories: Drill and practice programs, tutoring systems, intelligent tutoring systems, simulations, and hypermedia systems (Hillmayr et al., 2020; Ünal & Yeşilyurt, 2023). Digital tools allow students to visualize their complex mathematical relations, learn abstract conceptual structures in an interactive and exploratory manner, create more than one representation, easily move from one representation to another and develop strategies to solve real-life problems (Greefrath et al., 2018).

Digital game-based instruction

Digital games, constituting a pedagogical approach incorporating the utilization of digital gaming within the learning framework, represent a significant method fostering both cognitive and affective development of students through internet-based tools (Koparan, 2021; Matic et al., 2023). Digital-based games ease interpreting mathematical concepts and support four operations skills (Aktaş et al., 2023; Benavides-Valera et al., 2023; Lee et al., 2016). They on the other hand enable transmitting conceptual knowledge, operational sufficiency, and affection skills, into real-life problems (Aktaş et al., 2018). These games, requiring organizing and improving strategies to find solutions to a constructed problem and reasoning that will lead to success, also serve to develop problem-solving skills, regarded as an important sufficiency in mathematics (Byun & Young, 2018; Fadda et al., 2021). Digital games ease objectifying mathematical issues in digital environments by evoking visual, audible, and tactual senses. Students who have negative attitudes towards mathematics can overcome their prejudices and improve positive affective attitudes (Aktaş et al., 2018).

Mobile technology-based instruction

Besides the increase in the use of technological devices such as telephones, tablets, and laptops, comfortable learning environments based on the principle of uninterrupted learning have been developed (Yalçın et al., 2023). Touch screens, and the attractive visual and dynamic structure of mobile tools contribute to the interaction of students directly with mathematical phenomena and participate in discussions about mathematics in a cooperative environment. They also enable students to improve their mathematical thinking skills (Larkin & Calder, 2015; Chen, 2019). Mobile education, supporting flexible learning give teachers the chance to design efficient educational methods and techniques and use pedagogical approaches and practices in the process of teaching (Taleb et al., 2015; Viberg et al., 2023). Researches indicate that mobile learning supports internalizing mathematical concepts (Crompton, 2015) and improving problem-solving skills (Huda et al., 2019). It, on the other hand, positively affects effective features such as motivation, attitude, perception, and agitation (Chen, 2019). Conversely, it is imperative to acknowledge that various factors such as diminished concentration during mobile device-assisted learning, heightened cognitive burden arising from the influx of extensive information from both real-world and digital sources, constrained utilization of touch screens, allure of social networking applications, and inadequately designed learning materials can impede the learning process (Poçan et al., 2023).

Educational software-based instruction

Educational software that is developed for learning and teaching processes, is technological hardware that can be used online and/or offline (Aydoğmuş, 2010). Besides being used as an environment for education, they can be used as supporting materials for exemplification, problem-solving, and repetition (Aydoğmuş, 2010). Software that has multimedia content such as diagrams, graphics, and voice, develops the individual learning experience of students through interaction; they, on the other hand, ease following their academic development in a systematic structure (Chan & Leung, 2014; Juandi et al., 2021). Mathematical software, generally developed as supporting hardware for teaching mathematics, are supporting elements that ease and direct a beneficial learning environment (Aydoğmuş, 2010). Computer algebra software such as Derive, Mathematica, and Matlab is used by the experts; dynamic geometry software such as Cabri 3d, Geogebra, and Sketchpad are also used often. Mathematical software is most effective in improving student skills such as discovering theories and relations, reasoning, mathematical thinking, and problem-solving skills. Students can see misconceptions, make mathematical modeling, create spatial perception, and support permanent learning by using graphical and geometrical demonstrations (Dogruer & Akyuz, 2020; Özen-Ünal & Filiz, 2023).

Web Based Instruction

Web-based learning is the process of online education that brings teachers and students that are physically in different locations (Zheng, 2008). In this method, synchronized, unsynchronized, and combined participation is possible; teachers and students can have closer communication in the virtual environment. There are mutual interactions and instant feedback through various multimedia text, voice, video, and graphics (Lin, 2009). This method has the other opportunities presented by technology-based instruction; it thus supports critical thinking and problem-solving skills by presenting environments enabling discussion and questioning (Kilit & Güner, 2021). Visual models and animations that are created with interactive internet resources have important benefits in constructing mathematical concepts (Lin, 2009). On the other hand, while preparing web-based mathematics learning environments, the cognitive, social, and physical features of students should be taken into consideration; diagrams, animations, and worksheets should be prepared and presented in different formats (Güzeller & Akin, 2012; Yorganci, 2018). Preparing problems that will support cooperation among students and using simultaneous communication tools in teaching difficult mathematical concepts in teaching environments are important (Yorganci, 2018).

Math Performance and Technology

Technology-based instruction enables students to understand mathematics by giving them the opportunity to actively participate and think at higher levels (Karim & Zoker, 2023; Kim et al., 2020; Young, 2017). In addition, technology-enhanced instruction facilitates students' understanding of mathematical concepts and mathematical modeling (Uwineza, et al., 2023). Technology-supported mathematics instruction provides students at various academic levels with the opportunity to access mathematical content, deepen their conceptual understanding, improve their problem-solving skills, and increase their computational abilities (NCTM, 2014). The emergence of these outcomes depends on how technology is integrated into mathematics instruction and how tasks are designed (Leung, 2017).

Technology-supported instruction is reported to have a positive impact on students' mathematics performance and increase student achievement (Ran, Kim & Secada, 2022). In different meta-analysis studies, different types of technology such as intelligent tutoring systems (Steenbergen-Hu & Cooper, 2013), digital game-based learning (Byun & Joung, 2018), dynamic geometry software (Chan & Leung, 2014), and collaborative scenarios (Radkowitsch et al., 2020) were found to improve students' mathematics performance. On the other hand, few studies have focused on the role of instructional technology in supporting any learning goal (Ran, Kim & Secada, 2022). In this second-order meta-analysis, we systematically examined the possibilities of technology-enhanced instruction in mathematics instruction and its effects on students' mathematics performance.

Purpose

As a result of the literature reviews, it is determined that no study combines the findings of meta-analysis research about the impact of technology-based mathematics training on students' math performance in the last five years. In this respect, findings obtained from this research study will contribute to the related literature. In this research, technology-based mathematics teachings' effects on student performance are the primary purpose. The below-mentioned questions are researched in the scope of this purpose.

1. Does technology-based instruction have an impact on mathematics performance?

2. Does the impact of technology-based training on mathematics performance vary according to moderator variables?

Method

Different teaching tools have been used in the scope of technology-based mathematics instruction. These varieties, the frequent use of these materials in instruction processes, and the high number of research in the literature have led to the use of a specific approach in this research study. The second-order meta-analysis method is preferred to combine the necessary information and summarize obtained information properly. The second-order meta-analysis method is the meta-analysis of meta-analyses (Schmidt & Oh 2013). This is why; the second-order meta-analysis method is called meta meta-analysis. In the second-order meta-analysis method, statistical findings of first-order meta-analysis research are carefully combined (Oh, 2020; Schmidt & Hunter, 2015).

Data Collection Process

Research data are collected by using Web of Science, Scopus, and ERIC databases. The years between 2017 and 2022 are preferred. A deep-survey process based on the defined electronic database is followed. The feature of advanced search is used for the electronic survey. Surveys are carried out with pre-determined keywords. The keywords "mathematics", "technology", "mathematics performance", "mathematics achievement", and "mathematics attitudes" are used in the first line; "computer-assisted", "computer-based", "web-based", "computer-aided", "video games", "digital games", "mobile learning", "e-learning", "distance education", "mobile devices", "applications" and "educational games" are used in the second line and "meta-analysis" and "systematic review" are used in the third line. As a result of the surveys, a total of 934 studies are determined. The ones that are not related to the topic and the ones that are the same are excluded (n=897). The obtained studies are analyzed in terms of their abstract section and the ones that are not related are excluded (n=4). The complete articles that are evaluated according to appropriateness, are analyzed in terms of inclusion and exclusion criteria (n=31). Studies that do not contain proper statistical data (n=7) and the ones that overlap (n=2) are excluded. Full-text articles that meet the criteria (n=22) are included in the second-order meta-analysis. The review process is presented in Figure 1 with a PRISMA diagram.

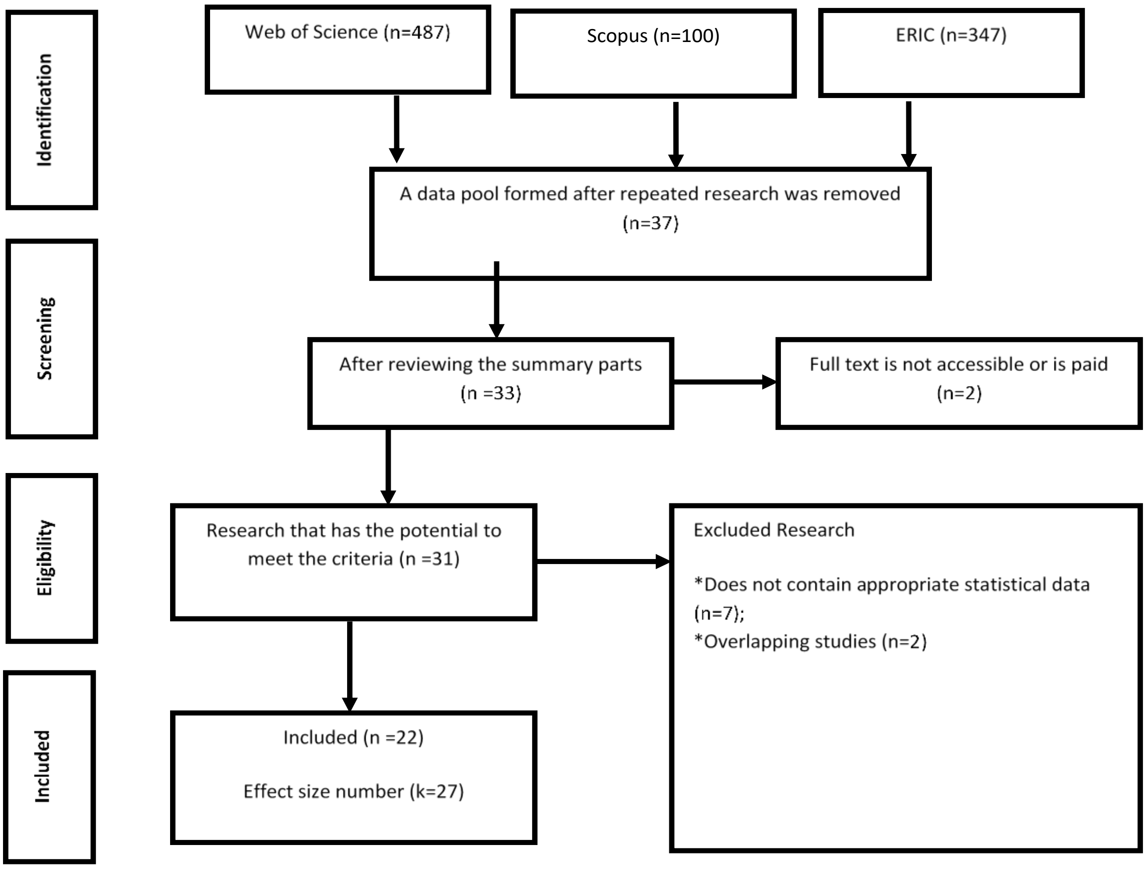

Figure 1. General Dataflow Diagram

Inclusion and Exclusion Criteria

Inclusion Criteria: The below-mentioned criteria are taken into consideration in determining the studies to be included in the analysis.

1. Meta-analysis research that will be included in the research should focus on technology-based mathematics instruction.

2. Meta-analysis research should focus on the mathematics performance of students.

3. Meta-analysis research should be published between the years 2017 and 2022.

4. Research should include statistical data necessary for calculating impact size.

Exclusion Criteria: Researchers are excluded according to the below-mentioned criteria.

1. Studies that are below 23 scores from the R-AMSTAR scale, used for publication quality, are excluded from the analysis.

2. Cooper & Koenka (2012) state that if the overlapping ratio is below 25%, meta-analysis studies are independent. When meta-analysis studies' overlapping ratios are over 25%, a more current and coherent study is preferred, and the other one is excluded.

Data Encoding

TBL: CBL, DBL, GBL, MBL, SBL, and WBL are encoded as technology-based learning models. If different TBL models are used in a meta-analysis study and separate impact sizes are not presented, they are encoded as "mixed". On the other hand, if a meta-analysis study includes more than one TBL model, they are encoded as "independent" (Codes: CBL, DBL, GBL, MBL, SBL, WBL).

Student performance: Student performance is encoded as academic success and effective features. If all variables are taken into consideration and presented as math skills, they are encoded as "combined".

Education level: If meta-analysis research includes many levels of education, they are encoded as "mixed". If they include only elementary level, they are encoded as "elementary" (Codes: Mixed, Elementary).

Location: If meta-analysis research is made of researchers from different countries, they are encoded as "mixed". If they represent only one country, they are encoded accordingly (Codes: Mixed, Turkey, Indonesia, China).

Report type: If meta-analysis research includes a minimum of two articles, notices, or master's thesis, they are encoded as "mixed". If they include only one of these studies, they are encoded accordingly (Codes: Mixed, Article).

Publication bias: If a meta-analysis study found publication bias, it is encoded as "no". If there is no information about publication bias, it is encoded as "Unknown" (Codes: Yes, No, Unk.).

Quality level: Meta-analysis research is encoded according to the scores they obtained from the quality scale (Codes: Insufficient, Low, Medium, and High).

Quality Evaluation

The revised Assessment of Multiple Systematic Reviews (R-AMSTAR) scales, revised by Kung et.al (2010) is used while evaluating the quality of meta-analysis research. Scores obtained from the R-AMSTAR scale are 0 to 11=Insufficient, 12 to 22=Low, 23 to 33=Medium, and 34 to 44= High (Young, 2017). Items number 8C and 8D in the R-AMSTAR scale are developed for research about clinical practices; because of that, they aren't used. Items 8A and 8B are encoded as "double scores". Quality evaluation processes are carried out by the second author.

Data Analysis

Overlapping problem: Different first-order meta-analysis research might include the same basic research. This situation is called the problem of overlapping (Cooper & Koenka, 2012). The overlapping problem is taken into consideration in this research. An overlapping analysis of research that forms the datasets of this research study is presented in Appendix 1. According to Cooper, & Koenka, (2012) and Wilson & Lipsey (2001), if the overlapping ratio is below 25%, meta-analysis research is independent. If the overlapping ratio is over 25%, meta-analysis research is preferred. More comprehensive and current research is preferred in such cases.

Statistical independence: Meta-analysis research that is the dataset of this research is shaped in different designs. The purpose of this research is to analyze the effects of technological tools of education on mathematics performance. These tools can be different from one another. These two different issues are taken into consideration and the independent impact sizes produced by meta-analysis research are encoded as data. For instance, Higgins et al. (2017) state that technology-based instruction focuses on three different learning outputs: math achievement, math motivation, and math attitude. The research study is represented with three independent impact sizes.

Statistical model: Meta-analysis research is carried out with random effects and fixed effect models. A random effect model is suggested when research features and samplings are different (Borenstein, et al. 2021; Tufanaru et al, 2015). Researchers that form the dataset of this study are different from one another in terms of the instruments and other features; this is why, mean impact size, moderator, and heterogeneity analyses of the study are carried out under the random effect model.

Impact size choice: It is observed that 6 meta-analysis research that form the dataset of this research study used the Cohen d index while 16 meta-analysis research used the hedge’s g index. Hedge’s g index is the corrected value of the Cohen d index for small samplings (Goulet-Pelletier & Cousineau, 2018). In other words, Hedge’s g value and Cohen's d value are equal in samplings that are big enough (Marfo & Okyere, 2019). When this situation is taken into consideration, it is regarded that the samplings of the basic research that meta-analysis research include are high enough. Researchers carry out their second-order meta-analysis research based on this assumption (Hew et. al, 2021; Tamim et. al, 2011; Young, 2017).

Publication bias analyses: Publication bias is another element that affects the credibility of the mean impact size of meta-analysis research (Borenstein, et al. 2021). Publication bias of the impact size distribution is checked in this research. Funnel-plot graphic inspection, Begg and Mazumdar rank correlation test, Egger’s test, and Duval & Tweedie trim and fill analysis techniques are used in this research to check the publication bias (Jin et al. 2015).

Moderator and heterogeneity analysis: A variety of moderators are determined according to the characteristics of meta-analysis research (Technology based learning model, outcomes type, and grade level). The mean impact size according to the moderators is calculated. Q(t) statistics are used to determine the total heterogeneity of the distribution of impact sizes. Besides, I2 statistics are used to determine the heterogeneity level. On the other hand, intergroup Q (b) statistics is used to inspect the statistical difference among groups.

Findings

This research includes 22 meta-analysis research and 953 basic research. This research includes k=27 impact size obtained from 22 meta-analysis research. Impact sizes are between ES=.13 and ES=1.14.

Mean impact size and total heterogeneity: It is determined that the mean impact size of the effect of technology-based instruction on mathematics performance is ES=.60 (LL=.48 UL=.71). In other words, the impact of technology-supported instruction on mathematics performance is medium-level. The total heterogeneity of the dataset is Q (26) =439.42. It is determined that the dataset is highly heterogeneous (I2=94.74).

Publication bias analyses: According to Begg and Mazumdar rank correlation test results there is no publication bias (tau=.21 z=1.54 p=.12). However, Egger's regression test result indicates that there is publication bias (t=4.7 p=.00). Duval & Tweedie trim and fill analysis results show that there is no publication bias. Funnel Plot designed for the distribution or impact size according to standard deviations; is presented in Figure 1. When the figure is analyzed, it can be seen that the impact sizes' distribution according to standard deviation is approximately symmetrical. When this information is taken into consideration, it can be said that there is trivial publication bias.

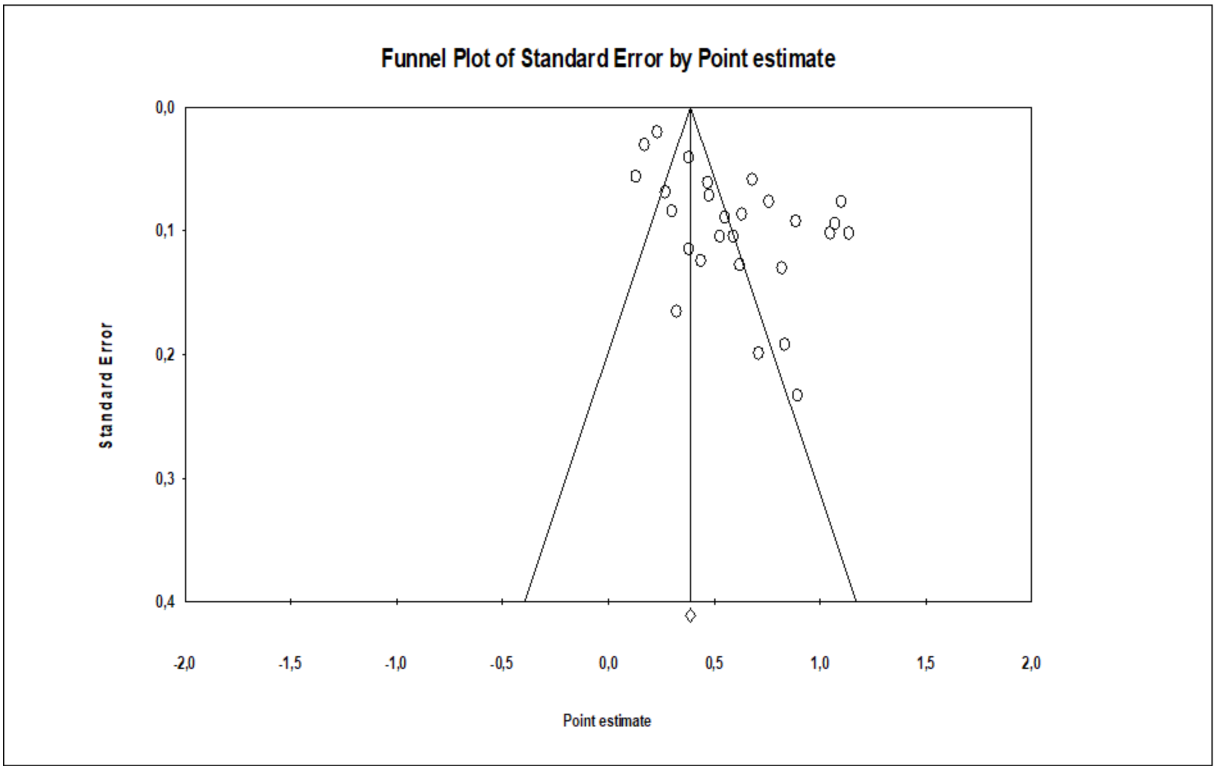

Figure 2. Funnel Plot

Moderator and intragroup heterogeneity analyses of the dataset are carried out and the findings are presented in Table 1. Important findings are presented below.

Table 1. Moderator and heterogeneity analysis of the dataset

Group	*k in meta	k	ES	LL	UL	Q(b)	df (Q)	p
Performance								
Achievement	744	21	.59	.47	.72			
Emotional	119	4	.42	.14	.69			
Combined	90	2	.98	.59	1.37	5.37	2	.07
Technology-Based Instruction Models**								
CBI	50	3	.48	.18	.79			
DBI	117	3	.80	.50	1.10			
GBI	186	4	.38	.13	.63			
MBI	50	3	.49	.19	.79			
SBI	96	3	.94	.63	1.25			
WBI	122	2	.77	.39	1.14			
Mixed	332	9	.55	.39	.72	11.65	6	.07
Grade Level								
Elementary	99	5	.45	.17	.73			
Mixed	854	22	.63	.50	.76	1.31	1	.25
Quality								
High	609	16	.49	.37	.61			
Medium	344	11	.76	.60	.91	6.86	1	.01
Bias Status								
Low	240	6	.40	.17	.63			
No	685	19	.67	.54	.81			
Unknown	28	2	.50	.07	.92	4.17	2	.12
Report								
Article	295	10	.50	.31	.70			
Mixed	658	17	.65	.50	.81	1.39	1	.24
Year Range								
2017-2019	232	7	.57	.34	.79			
2020-2022	721	20	.61	.47	.74	.10	1	.75
Location								
Global (mixed)	670	21	.51	.40	.62			
Turkey	156	3	.97	.69	1.26			
Indonesia	90	2	.98	.63	1.32			
China	37	1	.38	-.08	.84	14.87	3	<.01

*k in meta= primary research number in meta-analysis, **TBI= CBI: Computer Based Instruction; DBI: Digital Tools Based Instruction; GBI: Digital Game Based Instruction; MBI: Mobile Technologies Based Instruction; WBI: Web Based Instruction

It is determined that meta-analysis researchers' mean impact sizes according to the quality level are statistically different (Q(1)=6.86 p=.01). Meta-analysis with high quality produces lower impact size (ES=.49 LL=.37 UL=.61) while medium-level meta-analysis research produce higher impact size (ES=.76 LL=.60 UL=.91). It is observed that the mean impact sizes of meta-analysis researches according to the location they comprise are statistically different (Q(3)=14.87 p<.01). Meta-analysis research that includes different countries (mixed) produce lower impact size (ES=.51 LL=.40 UL=.62); researches including Turkey and Indonesia produce higher impact size (ES=.98 LL=.63 UL=1.32). Besides, there is only one research from China and according to it, the impact size is low (ES=.38 LL=-.08 UL=.84).

On the other hand, there is no statistical difference in terms of TBI, performance type, grade level, bias status, report type, and year range moderator variables. However, there are some interesting cases. It can be said that the effect of DBI and SBI models on mathematics is high-level (ES=.80 LL=.50UL=1.10; ES=.94LL=.63 UL=1,25 respectively). It is observed that the effect of GBI on mathematics performance is low (ES=.38 LL=.13 UL=.63).

Discussion

Technology-based mathematics instruction improves the performance of students in math lessons (Cohen, 1998 p.2; cit. Young, 2017). Developing technologies and their use in the mathematics instruction process have increased in recent years. In this respect, impact sizes obtained from the first-order meta-analysis research focused on the impacts of technology-based mathematics instruction are combined in this research study. At the end of the research process, it is determined that mathematics instruction has a medium-level impact on the mathematics performance of students. When the literature was examined, it was determined that the effect of technology-enriched instruction on mathematics was consistent with the findings of the study and at a moderate level (Helsa et al. 2023; Ran et al. 2022; Tamim et al., 2011; Taşpınar-Şener, 2023; Young, 2017). In his research which is a combination of meta-analysis research of 30 years, Young (2017) determined that technology-based mathematics instruction has cumulative effect on mathematics success. Similarly, in both Ran at al. (2022) and Taşpınar-Şener (2023) studies, the general effect of technology on academic success in mathematics course was found to be moderate. In this respect, it can be said that technology-based mathematics instruction is efficient in terms of increasing math performance.

It is stated that all the technological supports used in mathematics instruction have the potential power to positively affect mathematics performance (Young, 2017). In this research study, research that is about the use of technology in mathematics instruction are categorized according to technology-supported instruction models. This categorization enabled us to compare these models, which are used for teaching mathematics, as moderators. On the other hand, performance types, education level, publication quality, publication bias, report types, year range, and the region of the research are analyzed as other moderator variables.

At the end of this research, it is found that the technology-based instruction models that are analyzed in meta-analysis studies are moderator variables. According to the obtained findings, Computer Based Instruction, Game Based Instruction and Mobile Technologies Based Instruction education models produce low impact size. It is found that research that is categorized as Web Based Instruction and Mixed produce medium-level impact size. Additionally, digital Tools Based Instruction and Software Based Instruction education models produce high-level impact size. In line with the results obtained, it was determined that all different technology-supported teaching methods had a statistically significant average effect on students' mathematics achievement (Young, 2016, Young, 2017).

Findings obtained from this research indicate that the quality of meta-analysis included in the research study causes a meaningful difference in terms of the effects on mathematics performance. The research indicates that high-quality meta-analysis research produce a lower-level impact size while medium-quality meta-analysis research produce a higher-level impact size. Feeley (2020) states that researchers conducting meta-analysis studies should carry out quality evaluations for the research they include in their study. Helsa et al. (2023) state that in order for students to acquire the highest academic levels in mathematics, they need improve their computer technology skills through their study of mathematics. This suggests that by improving students' skills, computer-based learning interventions in mathematics can help them attain the best learning outcomes. It is found that the location included in meta-analysis research is a moderator variable in terms of the impact of technology-based instruction on the mathematics performance of students. Location bias in meta-analysis research is a significant problem. According to Higgins & Green (2011), location bias has two different forms. The first is the database in which research exist and the second is the countries from which research is collected. Vickers et al. (1998) stated that impact sizes in clinical practices statistically vary according to country. This situation in clinical practices might also exist in educational environment practices.

Conclusion

This research is a second-order meta-analysis study in which first-order meta-analyses about the effects of technology-based instruction on the mathematics performance of students are combined. The first-order meta-analyses combined in the scope of this study were carried out between 2017 and 2022. Four important results are obtained at the end of this research, whose purpose is to determine the effects of technology-based instruction on the mathematics performance of students. Firstly, supporting mathematics instruction with technology has a positive impact on the math performance of students. Secondly, all the learning models supported with technology increase the math performance of students; however, the uses of digital tools-based instruction and software-based instruction in the teaching process are more efficient when compared to the other learning methods. Thirdly, it is determined that the quality of the first-order meta-analysis research included in the second-order meta-analysis research has effects on the impact size obtained at the end of the research. Finally, it is determined that the location of research data included in terms of meta-analysis research has effects on impact size.

Suggestions

The research study results indicate that technology-based instruction is efficient in terms of the mathematics performance of students. In this respect, teachers can use technology-based instruction models in their classes to benefit from their positive effects on student performance. On the other hand, it is suggested that these technologies should be used by decision-makers and necessary hardware should be prepared for this purpose. Additionally, it is determined that Digital Tools Based Instruction and Software Based Instruction models are more efficient methods in supporting and increasing the mathematics performance of students. In this respect, teachers can give more importance to these models to increase student performance. According to the results obtained at the end of the research process, the quality of meta-analysis studies is efficient in terms of impact size. Quality evaluations should be carried out in second-order meta-analysis studies in which meta-analysis studies are compared. It is also found that the variable of location is a moderator in terms of impact size. According to this finding, meta-analysis research can be carried out in a way that includes different countries and different databases to cope with the problem of location bias.

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Appendix 1. Study characteristic

	Year	k	ES Type	ES	LL	UL	Culture	Report	Group	Outcome	Technology based learning model	Bias	Year range
Akar, 2020	2020	16	Cohen d	0,71	0,32	1,82	Global	mixed	mixed	Math Achievement	Computer Based Learning	no	2000-2019
Talan, 2021	2021	7	Hedges g	0,437	0,193	0,68	Global	mixed	mixed	Math Achievement	Computer Based Learning	no	2010-2020
Xie vd, 2020	2020	37	Cohen d	0,38	0,3	0,46	China	mixed	k-12	Math Achievement	Computer Based Learning	no	1999-2018
Hilmayr vd, 2020	2020	33	Hedges g	0,55	0,37	0,72	Global	article	grade (5-13)	Math Achievement	Digital Tools Assisted Learning	yes	2000-2018
Kul, Çelik & Aksu, 2018	2018	58	Cohen d	1,047	0,85	1,25	Türkiye	mixed	k-12	Math Achievement	Digital Tools Assisted Learning	no	2005-2016
Wijaya vd, 2022	2022	26	Hedges g	0,82	0,56	1,07	Global	mixed	mixed	Math Achievement	Digital Tools Assisted Learning	low	2010-2021
Fadda vd, 2021	2021	43	Cohen d	0,27	0,14	0,41	Global	mixed	k-12	Math Motivation	Game Based Learning	yes	2006-2019
Lei, 2022a	2022	39	Hedges g	0,526	0,32	0,73	Global	mixed	k16	Positive emotion	Game Based Learning	yes	2000-2021
Talan, vd. 2020	2020	65	Hedges g	0,63	0,46	0,8	Global	mixed	mixed	Math Achievement	Game Based Learning	no	2004-2019
Tokac vd, 2019	2019	39	Hedges g	0,13	0,02	0,24	US & global	mixed	preK-12	Math Achievement	Game Based Learning	small	2000-2017
Chauhan, 2017	2017	41	Hedges g	0,469	0,35	0,59	Global	article	k-12	Math Achievement	Mixed interventions	no	2000-2016
Çavuş & Deniz, 2022a	2022a	52	Hedges g	0,758	0,61	0,91	Türkiye	mixed	mixed	Math Achievement	Mixed interventions	no	2000-2016
Çavuş & Deniz, 2022b	2022b	46	Hedges g	1,136	0,94	1,34	Türkiye	mixed	mixed	Geometry Achievement	Mixed interventions	no	2000-2016
Higgins vd, 2017a	2017	52	Cohen d	0,68	0,56	0,79	Global	article	k-12	Math Achievement	Mixed interventions	no	1985-2013
Higgins vd, 2017b	2017	21	Cohen d	0,3	0,14	0,47	Global	article	k-12	Math Motivation	Mixed interventions	no	1985-2013
Higgins vd, 2017c	2017	16	Cohen d	0,59	0,39	0,80	Global	article	k-12	Math Attitude	Mixed interventions	no	1985-2013

Major vsd, 2021	2021	12	Hedges g	0,17	0,11	0,23	Global	mixed	k-12	Math Achievement	Mixed interventions	no	2007-2020
Ran, Kim, Secada, 2021	2021	77	Hedges g	0,23	0,19	0,27	Global	article	K-12	Math Achievement	Mixed interventions	small	2000-2020
Sung, Yung &Lee, 2017	2017	5	Hedges g	0,894	0,437	1,351	Global	article	mixed	Math Achievement	Mixed interventions	no	2000-2015
Aspiranti & Larwin, 2021a	2021	14	Hedges g	0,38	0,15	0,60	US & global	article	k-12	Math Achievement	Mobile Learning	unk	2002-2018
Aspiranti & Larwin, 2021b	2021	14	Hedges g	0,62	0,37	0,87	US & global	article	k-12	Math Achievement	Mobile Learning	unk	2002-2018
Güler vd, 2021	2021	22	Hedges g	0,476	0,34	0,62	Global	article	mixed	Math Achievement	Mobile Learning	weak	2010-2020
Akçay, 2021a	2021	6	Cohen d	0,833	0,457	1,21	Global	mixed	k12	Math Achievement	Software Based Learning	no	2013-2019
Juandi vd., 2021	2021	50	Hedges g	1,07	0,89	1,26	Endonezya	article and proceeding	mixed	Math Ability (thinking skill,)	Software Based Learning	no	2010-2020
Tamur, 2021	2021	40	Hedges g	0,886	0,705	1,067	Endonezya	mixed	unk	Math Ability	Software Based Learning	no	2010-2020
Akçay, 2021b	2021	7	Cohen d	0,322	-0,002	0,646	Global	mixed	kl12	Math Achievement	Web Based Learning	no	2013-2019
Akın, 2022	2022	115	Hedges g	1,1	0,95	1,27	Global	mixed	k16	Math Achievement	Web Based Learning	no	2000-2020