MAKÜ EĞT EĞİTİM FAKÜLTESİ

Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 2026, 79 Sayfa: 161-182
Mehmet Akif Ersoy University Journal of Education Faculty, 2026, 79 Page: 161-182

Research Article
Araştırma Makalesi

https://doi.org/10.21764/maeuefd.1965499

A Longitudinal Exploration of Assistive Technologies and Educational Technologies in Special Education: Reflections from a Half Century

Özel Eğitimde Yardımcı Teknolojiler ve Eğitim Teknolojilerinin Boylamsal Bir İncelemesi: Yarım Asırdan Yansımalar

Elif Elumar-Efe[1] **Zekeriya Alperen Sağdıç[2]** **Sunagül Sani-Bozkurt[3]** **Aras Bozkurt[3*]**

[1] Pamukkale University, Denizli, Türkiye
[2] SOBE Vakfı, Konya, Türkiye
[3] Anadolu University, Eskişehir, Türkiye

Abstract: This study provides a longitudinal exploration of assistive and educational technologies in special education, reflecting on 60 years of research (1965-2025). The field lacks a review that bridges broad bibliometric structure with deep pedagogical substance. We address this gap by integrating a systematic review of 334 Scopus publications with a multi-method triangulation using bibliometrics, t-SNE, text mining, and social network analysis (SNA). Bibliometric findings briefly confirm a recent, rapid acceleration in research and a significant geographical imbalance, with the USA dominating the field (35%). The thematic analysis, which forms the core of this study, reveals a clear conceptual journey. The research evolved from foundational, parallel themes (1965-2010) to a consolidated hub (2011-2021) centered on "special education" and "educational technology". This hub recently "fractured" into highly specialized, applied topics (2022-2025) like "adaptive learning technologies," "accessibility," and "autism spectrum disorders". Six triangulated themes were identified, including: (1) the foundational AT-Special Education nexus; (2) the critical role of teacher training, self-efficacy, and TPACK; (3) the pivot to inclusive pedagogy via UDL; (4) a distinct focus on autism; (5) support for sensory impairments; and (6) the new frontier of AI, VR, and e-learning. This study maps the field's maturation from foundational concepts to solving complex, practical challenges.

Keywords: Special education, individuals with special learning needs, assistive technology, educational technology, edtech.

Özet: Bu çalışma, 60 yıllık bir araştırma dönemini (1965-2025) temel alarak, özel eğitimde yardımcı ve eğitim teknolojilerinin boylamsal bir incelemesini sunmaktadır. Alanyazında, geniş kapsamlı bibliyometrik yapıyı derin pedagojik içerikle ilişkilendiren bir inceleme eksikliği bulunmaktadır. Bu çalışma; Scopus veri tabanındaki 334 yayının sistematik incelemesini bibliyometri, t-SNE, metin madenciliği ve sosyal ağ analizi (SAA) yöntemlerini içeren çoklu yöntemli bir çeşitleme (triangülasyon) ile bütünleştirerek söz konusu eksikliği gidermeyi amaçlamaktadır. Bibliyometrik bulgular, son dönemde araştırmalarda yaşanan hızlı ivmelenmeyi ve ABD'nin alana hakim olduğu (%39) belirgin bir coğrafi dengesizliği kısaca doğrulamaktadır. Bu çalışmanın özünü oluşturan tematik analiz ise net bir kavramsal dönüşümü ortaya koymaktadır. Araştırmaların; temel düzeydeki paralel temalardan (1965-2010), "özel eğitim" ve "eğitim teknolojisi" odaklı konsolide bir merkeze (2011-2021) evrildiği görülmektedir. Bu merkez yakın zamanda (2022-2025) "uyarlanabilir öğrenme teknolojileri", "erişilebilirlik" ve "otizm spektrum bozuklukları" gibi son derece uzmanlaşmış, uygulamalı konulara ayrışmıştır. Üçgenleme yöntemiyle belirlenen altı ana tema şunlardır: (1) temel nitelikteki Yardımcı Teknoloji (YT)-Özel Eğitim ilişkisi; (2) öğretmen eğitimi, öz-yeterlik ve Teknolojik Pedagojik Alan Bilgisi'nin (TPAB) kritik rolü; (3) Evrensel Tasarım Rehberliği (ETR) aracılığıyla kapsayıcı pedagojiye geçiş; (4) otizm üzerine belirgin bir odaklanma; (5) duyu yetersizliklerine yönelik destekler ve (6) yapay zeka (YZ), sanal gerçeklik (SG) ve e-öğrenmeyi kapsayan yeni ufuklar. Sonuç olarak bu çalışma, alanın temel kavramlardan karmaşık ve pratik sorunların çözümüne doğru geçirdiği olgunlaşma sürecini haritalandırmaktadır.

Anahtar Kelimeler: Özel eğitim, özel öğrenme gereksinimi olan bireyler, yardımcı teknoloji, eğitim teknolojisi

*Corresponding author: arasbozkurt@gmail.com
Received: *06/06/2026*
Revised: *12/07/2026*
Accepted: *25/07/2026*

1. Introduction

Building on McLuhan's (1964) perspective that technology acts as an extension of human capabilities, this concept finds a significant application in special education, particularly in the use of educational and assistive technologies for individuals with special learning needs. Special education, being an expansive field, encompasses a variety of sub-disciplines—including intellectual and developmental disabilities, autism spectrum disorders, learning disabilities, emotional and behavioral disorders, sensory impairments, and gifted education—each catering to distinct needs and challenges.

The inherent diversity within special education reflects the varied nature of learning needs among individuals. This diversity highlights the necessity for a range of technologies tailored to meet these unique requirements. In this sense, the current study is designed to delve into the research surrounding the application of educational and assistive technologies in special education. The overall purpose is to uncover and analyze emerging research trends and thematic research patterns, offering insights into how these technologies are being utilized and adapted to cater to the diverse spectrum of needs within this field.

1.1. Related Literature

Special education, as a field that emphasizes individual differences and seeks to maximally support the learning process, is one of the disciplines most profoundly affected by technological advancements. Today, educational technologies not only transform teaching processes but also significantly expand learning, communication, and social interaction opportunities (Bozkurt et al., 2026) for individuals with special needs. In this context, the use of assistive and educational technologies (AT) in special education is of critical importance as it creates individualized teaching opportunities, increases accessibility, and supports inclusive education practices (Gallud et al., 2021; Lin & Chang, 2015).

The evolution of this field is well-documented. Initial research focused on the effectiveness of computer-assisted instruction (Pennington, 2010; Woodward & Rieth, 1997). Subsequently, the focus shifted to mobile applications, web-based platforms, and cloud-based solutions (Wu et al., 2012). Currently, the potential of advanced technologies such as augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and humanoid robots is attracting significant attention (Sagdic et al., 2024; Sani-Bozkurt, 2017), with applications moving beyond academic skills to support social interaction, communication, and independence.

To make sense of this growth, researchers have employed two primary methods: systematic reviews and bibliometric analyses. Systematic reviews have offered granular insights by focusing on specific disability groups, educational levels, and contexts. For instance, studies have examined AT for visual impairment (Mendes et al., 2025), dysgraphia (Rahim et al., 2025), and autism (Zhou et al., 2025), and explored impacts on pre-service teacher self-efficacy (Park et al., 2024) and use in higher education (Soeprapto Putri et al., 2025). While these reviews confirm AT's value in enhancing learning, access, and independence, they share common limitations: small sample sizes, methodological constraints, a predominantly Western-centric focus, and the underrepresentation of many disability groups. This suggests a need for more comprehensive, culturally inclusive, and long-term research.

Concurrently, bibliometric analyses have mapped the field's macro-level structure, revealing thematic orientations and international collaborations. These studies have identified 25-year trends in key journals (Sinha et al., 2024), mapped the global rise of STEM and Universal Design for Learning (UDL) (Filiz & Albay, 2025), and highlighted the emergence of

AI and VR as rising themes (Yang et al., 2025). While valuable for visualizing global trends, these bibliometric studies mostly focus on publication counts, citation density, and collaboration networks. Consequently, the substantive application of technology in instructional practice, its impact on learning outcomes, and the nuances of user experience are not examined in sufficient depth.

This critical review of the literature reveals a significant methodological gap. The field is currently served by two disparate forms of review: (1) deep, narrow systematic reviews that often lack generalizability and broad temporal context, and (2) broad, structural bibliometric analyses that often lack pedagogical depth. A comprehensive study that bridges these two approaches is missing. This epistemic friction between macro-structural landscapes and micro-level semantic shifts has historically obscured long-term trends. By deploying a multi-method triangulation strategy, research can move past fragmented viewpoints to map complex, non-linear thematic distances that single-method reviews systematically fail to capture. Therefore, the present study is designed to fill this gap by integrating a longitudinal, large-scale bibliometric analysis with a deep, multi-method thematic analysis (including t-SNE, text mining, and SNA).

The objective is to provide a holistic and critical understanding of the research landscape, mapping not only the structure of the field but also the substance of its thematic evolution over the past half-century. This approach is vital to grasp the full scope of how these technologies are being implemented, their impacts, and potential future developments, and it provides the methodological justification for the research design that follows. To bridge the macro-structural landscape and micro-level semantic shifts, this study addresses three central research questions:

RQ1: What are the macro-level bibliometric trajectories and geographical distribution patterns in special education technology research over the past half-century?

RQ2: How has the thematic landscape structurally evolved and fragmented across different historical eras?

RQ3: What core pedagogical, human, and advanced technological dimensions emerge when triangulating text-mining, t-SNE, and social network analyses?

2. Methodology

This section describes the research method, sampling approach, and study limitations.

2.1. Research Method and Design

To gain a thorough and expansive insight, particularly in recognizing evolving trends and patterns related to the implementation of educational and assistive technologies in special education, this study integrates a systematic literature review, as outlined by Gough et al. (2012), and employs bibliometric analysis methods, following Donthu et al. (2021). The rationale behind this approach is to ensure a comprehensive and methodical examination of existing literature, thereby capturing a wide array of perspectives and developments in the field. Additionally, the study employs a triangulation strategy to scrutinize the research material from various dimensions, as suggested by Thurmond (2001). This includes the utilization of data mining and advanced analytical techniques like t-SNE analysis (van der Maaten & Hinton, 2008), text mining (Feldman & Sanger, 2007), and social network analysis (SNA; Hansen et al., 2010). The justification for this multi-method approach is to provide a layered and nuanced analysis of the research questions, leveraging different methodologies to validate and enrich the findings, thereby offering a more holistic view of the research landscape.

2.2. Inclusion Criteria and Research Sampling

In this study, the research material was meticulously gathered from publications indexed in the Scopus database. The selection of Scopus was strategic due to its broad spectrum of peer-reviewed literature, ensuring a thorough coverage of the subject matter. The focus was on sourcing documents that were either accessible via library services or available as open access, specifically those featuring designated search terms related to educational and assistive technologies in special education in their titles or keywords, as detailed in Table 1.

The construction of the research corpus was guided by these targeted search terms, ensuring relevance and specificity in the context of the study. Following the principles of the PRISMA protocol, as elaborated by Page et al. (2021), the research team meticulously curated the final collection of literature. This protocol is renowned for its systematic and transparent approach in literature selection and review, which is critical for the integrity and credibility of research. Ultimately, the research corpus culminated in a substantial body of 334 publications, offering a comprehensive perspective on the topic under investigation. This rigorous selection process, anchored in a respected protocol and a reputable database, underscores the robustness and breadth of the research approach.

Table 1
Search Strings and PRISMA Protocol

Search Strings	
Database	Scopus
Title	"special education" AND "educational technolog*" OR "assistive technolog*" OR "technolog*"
OR	
Keywords	"special education" AND "educational technolog*" OR "assistive technolog*" OR "technolog*"
PRISMA Protocol	
Identification	A total of 466 documents were identified in social sciences.
Screening	Document types were limited to conference papers (n=39) and articles (n=338). Excluded: Book chapter (n=64), Book (n=13), Editorial (n=6), Note (n=4), Erratum (n=2). Excluded if the articles were not written in English (n=47).
Inclusion	A total of 334 documents were included in the final research corpus.

2.3. Limitations

This research, while extensive, recognizes inherent limitations in its scope and interpretation of results. The primary constraint arises from the exclusive reliance on the Scopus database for sourcing peer-reviewed publications. Despite Scopus being one of the most comprehensive databases in this field, this singular dependence implies that the study's findings are based solely on the literature indexed within it.

This approach, while yielding a significant research corpus, inherently excludes potential contributions from other databases, sources, and formats. Notably, relevant articles on educational and assistive technologies in special education could be present in alternative databases or in various forms of grey literature, which encompasses materials like reports, theses, and conference proceedings that are not typically subject to the same level of peer review as published journal articles.

The recognition of this limitation is critical in contextualizing the findings of the study. It suggests that while the research provides a comprehensive overview based on available Scopus-indexed literature, it may not encompass the complete spectrum of existing scholarly work on the subject. This acknowledgment highlights the need for a cautious interpretation of the results, bearing in mind the potential existence of additional relevant studies and insights outside the Scopus database.

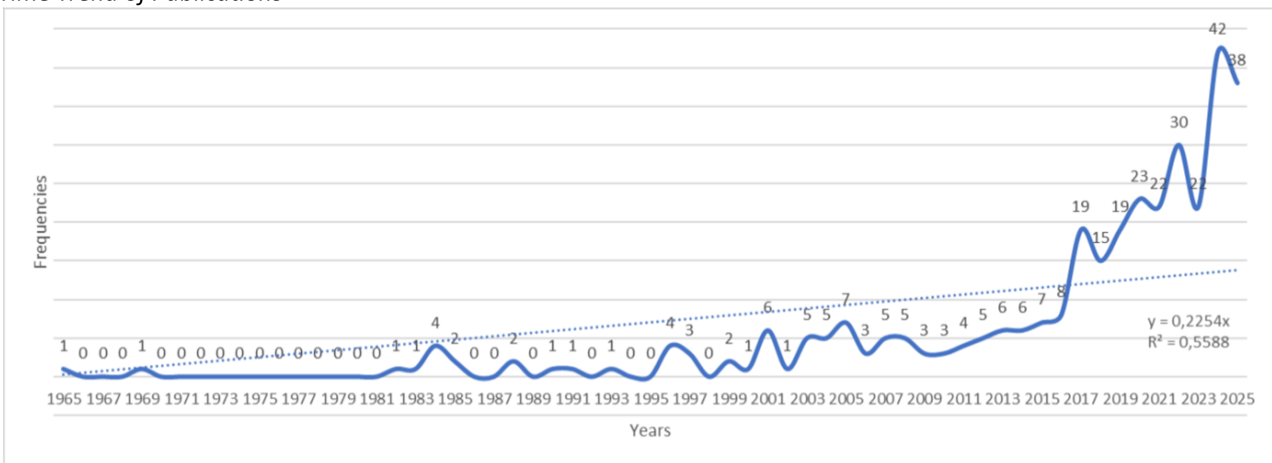
3. Findings and Discussion

This section reports bibliometric trends and research patterns.

3.1. Bibliometric Trends

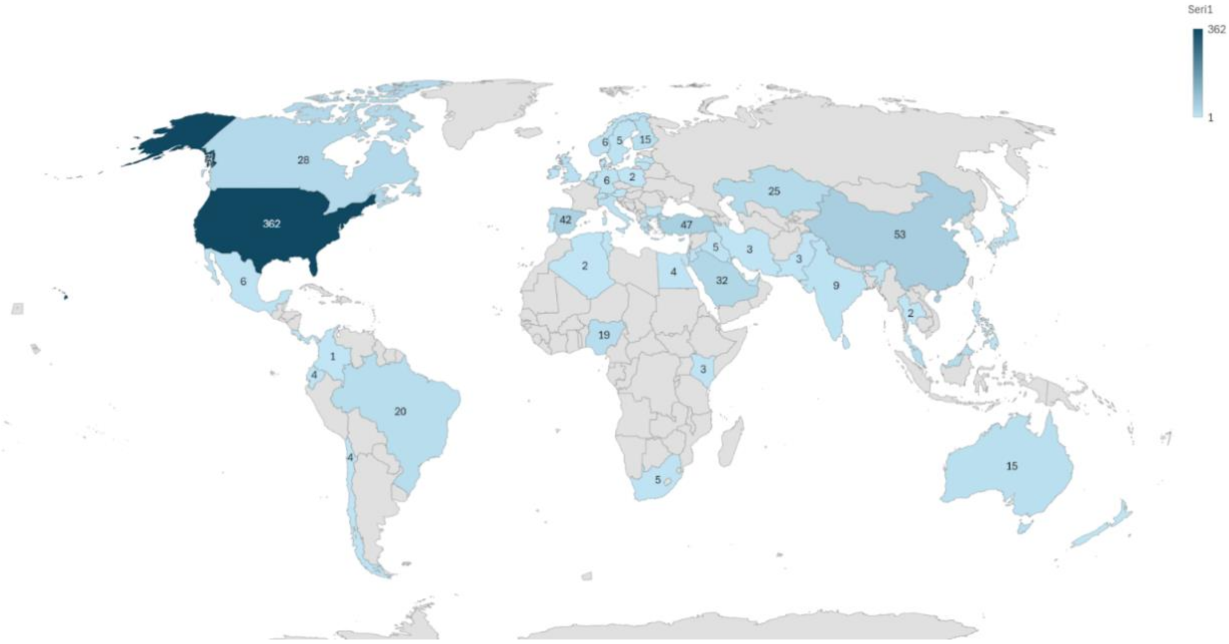
The research corpus assembled for this study spans an impressive duration of over sixty years, ranging from 1965 to 2025, as depicted in Figure 1. This extensive temporal coverage provides a comprehensive historical and contemporary perspective on the subject.. Within this corpus, a total of 334 publications, comprising both articles and conference papers, were compiled from 148 distinct sources.

Figure 1
Time Trend of Publications



This temporal expansion, spanning six decades, demonstrates the field's evolution from niche to nascent sub-discipline to mainstream research agenda. Beyond publication volume, the composition of the corpus reveals critical characteristics about the research community itself. A notable aspect of this corpus is the collaborative nature of the research in this field. Out of the 334 publications, an extensive network of 1048 researchers contributed as co-authors, illustrating the collaborative and interdisciplinary nature of research in this domain. Furthermore, the final research corpus is characterized by its diversity and richness in terms of content, as evidenced by the inclusion of 775 distinct keywords. This variety reflects the wide range of topics and subtopics covered within the field. Additionally, the corpus is substantiated by an extensive reference list, encompassing 10,775 references. This substantial number of references not only underpins the depth of research conducted but also highlights the interconnectedness of the works within this corpus, providing a robust foundation for the study.

Figure 2
Geographical Distribution of the Corresponding Authors



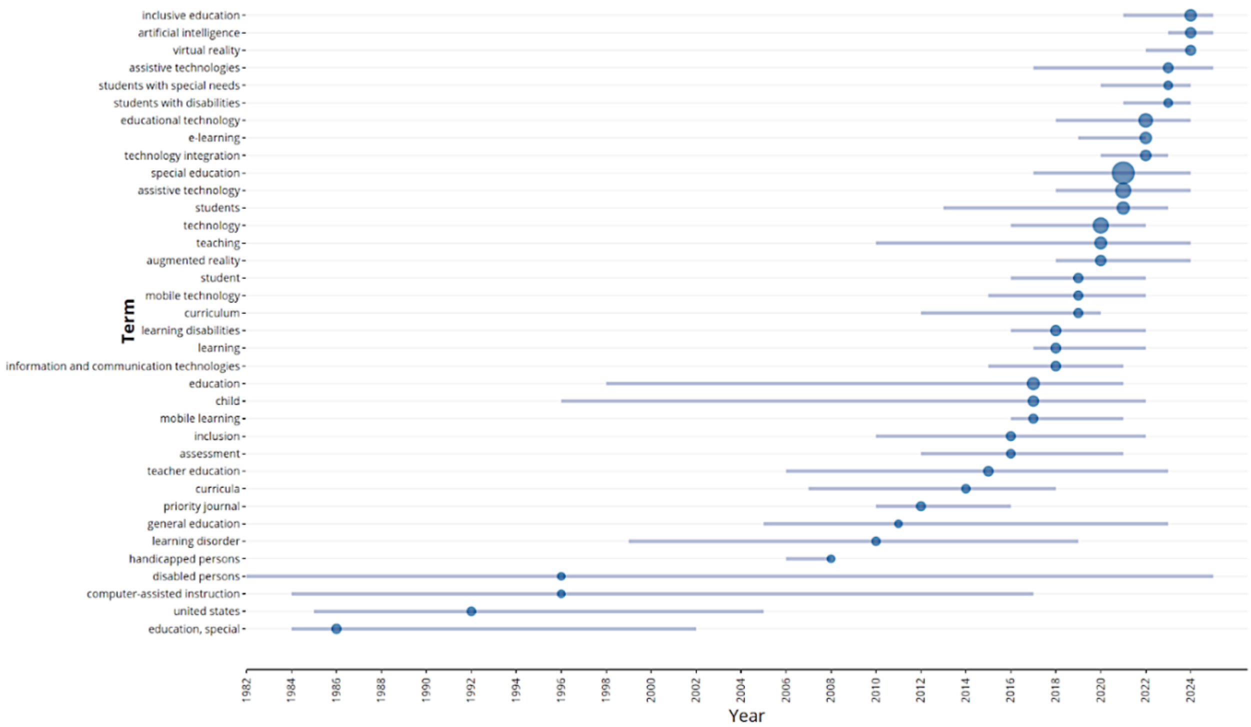
The geographical analysis of the authors contributing to the research corpus (n=1048) reveals a notable pattern in terms of regional representation, as illustrated in Figure 2. The top four countries in terms of contributions are the USA (n=362), China (n=88), Turkey (n=47), and Spain (n=42), collectively accounting for more than half of the total contributions. This concentration indicates a significant skew towards these regions in the field of educational and assistive technologies within special education. The USA's dominant position, contributing 35% on its own, highlights a considerable imbalance. It suggests that much of the research and development in this field is concentrated in, and potentially influenced by, a single country. This dominance raises questions about global diversity and inclusivity in the development and application of these technologies. The lesser representation from other countries implies a limited engagement or interest in the use of technology in special education in these regions. This could be due to various factors such as resource availability, policy priorities, or research focus areas. The data suggests a need for more globally diverse contributions to ensure a broader, more inclusive understanding and application of educational and assistive technologies in the field of special education.

3.2. Thematic Research Patterns

The plot in Figure 3 illustrates a clear temporal evolution in the research field, highlighting a significant paradigm shift from foundational concepts to high-tech, specialized applications. The early research landscape, prominent from the 1980s through the 1990s, was dominated by foundational terms such as "education, special," "disabled person," "computer-assisted instruction," and "United States." This suggests an initial focus on establishing the field and addressing basic access, often within a specific national policy context. A critical shift is also evident in the terminology itself; the plot captures the field's move away from pathologizing labels like "handicapped persons" toward more inclusive, person-first language such as "students with disabilities" and "students with special needs," reflecting a significant socio-cultural and theoretical maturation.

Figure 3

Temporal Evolution in Special Education from the Perspective of Educational Technology



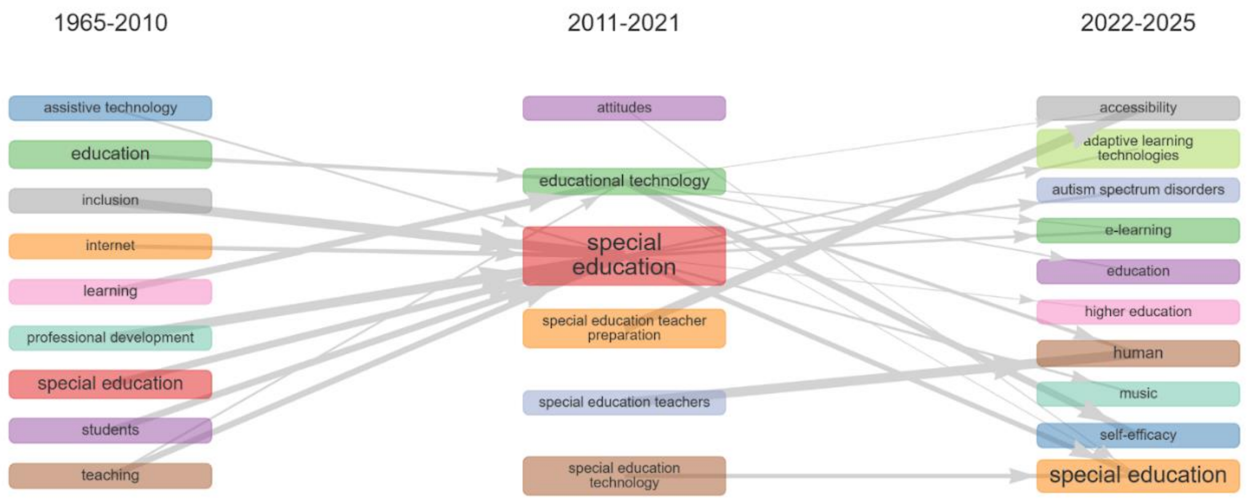
The analysis of research trends (See Figure 3) reveals three distinct eras, each with a unique thematic focus. The first, the "Foundational Period" (1980s-1990s), was concerned with establishing the field's core elements. Dominant terms like "education, special," "disabled persons," and "computer-assisted instruction" suggest that research was primarily focused on basic access, early technological interventions, and policy, often within the "United States" context. This was followed by a "Transitional Period" (c. 2000s), which marked a clear pivot toward integration and inclusivity. The emergence of terms such as "mobile learning," "inclusion," "assessment," and "ICT (Information and Communication Technologies)" indicates a growing interest in moving beyond basic instruction. The research focus expanded to embedding technology systemically into education, adopting inclusive practices, and developing methods to measure their effectiveness. Finally, the "Acceleration Period" (2010s-Present) demonstrates a significant sharpening and specialization of the research agenda. This modern era is characterized by the high frequency (indicated by the larger bubble sizes) and rapid proliferation of advanced technologies. Terms like "artificial intelligence (AI)," "virtual reality," "augmented reality," and "assistive technologies" are no longer niche topics but have become dominant themes. This signals a major shift where research is driven by rapid technological advancements and a strong emphasis on leveraging these tools for diverse learners. The plot confirms that the intersection of "technology integration" and "special education" has evolved from a sub-topic into the critical nexus of the modern research field.

The trend observed in Figure 3 demonstrates that technology in special education has transcended its role as mere instrumental support to become a fundamental paradigm shaping the field's trajectory. This evolution reveals a transformation characterized not by a quantitative increase in tools, but by qualitative shifts in educational practice: from limited applications focused on access and computer-assisted instruction, where technology served as auxiliary support, to systemic, inclusive, and individualized applications that position technology as integral to participation, autonomy, and inclusion (Abdelwahab et al., 2025; Yang et al., 2025).

This development also signifies a concurrent linguistic and conceptual maturation; the move away from pathologizing terms like "handicapped" toward person-first language such as "students with disabilities" is an indicator of a growing ethical and pedagogical awareness within the discipline. This change signals a fundamental transformation not only in the technological tools but in the field's core perspective on knowledge and learning.

In essence, the central research question has shifted from, "Does technology facilitate learning?" to, "How does technology transform learning and redefine inclusion?". This shift in perspective can be framed as an epistemological transformation of the field. Technology is no longer viewed as a mere support mechanism but as an integral agent that actively reshapes the very nature of learning. This transformation is driven not only by high-end, advanced technologies but also by the proliferation of low-cost, accessible, and multi-modal solutions (Mendes et al., 2025; Mukhtarkyzy et al., 2025). The current proliferation of advanced technologies like artificial intelligence, augmented reality, and social robots signifies a crucial pivot in special education—from a perspective focused merely on compensating for deficits to one centered on unlocking human potential. Thus, this technological evolution has become a direct reflection of the field's own intellectual and theoretical maturation.

Figure 4
Thematic Evoluation of Educational and Assistive Technologies in Special Education Research.



The thematic evolution diagram (Figure 4) illustrates the field's conceptual journey, revealing a clear progression from foundational, parallel themes to a consolidated, and subsequently, highly specialized and applied research landscape.

The Centrality and Shifting Role of "Special Education"

"Special Education" acts as the unwavering conceptual spine of the entire research domain, demonstrating high centrality in all three time periods. Its role, however, changes significantly. In the foundational period (1965-2010), it runs as a primary, but parallel, theme alongside other core concepts like "assistive technology," "learning," and "teaching." By the consolidation period (2011-2021), it evolves into the field's dominant gravitational hub, absorbing and integrating nearly all other foundational themes, including "inclusion," "internet," "students," and "learning." In the current period (2022-2025), this massive hub "fractures" into numerous applied specializations, feeding into emergent topics like "self-efficacy," "higher education," and "music," while also retaining a smaller, self-perpetuating "special education" theme.

The analysis shows distinct shifts in how the position of special education within the research field has evolved and has become an interdisciplinary centre of gravity. While special education was initially a field progressing in parallel with foundational concepts such as "teaching," "learning," and "assistive technology," since the 2010s, it has acquired a structure that incorporates these themes and has become the center of inclusivity, digitalization, and pedagogical transformation processes (Saini et al., 2025; Sinha et al., 2024). During this period, special education has become a fundamental reference point for both educational technologies and teacher training programs (Filiz & Albay, 2025; Park et al., 2024). Today, the field of special education, expanding with themes such as "self-efficacy," "higher education," and "music," is generating new sub-specialization areas that include not only pedagogical but also cultural and creative dimensions (Buli-Holmberg & Jeyaprathaban, 2016; Yang et al., 2025). This trend indicates that special education has now transcended its own boundaries to become an innovative, inclusive, and sustainable knowledge production ecosystem integrated with diverse disciplines.

The Evolution of Technology as an Integrated Environment

The diagram vividly maps the maturation of technology within the field. It begins in the 1965-2010 period with two distinct themes: "assistive technology" and "internet." By 2011-2021, these concepts merge and are re-conceptualized under the broader, more systemic theme of "educational technology," which becomes the second major hub. This signals a critical shift from viewing technology as a discrete tool (like AT) to viewing it as an integrated environment (EdTech). This "educational technology" hub then becomes the primary engine for specialization in the 2022-2025 period, branching directly into today's most prominent research fronts: "adaptive learning technologies," "accessibility," and "e-learning."

These findings are consistent with the technological transformation emphasized in the related literature. Florian (2004), for instance, noted that the proliferation of technology in special education has been systematically supported through legislation, policies, and investments. Since the 2000s, this support has accelerated the integration of educational technologies with special education, making it one of the field's fundamental dynamics (López-Belmonte et al., 2021; Rodriguez Jiménez et al., 2019). Furthermore, İnci and Köse (2024) emphasize that while tools like computers were prominent in the early periods, current research highlights advanced technologies such as augmented reality and machine learning. Moreover, the COVID-19 pandemic has had a decisive impact on the prominence of the "e-learning" concept in recent years, with research focus increasingly shifting toward this area. This situation demonstrates that technology has evolved from being merely a tool that facilitates instruction to becoming an inclusive and sustainable learning environment that shapes the nature of learning, interaction modalities, and accessibility. This dramatic shifting role—where a consolidated 'educational technology' hub suddenly fractured into highly specialized applications post-2022—reflects systemic and socio-political catalysts. The confluence of mobile ubiquity, cloud computing infrastructure, and accelerated digital transformations during global disruptions forced the field to abandon generalized models. Research swiftly decentralized to address immediate, hyper-localized operational crises, driving the sudden fragmentation into independent fronts like digital accessibility policies, e-learning resilience, and targeted autism interventions.

The Specialization of Research

This flow from general concepts to applied specializations is the diagram's most compelling story. The initial period (1965-2010) is defined by broad themes. The middle period (2011-2021) not only consolidates these but also introduces a new, critical focus on the human element: "special education teacher preparation," "special education teachers," and "attitudes." The current period (2022-2025) is defined by this specialization. Research has clearly pivoted to address specific, high-need areas, with "autism spectrum disorders" and "accessibility" emerging as dominant new fields of inquiry, fed directly by the consolidated themes of "educational technology" and "special education." This indicates a mature field that is now channeling its foundational knowledge to solve specific, complex, and practical challenges.

These findings reveal an increasing thematic specialization in special education research as the field matures. Saini et al. (2025) show that, over the past two decades, studies on intellectual disabilities and inclusive education have been conducted with greater interdisciplinary collaboration, and the research focus has gradually shifted toward specific subfields such as inclusive education practices and specialized instructional approaches. Similarly, Mukhtarkyzy et al. (2025) and Heredia-Solórzano & Villafuerte-Holguín (2025) report that research is now concentrated in distinct areas of need such as autism, accessibility, and mobile learning, with technological tools serving as catalysts that facilitate this specialization. In addition, Yang et al. (2025) indicate that artificial intelligence, augmented reality, and social robots have transformed applied research themes in special education, while Zhou et al. (2025) note that studies in employment contexts increasingly focus on real-life skills such as social participation and independence.

This trend suggests that the field is evolving from abstract theoretical discussions toward an applied research structure that responds to individual needs and addresses complex practical problems. This shift also marks a critical turning point for the sustainability of special education. The emerging research trajectory—characterized by technology-supported, individualized, and real-life-oriented approaches—offers resilient solutions not only to current needs but also to future challenges related to learning, accessibility, and participation. Sustainable special education requires continuously adaptable systems, accessible digital ecosystems, and interventions that support long-term independent living skills. In this sense, the field's move toward applied, technology-enhanced, and individualized research demonstrates that innovative tools provide a sustainable framework for developing lasting, scalable, and inclusive educational models. Consequently, these emerging research trends strengthen not only the academic knowledge base but also the infrastructure of a more sustainable special education system that enhances lifelong learning, social participation, and employment opportunities for individuals with special needs.

3.3. Research patterns

By synthesizing the findings of t-SNE (Figure 5), text mining (Figure 6) and SNA analysis (Figure 7), thematic research patterns were identified. Accordingly, the following themes were identified by triangulating the findings of three analysis strands:

Figure 5

t-SNE Analysis of the Titles on Educational and Assistive Technologies in Special Education Research

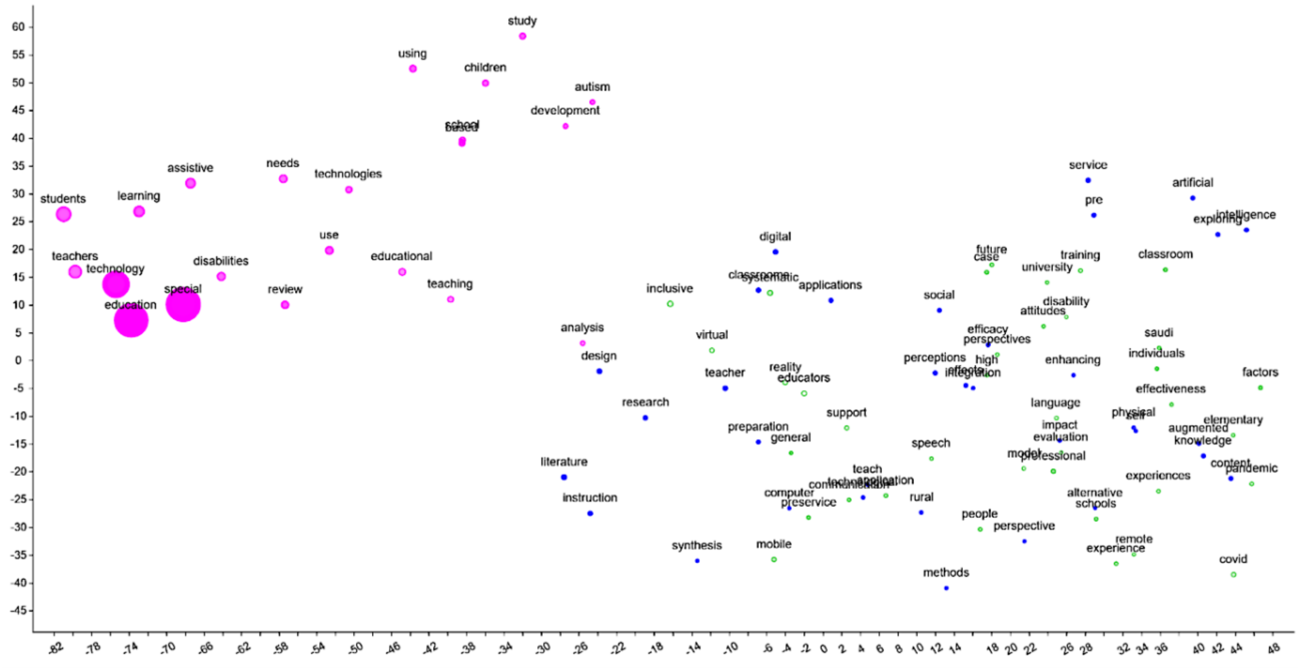


Figure 6

Text Mining of the Abstracts on Educational and Assistive Technologies in Special Education Research

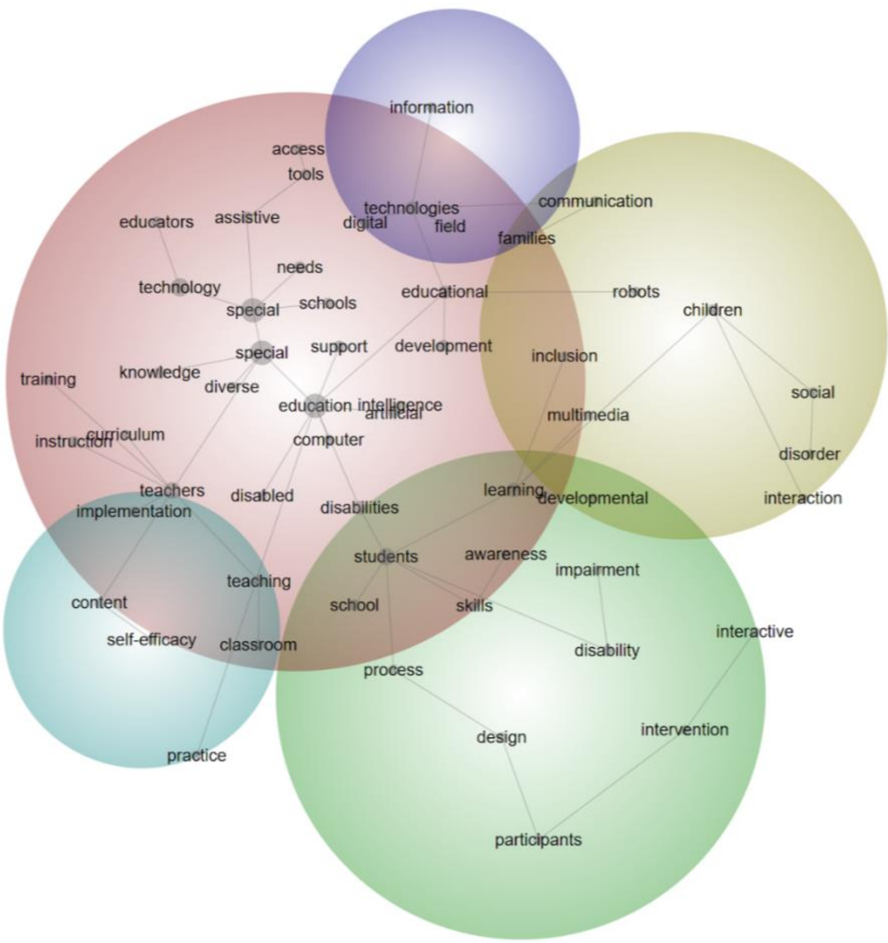
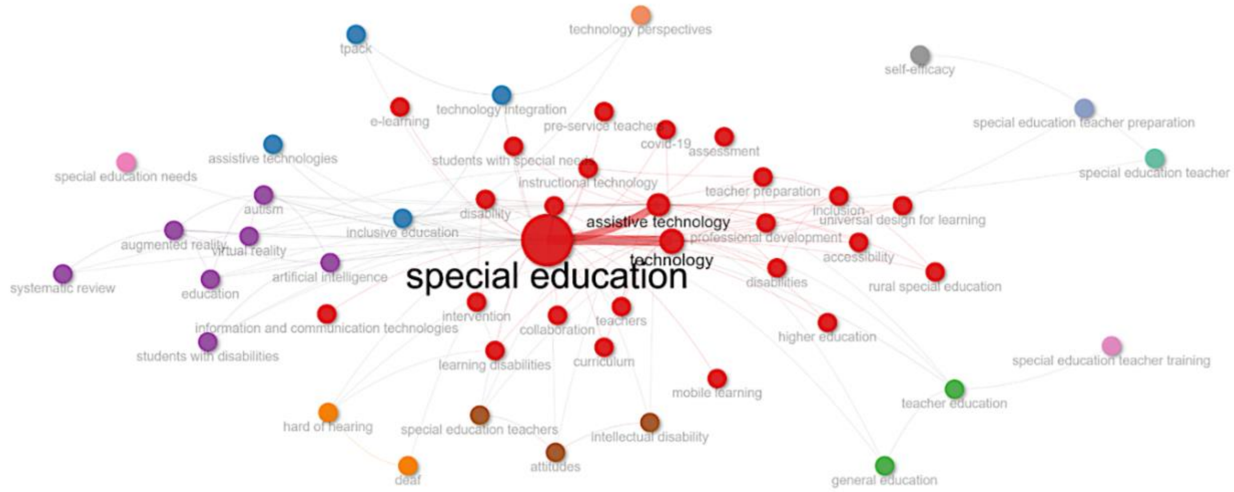


Figure 7

SNA of the Keywords on Educational and Assistive Technologies in Special Education Research



Theme 1: The Core Nexus of Assistive Technology and Special Education

See key nodes in Figure 5: special, education, technology, assistive, technologies, students, disabilities, needs, learning; See connected paths in Figure 6: special, education, support, disabilities, students, technology, assistive, needs, computer; See the strategic nodes in Figure 7: special education, assistive technology, technology, disability, disabilities, students with special needs.

This theme represents the foundational, gravitational center of the entire research corpus. The analysis shows that "special education" and "assistive technology" are the dominant, inseparable hubs. This core inquiry of the field focuses on how technology is identified, adapted, and used to support students with diverse learning needs and disabilities.

In special education, technology has evolved from a mere support tool into a fundamental component that shapes the very nature of education, from instructional methods to the design of learning environments. Developments in literature demonstrate that assistive technologies have integrated with special education to form an inseparable structure. A wide body of research confirms that these technologies play a critical role in increasing the levels of educational access, participation, and independence for individuals with special needs (Abdelwahab et al., 2025). This represents a significant shift from early-period studies, which were primarily concentrated on computer-assisted instruction tools and hardware-based solutions (Alper & Raharinirina, 2006; Woodward & Rieth, 1997). However, as Mendes et al. (2025) note, in subsequent years assistive technology has been reconceptualized as a multidimensional learning ecosystem, encompassing software, mobile applications, and digital systems. Similarly, the rise of next-generation technologies, such as augmented reality and mobile applications, signifies the field's pivot away from individual support tools and toward system-level solutions that empower participation (Mukhtarkyzy et al., 2025). Consequently, technology has transcended its role as a simple tool to support the learning process; it now redefines the holistic structure of education, establishing an increasingly strong equilibrium between pedagogical innovation and technological advancement.

Theme 2: The Educator's Role in Technology Implementation

See key nodes in Figure 5: teachers, pre (pre-service), service, professional, attitudes, efficacy; See connected paths in Figure 6: teachers, educators, training, knowledge, implementation, curriculum, practice, self-efficacy, content; See the strategic nodes in Figure 7: teachers, professional development, teacher preparation, pre-service teacher, special education teacher, attitudes, self-efficacy, tpack.

This theme highlights that technology is not implemented in a vacuum. The research corpus places significant emphasis on the human element: the teacher. This includes pre-service training, ongoing professional development, teacher attitudes toward technology, and the development of pedagogical content knowledge (TPACK) and self-efficacy required for successful classroom implementation.

The effective implementation of technology in special education environments is directly correlated with teachers' knowledge, pedagogical competencies, and attitudes toward technology. In this context, the TPACK (Technological Pedagogical Content Knowledge) model provides a foundational theoretical framework for assessing teacher competencies in technology integration (Mishra & Bozkurt, 2026). The literature indicates that the most significant variables explaining technology adoption by special education teachers are the TPACK components and self-efficacy beliefs (Chai et al., 2010; Pamuk et al., 2015). However, it is emphasized that increases in technological, pedagogical, and content knowledge do not automatically guarantee TPACK development. Rather, TPACK is identified as an independent and holistic construct that emerges from the integration of these knowledge domains within a specific teaching context, not their mere summation (Kaplon-Schilis & Lyublinskaya, 2020). This finding illustrates that technology integration is shaped not only by technical skills but also by teachers' pedagogical reasoning, reflective thinking, and their capacity to design inclusively-oriented learning environments. Despite this, it is also reported that teachers do not always use assistive technologies at the expected level of efficacy. Insufficient training, a lack of in-class guidance, and hardware or financial constraints are cited as primary factors limiting the potential of these technologies (Fernández-Batanero et al., 2022).

Rather than treating tools as isolated add-ons, modern special education settings require an agile, contextual understanding to dynamically blend technological pedagogical content knowledge and mitigate equity divides. In this light, technology implementation must transcend simple accessibility; it must be intentionally leveraged to optimize affective proximity and minimize transactional distance between the educator and the student, thereby systematically cultivating learner agency within complex, post-digital environments. These findings mandate that for effective technology integration in special education; teacher education must move beyond a focus on mere tool usage. Despite these challenges, the research clearly shows that the integration of technology in special education requires more than mere tool provision. For effective implementation, teacher education must move beyond a focus on mere tool usage and embrace holistic TPACK development within inclusive pedagogical frameworks

Theme 3: Inclusive Pedagogy, Accessibility, and Universal Design

See key nodes in Figure 5: inclusive, design, classroom, applications; See connected paths in Figure 6: inclusion, access, tools, digital, technologies, design, curriculum, field; See the strategic nodes in Figure 7: inclusion, inclusive education, accessibility, universal design for learning, curriculum.

This theme focuses on the pedagogical frameworks that guide technology use. The research connects technology integration not just to individual student needs (accommodation) but to the broader systemic goal of creating inherently inclusive classrooms. The prominence of "accessibility" and "universal design for learning" (UDL) indicates a significant research focus on proactive, inclusive design rather than retroactive fixes.

In recent years, special education research has begun to conceptualize technology not merely as a tool to compensate for individual differences, but as a systemic element that guides the design of inclusive learning environments. In this transformation, the principles of Universal Design for Learning (UDL) have taken a central position, aiming to integrate the accessibility, flexibility, and participation dimensions of the learning process through technology. Filiz and Albay (2025) noted that inclusive STEM research in special education has enhanced accessibility, particularly with an emphasis on UDL-based curricula and teacher training; however, they also highlighted that this research is concentrated in specific geographical regions and remains methodologically limited. Similarly, Sánchez et al. (2023) reported that while UDL principles have become more prevalent in digital and distance education contexts, the majority of research is limited to visual and hearing impairments and lacks sufficient applied evidence. These findings demonstrate that despite the recognition of technology's potential, its interdisciplinary and inclusive integration has not yet been achieved in practice. This gap emphasizes the need to explicitly tie localized UDL instructional frameworks directly to broader digital accessibility policies and international human rights conventions, ensuring that inclusive curriculum design transforms from a theoretical goal into an enforceable, proactive educational standard.

Furthermore, Heredia-Solórzano and Villafuerte-Holguín (2025) revealed that although assistive technologies have become part of inclusive education policies, inadequacies in teacher training and institutional resources impede the effective implementation of these policies. This situation stands in contrast to UNESCO's (2020) call for "inclusive education for all" and the CRPD's (2006) definition of technological access as a fundamental right. Therefore, for technology to become an effective tool in inclusive pedagogy, it is necessary not only to have legal frameworks in place but also to disseminate applied pedagogical models that strengthen teachers' skills in designing accessible learning environments. This recognition of systemic barriers highlights a critical imperative: emerging research trends must bridge the gap between policy and practice. These trends—characterized by technology-supported, individualized, and real-life-oriented approaches—not only strengthen the academic knowledge base but also establish infrastructure for a more sustainable special education system.

Theme 4: Technology for Autism Spectrum Disorder and Social Communication

See key nodes in Figure 5: autism, development, children, social; See connected paths in Figure 6: autism, disorder, social, interaction, communication, children, robots, multimedia; See the strategic nodes in Figure 7: autism, autism spectrum disorder.

This theme represents one of the largest and most specific application areas within the corpus. The data shows a strong convergence of various technologies (including robotics, multimedia, and as seen in Theme 6, VR/AR) with the specific needs of children with autism. The research focus is heavily oriented toward using technology to develop and support social, interactive, and communication skills.

Autism spectrum disorder (ASD) represents one of the areas in special education where technology finds its most intensive application (Elumar-Efe et al., 2026). The literature indicates that technological solutions carry significant potential for supporting the social interaction, communication, and emotional awareness skills of individuals with ASD (Grynszpan et al., 2014). Systematic analyses in recent years have revealed that robotic-assisted instruction, in particular, facilitates the development of social prerequisite skills in children, such as making eye contact, turn-taking, and joint attention (Kouroupa et al., 2022). However, a significant portion of existing research is conducted outside of natural teaching environments, and the generalizability of acquired skills to real-world social settings often remains limited (Lorenzo & Lorenzo-Lledó, 2024). This dynamic requires a distinct shift in focus from rigid, highly structured laboratory-based robotic interventions toward naturalistic, classroom-embedded assistive platforms. Transitioning to natural settings allows researchers to observe organic peer interactions and gauge the long-term ecological validity of tech-supported social skill developmental trajectories. This highlights the need for technology to be systematically planned not only for the instructional process but also for the generalization phase of social skills.

Theme 5: Supporting Sensory Impairments

See key nodes in Figure 5: learning, skills; See connected paths in Figure 6: impairment, communication, skills, learning, developmental; See the strategic nodes in Figure 7: deaf, hard of hearing.

This theme, clearly identified in the keyword analysis and supported by the abstract paths, shows a distinct focus on sensory disabilities. This body of research investigates the use of technology to support learning, skill development (particularly literacy and language), and communication for students who are deaf or hard of hearing, representing another major disability-specific application.

The use of assistive technologies for sensory impairments is central to special education research, situated at the intersection of accessibility and pedagogical inclusivity. The literature shows that technologies developed for visual and hearing impairments (e.g., screen readers, haptic maps, sign language recognition systems) expand learning opportunities; however, these applications are often limited to specific disability groups (Sánchez et al., 2023; Soeprapto Putri et al., 2025). This situation highlights the need for technology in special education to be addressed with a more holistic and interdisciplinary approach. Filiz and Albay (2025) stated that despite the growing adoption of inclusive learning and Universal Design for Learning (UDL) principles in STEM-based special education research, pedagogical practices have not achieved sufficient depth, and systemic barriers persist. When these findings are evaluated collectively, it can be asserted that the use of technology in the field of sensory impairments is no longer merely about providing access; rather, it represents the beginning of a transformation that centers inclusivity within instructional design.

Theme 6: The New Frontier: AI, VR/AR, and E-Learning

See key nodes in Figure 5: artificial, intelligence, virtual, reality, digital, pandemic, covid; See connected paths in Figure 6: artificial intelligence, robots, digital, technologies, multimedia; See the strategic nodes in Figure 7: artificial intelligence, augmented reality, virtual reality, e-learning, covid-19.

This theme captures the field's cutting edge. While foundational assistive technologies remain central, a distinct and rapidly growing body of research is exploring novel applications of immersive (VR/AR) and intelligent (AI) technologies. This new wave of research, accelerated by the challenges of "e-learning" and the "covid-19" pandemic, is focused on creating adaptive, personalized, and simulated learning experiences.

The literature demonstrates that technological development in special education has moved beyond assistive tools to create a new paradigm through intelligent, interactive, and adaptive systems. Specifically, artificial intelligence (AI), virtual and augmented reality (VR/AR), and e-learning applications are playing a transformative role in personalizing learning experiences and enhancing accessibility. The bibliometric analysis by Yang et al. (2025) reveals that AI applications in special education are rapidly diversifying—gaining prominence particularly in areas such as autism, cognitive rehabilitation, and attention tracking—and this process brings ethical responsibilities and teacher training requirements to the forefront. Mukhtarkyzy et al. (2025), meanwhile, reported that augmented reality and mobile learning solutions have positive effects on the participation, motivation, and learning outcomes of individuals with special needs, but noted that data regarding long-term impacts and pedagogical sustainability remain limited. E-learning environments, which became widespread with the onset of the COVID-19 pandemic, have shifted technology from being just a tool to becoming a fundamental component of flexible, inclusive, and personalized learning ecosystems. This transition toward intelligent software systems also accelerates the production of open educational resources (OER) and scalable micro-credentials, making complex learning materials infinitely customizable for diverse cognitive profiles. Immersive simulations offer predictable, low-anxiety spaces for communication training, while generative and agentic AI models autonomously synthesize personalized pathways, transforming tools from simple support mechanisms into proactive agents of human potential. While immersive simulations offer predictable, low-anxiety spaces for communication training, and generative or agentic AI models autonomously synthesize personalized pathways, this frontier introduces new complexities. The rapid deployment of large-scale AI models creates a critical tension between hyper-personalization and environmental sustainability. A truly sustainable special education ecosystem must critically weigh the high computational footprint and ecological costs of agentic systems against their instructional efficacy, ensuring ethical deployment is balanced with environmental responsibility. These developments show that technology in special education is no longer merely a pedagogical innovation but has initiated a human-centered and ethically-grounded transformation process.

4. Conclusion, Suggestions and Future Implications

This study bridged a critical methodological gap in literature by integrating a 60-year bibliometric analysis with a multi-method thematic synthesis. Our longitudinal exploration reveals a field that has undergone a profound maturation. The thematic evolution (Figure 4) shows a clear three-stage journey: a Foundational Period (1965–2010) of parallel, core concepts like "assistive technology" and "special education"; a Consolidation Period (2011–2021) where "special education" and "educational technology" became dominant hubs, absorbing other themes and introducing a new focus on the "human element" of teacher preparation; and a Specialization Period (2022–Present), where these consolidated hubs "fractured" into the highly-applied, high-need topics that define the modern landscape, such as "adaptive learning technologies," "accessibility," and "autism spectrum disorders".

This journey is confirmed by our six triangulated themes (see Table 2). The research field has solidified around a core nexus (Theme 1), while recognizing that the educator is the lynchpin (Theme 2) and that inclusive pedagogy via UDL is the goal (Theme 3). This mature foundation is now being channeled into major application areas like autism (Theme 4) and sensory impairments (Theme 5). Finally, the entire field is being propelled into a new era by a technological frontier of AI, VR, and e-learning (Theme 6), a trend bibliometrically confirmed by the rapid acceleration in publications post-2010 (Figure 1). In parallel, our findings expose a significant geographical imbalance, with the USA's dominance (35%) suggesting that much of this progress is not yet a global phenomenon.

Table 2

Triangulation Matrix of Synthesized Research Themes

Theme	Core Analytical Strands (t-SNE / Text Mining / SNA)	Primary Pedagogical/Theoretical Focus	Key Future Research Frontier
Theme 1: The Core AT-Special Education Nexus	special, education, technology, assistive, disabilities, students with special needs	Shift from pathologizing deficit-compensation tools to holistic, individual learning ecosystems.	Development of low-cost, multi-modal, and customizable open-source digital toolkits.
Theme 2: The Educator's Role in Implementation	teachers, pre-service, professional development, attitudes, self-efficacy, TPACK	Integrating technical skill with pedagogical reasoning to minimize transactional distance.	Cultivating contextual self-efficacy and affective proximity in post-digital environments.
Theme 3: Inclusive Pedagogy & Universal Design	inclusive, inclusion, accessibility, universal design for learning, curriculum	Transitioning from retroactive accommodation fixes to proactive, universal environmental design.	Aligning localized UDL curriculum frameworks with international human rights standards.
Theme 4: Autism & Social Communication	autism, development, children, social, interaction, communication, robots, multimedia	Utilizing interactive and robotic platforms to facilitate prerequisite social behaviors.	Transitioning from highly structured laboratory environments to naturalistic, classroom-embedded platforms.
Theme 5: Supporting Sensory Impairments	learning, skills, impairment, communication, deaf, hard of hearing	Enhancing linguistic, literacy, and multi-modal sensory access within instructional spaces.	Interdisciplinary development of haptic and sign-recognition digital ecosystems.
Theme 6: The New Frontier (AI, VR, E-Learning)	artificial intelligence, virtual reality, augmented reality, digital, e-learning, pandemic	Moving from passive assistance to proactive, agentic, and generative human potential optimization.	Developing ethical, privacy-preserving, and environmentally-sustainable frameworks for agentic AI.

The findings carry significant implications for practice, policy, and research.

- For Practice & Teacher Education: The prominence of Theme 2 (The Educator's Role) provides a clear mandate: simply providing technology is insufficient. The research corpus shows that "teacher preparation," "attitudes," and "self-efficacy" are central concerns. This implies that educational institutions must move beyond one-off training workshops and embed technology, pedagogy, and content knowledge (TPACK) into the core of pre-service and in-service training. This training should be pedagogically grounded in the principles of UDL and accessibility (Theme 3), training educators to be designers of inclusive environments, not just consumers of tools.
- For Policy & Global Equity: The stark geographical imbalance revealed in the bibliometric analysis (Figure 2) is a major policy implication. With 35% of contributions from the USA, there is a significant risk of geographical bias, where solutions and technologies are culturally monolithic and may not serve diverse global populations. Policymakers must actively foster international collaboration and fund research in underrepresented regions to prevent a new "assistive technology divide" and ensure equitable access to innovation.
- For Research: The emergence of Theme 6 (The New Frontier) and the specialization in the thematic evolution map (Figure 4) signal a paradigm shift. Topics like "artificial intelligence," "virtual reality," and "adaptive learning technologies" are no longer niche; they are the new mainstream. This implies that researchers must develop new ethical and methodological frameworks to assess these complex, often "black-box" technologies, moving beyond simple efficacy studies to explore their long-term, systemic, and cognitive impacts.

The stark geographical imbalance revealed in the bibliometric analysis (Figure 2) is a major policy implication. To actively dismantle this geopolitical centralization, global funding bodies must prioritize decentralized, open-source digital toolkits designed specifically for low-resource environments. Establishing cross-cultural research syndicates ensures that next-generation intelligent platforms develop as a universally accessible ecosystem rather than an exclusive privilege, thereby safeguarding educational equity on a global scale. Based on the patterns and identified limitations, we propose several key directions for future research:

- Broaden the Cultural and Geographical Lens: The heavy dominance of US-based research is the study's most critical finding. Future research must intentionally prioritize cross-cultural, comparative, and non-Western-centric studies to understand how assistive technologies are adapted and implemented in diverse linguistic, economic, and policy contexts.
- Investigate the "New Frontier" Longitudinally: While Theme 6 shows a rapid rise in AI, VR, and AR, this research is still nascent. We call for longitudinal studies that track the long-term impacts of these immersive and intelligent technologies on student learning, social development, and teacher practice, with a strong focus on ethics, data privacy, and scalability.
- Address Underrepresented Disability Groups: Our thematic analysis identified strong, specific clusters around "autism" (Theme 4) and "sensory impairments" (Theme 5) . This implies other disability groups may be underserved. Future research should systematically investigate the application of modern technologies for populations that were less prominent in the corpus, such as individuals with intellectual disabilities or complex physical disabilities.

Declaration of Conflicts of Interest

The authors confirm that they have no conflicts of interest related to this publication.

Declaration of Generative AI Use

Based on Academic Integrity and Transparency in AI-assisted Research and Specification Framework, the authors of this paper acknowledges that the paper was proofread and reviewed with the assistance of DeepL and Anthropic's Claude (Versions as of May 2026), complementing the human editorial process. The human authors critically assessed and validated the content to maintain academic rigor. The authors also assessed and addressed potential biases inherent in the AI-generated content. The final version of the paper is the sole responsibility of the human authors.

Ethical Statement

Ethical review and approval were waived for this study because it is a systematic review based on the analysis of publicly available secondary data and does not involve human or animal subjects.

Availability of Data and Materials

Data will be made available from the corresponding author on reasonable request.

Author Contributions

E.E.E. contributed to validation, formal analysis, data curation, writing—original draft preparation, and writing—review and editing. A.S. was involved in validation, formal analysis, data curation, writing—original draft preparation, writing—

review and editing, and funding acquisition. S.S.B. contributed to methodology, validation, formal analysis, data curation, writing—original draft preparation, writing—review and editing, project administration, and funding acquisition. A.B. was responsible for conceptualization, methodology, software, validation, formal analysis, data curation, writing—original draft preparation, writing—review and editing, and visualization. All authors have read and agreed to the published version of the manuscript.

Funding

This study was conducted within the scope of the project entitled "Comparison of Robot-Delivered and Teacher-Delivered Scriptfading Instruction in Teaching Conversational Skills to children with Autism Spectrum Disorder: Mixed Method " supported by Anadolu University under Project No: 2304E022.

References

Abdelwahab, M. M., Al-Karawi, K. A., & Semary, H. E. (2025). A systematic review of assistive technology for enhancing the students with disabilities. *Journal of Disability Research, 4*, 1–12. https://doi.org/10.57197/JDR-2024-0117

Alper, S., & Raharinirina, S. (2006). Assistive technology for individuals with disabilities: A review and synthesis of the literature. *Journal of Special Education Technology, 21*(2), 47–64. https://doi.org/10.1177/016264340602100204

Bozkurt, A., Crompton, H., Farrow, R., Kukulska-Hulme, A., Dron, J., West, R., Palalas, A. (Aga)., Bower, M., Xiao, J., Tlili, A., Henriksen, D., Pazurek, A., Huijser, H., Chiu, T. K. F., Jandrić, P., Jordan, K., Curry, J., Kimmons, R., Cukurova, M., Reeves, T., Hwang, G.-J., Shea, P., Lodge, J., Weller, M., Ng, D., & Asino, T. I. (2026). Redefining Educational Technology: A Critical Collaborative Inquiry. *Open Praxis, 18*(2), 192–211. https://doi.org/10.55982/openpraxis.18.2.1117

Buli-Holmberg, J., & Jeyaprathaban, S. (2016). Effective practice in inclusive and special needs education. *International Journal of Special Education, 31*(1), 119–134. https://eric.ed.gov/?id=EJ1099986

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society, 13*(4), 63–73. http://www.jstor.org/stable/jeductechsoci.13.4.63

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Elumar-Efe, E., Sagdic, A., Yiğit, H., Canpolat-Çiğ, N., & Sani-Bozkurt, S. (2026). GenAI and robots in autism spectrum disorder: A new frontier in the age of human–AI interaction. In A. Bozkurt (Ed.), *Rethinking education and agency in the age of human–generative AI interaction* (pp. 1–26). IGI Global. https://doi.org/10.4018/979-8-3373-1195-1.ch012

Feldman, R., & Sanger, J. (2007). *The text mining handbook: Advanced approaches in analyzing unstructured data*. Cambridge University Press. https://doi.org/10.1017/CBO9780511546914

Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2022). Assistive technology for the inclusion of students with disabilities: A systematic review. *Educational Technology Research and Development, 70*(5), 1911–1930. https://doi.org/10.1007/s11423-022-10127-7

Filiz, A., & Albay, C. (2025). Global trends in STEM-based special education research: Bibliometric mapping of the literature. *British Journal of Special Education, 52*(3), 300–318. https://doi.org/10.1111/1467-8578.70056

Florian, L. (2004). Uses of technology that support pupils with special educational needs. *ICT and special educational needs: A tool for inclusion*, 7-20.

Gallud, J. A., Carreño, M., Tesoriero, R., Sandoval, A., Lozano, M. D., Durán, I., Penichet, V. M., & Cosio, R. (2023). Technology-enhanced and game-based learning for children with special needs: A systematic mapping study. *Universal Access in the Information Society, 22*(4), 227–240. https://doi.org/10.1007/s10209-021-00824-0

Gough, D., Oliver, S., & Thomas, J. (2012). *An introduction to systematic reviews*. Sage.

Grynszpan, O., Weiss, P. L., Perez-Diaz, F., & Gal, E. (2014). Innovative technology-based interventions for autism spectrum disorders: A meta-analysis. *Autism, 18*(4), 346–361. https://doi.org/10.1177/1362361313476767

Hansen, D., Shneiderman, B., & Smith, M. A. (2010). *Analyzing social media networks with NodeXL: Insights from a connected world*. Morgan Kaufmann.

Heredia-Solórzano, M., & Villafuerte-Holguin, J. (2025). Inclusive education and the use of assistive technologies: A systematic review. *Education Quarterly Reviews, 8*(2), 1–14. https://doi.org/10.31014/aior.1993.08.02.574

İnci, G., & Köse, H. (2024). The landscape of technology research in special education: A bibliometric analysis. *Journal of Special Education Technology, 39*(1), 94–107. https://doi.org/10.1177/01626434231180582

Kaplon-Schilis, A., & Lyublinskaya, I. (2020). Analysis of relationship between five domains of TPACK framework: TK, PK, CK Math, CK Science, and TPACK of pre-service special education teachers. *Technology, Knowledge and Learning, 25*(1), 25–43. https://doi.org/10.1007/s10758-019-09404-x

Kouroupa, A., Laws, K. R., Irvine, K., Mengoni, S. E., Baird, A., & Sharma, S. (2022). The use of social robots with children and young people on the autism spectrum: A systematic review and meta-analysis. *PLOS ONE, 17*(6), e0269800. https://doi.org/10.1371/journal.pone.0269800

Lin, C. Y., & Chang, Y. M. (2015). Interactive augmented reality using Scratch 2.0 to improve physical activities for children with developmental disabilities. *Research in Developmental Disabilities, 37*, 1–8. https://doi.org/10.1016/j.ridd.2014.10.016

López-Belmonte, J., Segura-Robles, A., Moreno-Guerrero, A.-J., & Parra-González, M.-E. (2021). Robotics in education: A scientific mapping of the literature in Web of Science. *Electronics, 10*(3), 291. https://doi.org/10.3390/electronics10030291

Lorenzo, G., & Lorenzo-Lledó, A. (2024). The use of artificial intelligence for detecting the duration of autistic students' emotions in social interaction with the NAO robot: A case study. *International Journal of Information Technology, 16*(2), 625–631. https://doi.org/10.1007/s41870-023-01682-0

McLuhan, M. (1964). *Understanding media: The extensions of man*. McGraw-Hill.

Mendes, F. H., Bucci, G. de F. F. B., Chagas, A. L. de B., Felix, J., & Soares, F. (2025). Assistive technologies for teaching programming to visually impaired learners: A systematic review. In *2025 IEEE 49th Annual Computers, Software,* *and Applications Conference (COMPSAC)* (pp. 2082–2087). IEEE. https://doi.org/10.1109/COMPSAC65507.2025.00291

Mishra, P., & Bozkurt, A. (2026). TPACK in the Age of Context and Artificial Intelligence: Punya Mishra on the "Wicked Problem" of AI and Why Algorithms Can't Replace Context. *Open Praxis, 18*(2), 398–407. https://doi.org/10.55982/openpraxis.18.2.1093

Mukhtarkyzy, K., Smagulova, L., Tokzhigitova, A., Serikbayeva, N., Sayakov, O., Turkmenbayev, A., & Assilbayeva, R. (2025). A systematic review of the utility of assistive technologies for SEND students in schools. *Frontiers in Education, 10*, 1523797. https://doi.org/10.3389/feduc.2025.1523797

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Pamuk, S., Ergun, M., Cakir, R., Yilmaz, H. B., & Ayas, C. (2015). Exploring relationships among TPACK components and development of the TPACK instrument. *Education and Information Technologies, 20*(2), 241–263. https://doi.org/10.1007/s10639-013-9278-4

Park, J., Gremp, M., & Ok, M. W. (2024). Effects of assistive technology instruction on pre-service teachers: A systematic review. *Journal of Special Education Technology, 39*(3), 349–362. https://doi.org/10.1177/01626434231210988

Pennington, R. C. (2010). Computer-assisted instruction for teaching academic skills to students with autism spectrum disorders: A review of literature. *Focus on Autism and Other Developmental Disabilities, 25*(4), 239–248. https://doi.org/10.1177/1088357610378291

Rahim, N., Mokmin, N. A. M., & Wang, J. (2025). Empowering students with dysgraphia: The educational benefits of assistive technologies. *Disability and Rehabilitation: Assistive Technology*. Advance online publication. https://doi.org/10.1080/17483107.2025.2493737

Rodríguez Jiménez, C., Sanz Prieto, M., & Alonso García, S. (2019). Technology and higher education: A bibliometric analysis. *Education Sciences, 9*(3), 169. https://doi.org/10.3390/educsci9030169

Sagdic, A., Elumar-Efe, E., & Sani-Bozkurt, S. (2024). GenAI, robots, and inclusive special education: Autism spectrum disorder in the age of generative AI. In *Transforming education with generative AI: Prompt engineering and synthetic content creation* (pp. 309–326). IGI Global. https://doi.org/10.4018/979-8-3693-1351-0.ch015

Saini, R., Nordin, Z. S., Hashim, M. H., & Abol, M. T. (2025). 20 years (2004–2024) exploring research trend in intellectual disabilities towards inclusion: A bibliometric study. *Journal of Education and Learning (EduLearn), 19*(3), 1279–1287. https://doi.org/10.11591/edulearn.v19i3.22691

Sánchez, J., Reyes-Rojas, J., & Alé-Silva, J. (2023). What is known about assistive technologies in distance and digital education for learners with disabilities? *Education Sciences, 13*(6), 623. https://doi.org/10.3390/educsci13060623

Sani-Bozkurt, S. S. (2017). Özel eğitimde dijital destek: Yardımcı teknolojiler. *Açıköğretim Uygulamaları ve Araştırmaları Dergisi, 3*(2), 37–60. https://dergipark.org.tr/en/download/article-file/403817

Sinha, D. B., Sinha, S., Anu, G. S., Islam, M. T., & Sahoo, D. (2024). Twenty-five years of research in the *Journal of Special Education Technology*: A bibliometric analysis. *Journal of Special Education Technology, 39*(2), 174–189. https://doi.org/10.1177/01626434231187095

Soeprapto Putri, N. K., Yuhana, U. L., Siahaan, D. O., Rahayu, W., & Pardede, E. (2025). Assistive technology classification for students with disabilities in higher education: A systematic literature review. *IEEE Access, 13*, 15193–15217. https://doi.org/10.1109/ACCESS.2025.3538322

Thurmond, V. A. (2001). The point of triangulation. *Journal of Nursing Scholarship, 33*(3), 253–258. https://doi.org/10.1111/j.1547-5069.2001.00253.x

UNESCO. (2020). *Global education monitoring report 2020: Inclusion and education – All means all*. UNESCO Publishing. https://unesdoc.unesco.org/ark:/48223/pf0000373718

United Nations. (2006). *Convention on the Rights of Persons with Disabilities (CRPD).* United Nations. https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf

van der Maaten, L., & Hinton, G. (2008). Visualizing data using t-SNE. *Journal of Machine Learning Research, 9*, 2579–2605. http://www.jmlr.org/papers/volume9/vandermaaten08a/vandermaaten08a.pdf

Woodward, J., & Rieth, H. (1997). A historical review of technology research in special education. *Review of Educational Research, 67*(4), 503–536. https://doi.org/10.3102/00346543067004503

Wu, W.-H., Wu, Y.-C. J., Chen, C.-Y., Kao, H.-Y., Lin, C.-H., & Huang, S.-H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59*(2), 817–827. https://doi.org/10.1016/j.compedu.2012.03.016

Yang, Y., Chen, L., He, W., Sun, D., & Salas-Pilco, S. Z. (2025). Artificial intelligence for enhancing special education for K–12: A decade of trends, themes, and global insights (2013–2023). *International Journal of Artificial Intelligence in Education, 35*(4), 1129–1177. https://doi.org/10.1007/s40593-024-00422-0

Zhou, K., Richard, C., & Kim, J. (2025). Employment-related assistive technologies for autistic individuals: A scoping review. *Journal of Vocational Rehabilitation, 62*(2), 191–206. https://doi.org/10.1177/105222342312742