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Mapping the Evolution of Multimedia-Based Learning Technologies for Children with Autism Spectrum Disorder

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Abstract. This study analyzed research trends and scholarly impacts related to the application of multimedia in learning for children with autism spectrum disorder (ASD) using a bibliometric approach in RStudio. A total of 57 Scopus-indexed articles published between 1995 and 2025 were analyzed using the Biblioshiny tool to identify publication patterns, influential authors, keyword dynamics, and thematic evolution. The results revealed three major developmental phases: an early phase centered on psychological perspectives and basic communication skills, a transitional phase characterized by computer-assisted learning and multimedia systems, and a recent phase emphasizing immersive technologies such as augmented reality and virtual reality. This progression reflected a paradigm shift from clinically oriented interventions toward evidence-based pedagogical innovation in inclusive education. Overall, multimedia-based learning has demonstrated strong potential to improve social-emotional, communication, and language skills among children with ASD through interactive and adaptive environments in diverse educational contexts. The study concluded that multimedia integration supports more personalized and participatory learning experiences and highlights the importance of future research on AI-driven and adaptive multimedia systems to address individual learning needs better.

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1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that affects a person's communication skills, social interactions, and adaptive behavior. Children with ASD generally exhibit difficulties understanding social expressions, maintaining attention, and managing changes in routine, requiring a different learning approach than typical children (Mostajo et al., 2023). This condition creates a clear cause-and-effect relationship between ASD characteristics and multimedia needs: difficulties in communication, attention, sensory processing, and routine adaptation increase the need for learning media that are visual, structured, interactive, and predictable. In the context of inclusive education, these needs require structured, consistent learning strategies supported by media that adapt to the child's individual learning style and sensory characteristics (Mostajo et al., 2023). Theoretically, technology- and multimedia-based approaches offer opportunities to create more interactive, visual, and adaptive learning environments tailored to the needs of children with ASD (Theodoropoulos et al., 2022).

Developments in educational technology over the past decade have shown a significant increase in the use of multimedia, virtual reality (VR), and mobile-based learning as intervention and learning tools for children with ASD. Numerous studies have shown that integrating audio, visual, and digital interaction elements can help children with ASD improve focus, conceptual understanding, and social skills (Mostajo et al., 2023; Ntalindwa et al., 2022; Silva et al., 2022; Theodoropoulos et al., 2022; Zheng & Zhang, 2021). In the broader global context, this development is closely related to the rise of inclusive digital pedagogy, assistive learning technologies, and, more recently, AI-supported adaptive learning systems, which aim to provide more personalized and responsive educational experiences for diverse learners.

Although numerous studies have highlighted the effectiveness of multimedia-based technologies, there remains a gap in understanding global trends and the systematic impact of multimedia applications in learning for children with ASD. Most existing studies focused on the development of single applications or interventions (Gulati & Handa, 2021; Santiputri et al., 2019), lacking a comprehensive thematic mapping and development of research in this field. Several related studies have also investigated emotion regulation apps, inclusive transition programs, and multimedia-based interventions for children with ASD, but these studies remain limited to specific contexts and outcomes (Ashburner et al., 2018; Fage et al., 2019; Mostajo et al., 2023).

Furthermore, previous research tends to emphasize clinical or therapeutic aspects, while pedagogical dimensions, such as the effectiveness of multimedia design in academic and social learning outcomes, are limited (Ashburner et al., 2018; Fage et al., 2019). This situation highlights the need for a comprehensive study that analyzes the direction of multimedia research development in the context of learning for children with ASD and its impact on cognitive, social, and emotional

dimensions. This study is different because it does not examine a single intervention but systematically maps publication trends, thematic evolution, and scholarly impact in this research area through a bibliometric approach. In this sense, the study is positioned within the global research landscape as an effort to connect ASD-oriented multimedia research with wider developments in digital inclusion, adaptive learning, and emerging intelligent educational technologies.

Based on this, this study aimed to analyze the trends and impact of multimedia application use in learning for children with ASD through a bibliometric approach to recent scientific publications. This analysis included identifying dominant topics, researcher collaborations, keyword maps, and emerging research themes over the past two decades. Using Biblioshiny and VOSviewer, this study not only mapped the existing research landscape but also revealed development directions and research gaps that require further study.

The novelty of this study lies in its approach, which combines bibliometric trend analysis and conceptual synthesis to explain how multimedia technology has evolved and contributed to the education of children with ASD globally. This research is expected to provide new insights into future research directions, principles of effective media design, and strategic recommendations for educational technology developers and inclusive learning practitioners in creating adaptive, meaningful, and sustainable learning experiences for children with ASD.

To address these gaps, this study is guided by two research questions:

- RQ1.** What are the publication trends and growth patterns of research on multimedia applications in learning for children with ASD?
- RQ2.** Who are the most influential authors, sources, and thematic structures that shape the development of this field?

2. Literature Review

2.1 Autism Spectrum Disorder

Autism spectrum disorder is a neurodevelopmental disorder that affects communication, social interaction, and behavior. Symptoms vary widely across individuals and include difficulties in language use, understanding social cues, repetitive behaviors, and dependence on routines. This spectrum of characteristics requires educators to understand each child's specific needs so that learning strategies can be adapted to their cognitive and social profiles (Kamid, 2025).

Neuropsychologically, ASD is linked to differences in brain development that influence perception, attention, emotional regulation, sensory responsiveness, and executive functions such as planning, organization, and cognitive flexibility, making structured, consistent, and predictable learning environments especially important (Matharaarachchi et al., 2023). At the same time, from a social-emotional perspective, children with ASD often experience difficulties in interpreting facial expressions, maintaining eye contact, and understanding emotional nuances, which may hinder peer relationships, classroom participation, and self-confidence. However, they may also demonstrate distinctive strengths,

including strong visual memory, attention to detail, and systematic thinking abilities (Mostajo et al., 2023).

2.2 Multimedia

In general, multimedia refers to the integration of various media forms, including text, images, audio, video, and animation, to deliver information in a more engaging, meaningful, and interactive way (Munir, 2010; Munir et al., 2016; Munir, Setiawan et al., 2018; Munir, Sutarno, & Aisyah, 2018; Yandi et al., 2023). As an integrated digital system, multimedia combines visual and auditory elements within a single platform that enables active user interaction, thereby enriching learning experiences through multisensory stimulation (Furht, 2002).

From a learning perspective, multimedia supports understanding through the combination of verbal and visual representations, in line with multimedia learning theory, which explains that humans process information through auditory and visual channels, making dual-channel presentation more effective for comprehension and retention (Fletcher & Tobias, 2005; Mayer, 2002). Furthermore, multimedia may take the form of linear multimedia, where users remain passive, or non-linear multimedia, where users interact actively with the content. In educational settings, the non-linear form is considered more effective because it allows learners to control the pace and sequence of learning according to their individual needs (Pavithra et al., 2018). Overall, multimedia can be understood as an integrated approach that combines technology, cognitive design, and interactivity to create more effective and adaptive learning experiences.

Thus, a conceptual framework for this study can be described as a relationship between ASD characteristics and multimedia affordances. The communication, social, sensory, and cognitive characteristics of children with ASD create the need for structured, visual, interactive, and adaptive learning environments. Multimedia responds to these needs through the integration of images, audio, animation, repetition, and user-controlled interaction, which in turn can support attention, comprehension, communication, and social-emotional development (Fage et al., 2019; Matharaarachchi et al., 2023; Mostajo et al., 2023; Theodoropoulos et al., 2022).

3. Methodology

3.1 Research Design

Research trends describe the collective activity of researchers who are beginning to focus intensively on a specific scientific topic (Mazov et al., 2020). This study used a bibliometric analysis approach to identify research patterns and directions related to the application of multimedia in learning for children with ASD. Bibliometric analysis utilizes mathematical and statistical methods to quantitatively analyze the bibliographic characteristics of a body of literature (Passas, 2024). This design was appropriate because the research questions focused on publication trends, influential contributors, thematic structures, and the evolution of the field, all of which required systematic mapping of the literature rather than experimental measurement.

However, bibliometric analysis presented a macro snapshot of the research landscape rather than an in-depth examination of the content of individual studies. It focused on the number of publications, citation rates, and relationships between authors or themes, without evaluating the theoretical rigor, methodological quality, or pedagogical depth of the research reviewed. Thus, while this approach was effective in identifying key trends and thematic clusters, it potentially overlooked the deeper insights that emerge from qualitative research. As a complement, thematic analysis was applied to explore trends and the impact of multimedia implementation in learning for children with ASD.

3.2 Article Selection Process

The search protocol was determined by defining several categories: search keywords, article access method, publication period, publication type, and language used in the article. The Scopus database was chosen as the data source because it is a high-quality database of indexed international journals with broad interdisciplinary coverage and strong support for bibliometric analysis (Izhar et al., 2023). Although Web of Science is also a well-established database, Scopus was selected because of its broader interdisciplinary coverage and its suitability for bibliometric mapping in education, technology, and social science research. In addition, Scopus provides relatively consistent metadata and bibliometric features, including citation indicators and publication trend analysis, which were useful for this study (Ragazou et al., 2022).

However, we acknowledge the potential for selection bias resulting from the use of a single database, particularly in relation to local literature, non-English publications, and newly emerging open-access sources. Therefore, the findings of this study are limited to global trends represented by reputable journals indexed in Scopus. The 1995–2025 timeframe was selected because 1995 marked the earliest identified publication on interactive multimedia learning for children with ASD, while 2025 was the latest publication year available at the time of the search. This period enabled a longitudinal mapping of thematic evolution and research growth.

Figure 1 shows the article selection process used in this study to select publications relevant to the topics of “autism”, “multimedia”, and “education” from the Scopus database. The process began with the Search stage, where the initial search yielded 73 publications. Of these, several types of publication were excluded because they did not meet the criteria, namely book chapters (7), conference reviews (5), and reviews (1), leaving 60 publications in the form of articles (33) and conference papers (27). Furthermore, in the Screen stage, additional filtering was carried out by excluding publications that were still “in press” (2) and publications written in Spanish (1). The final stage, Synthesis, included only publications that had final publication status (58) and were in English (59), resulting in 57 final publications used in the analysis. The main characteristics of the selected publications are summarized in Table 1.

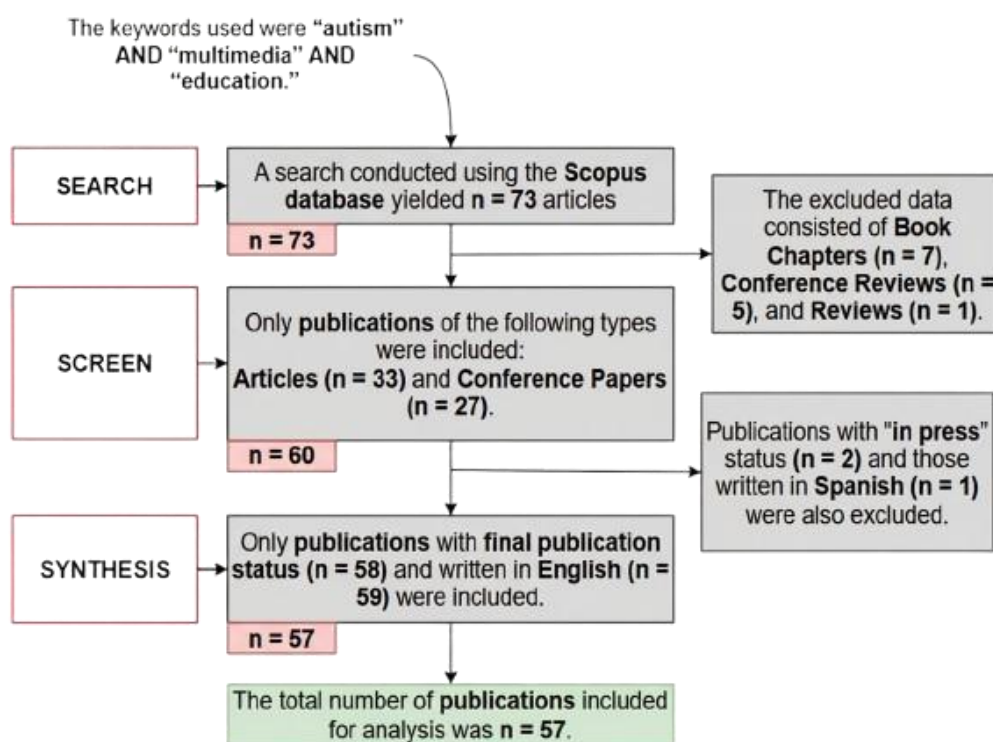


Figure 1: Article selection process

Table 1: Characteristics of selected publications

	Description	Results
Main information about the data	Timespan	1995:2025
	Sources (journals, books, etc.)	33
	Publications	57
	Annual growth rate %	2.34
	Publication average age	9.86
	Average citations per publication	29.02
	References	0
Publication contents	Keywords plus (ID)	433
	Author's keywords (DE)	195
Authors	Authors	194
	Author of single-authored publications	6
Authors collaboration	Single-authored publications	6
	Co-authors per publication	3.79
	International co-authorships %	19.3
Publication type	Article	31
	Conference paper	26

3.3 Data Processing and Analysis

Bibliometric search data were extracted in several formats, including Excel, Research Information Systems (RIS), comma-separated values (CSV), and

BibTeX (BIB). These formats contained essential information, such as article titles, publication years, author names and affiliations, keywords, abstracts, and citation counts. The BibTeX format was particularly useful for integrating data with reference management software such as Mendeley, Zotero, and EndNote while maintaining citation consistency across analytical platforms.

To ensure data validity and cleanliness, several procedures were applied. Duplicate publications were filtered based on DOI and author name-article title combinations. Publications with incomplete metadata, such as missing keywords or empty abstracts, were excluded. Keyword standardization was conducted semi-manually by merging similar terms, such as “ASD” into “autism”, to reduce distortion in co-occurrence mapping. In addition, article relevance was verified through title and abstract screening.

Data analysis and visualization were conducted using Biblioshiny in RStudio and VOSviewer. Biblioshiny was used to examine bibliometric indicators such as the h-index, publication frequency, keyword occurrence, and author collaboration, while VOSviewer was used to generate co-citation maps, keyword clusters, and thematic evolution visualizations. Together, these tools provided complementary perspectives, with Biblioshiny supporting descriptive and thematic analysis and VOSviewer strengthening spatial network mapping.

Several challenges were encountered during analysis, including inconsistent keyword usage, incomplete metadata in some documents, and the need to calibrate visualization thresholds carefully. These issues were addressed through iterative validation, cross-checking of results, and the application of established bibliometric procedures.

4. Results

Data analysis revealed four major developmental phases in multimedia research for children with ASD, which are presented in the following sections. The initial phase emphasized psychological perspectives and basic communication skills, the transitional phase marked the emergence of computer-assisted learning and multimedia systems, the consolidation phase reflected the expansion of interactive and adaptive educational technologies, and the recent phase focused on immersive, assistive, and increasingly intelligent learning environments. This phased structure was derived from the combined interpretation of publication trends, thematic evolution, influential sources, and media-ability mapping.

4.1 Annual Distribution: Production and Total Citations

Figure 2 displays the annual distribution of publications (blue line) and citable years (orange line). The initial pattern showed a surge in citations in the mid-1990s, coinciding with the publication of foundational works utilizing interactive multimedia for reading and communication in autistic children (Heiman et al., 1995). The subsequent surge in the early 2000s coincided with the emergence of structured multimedia programs for language and vocabulary (Bosseler & Massaro, 2003), along with other early articles on the effectiveness of

multimedia programs and media-based teacher-student interaction patterns (Marnik & Szela, 2008; Tjus et al., 2001; Wong, 2001).

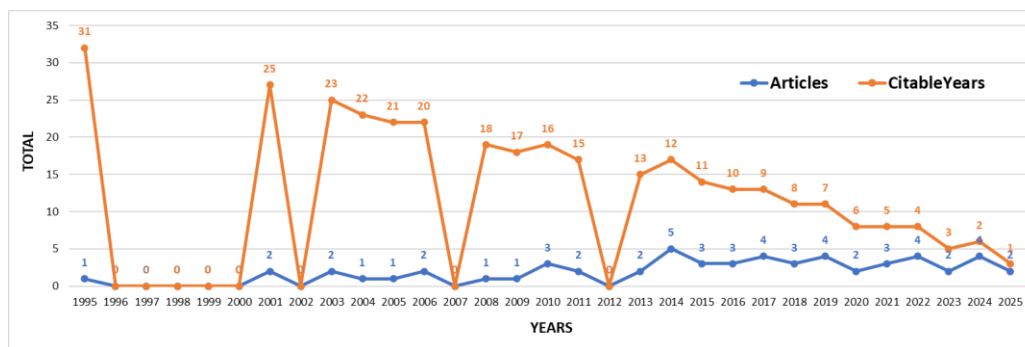


Figure 2: Annual distribution (publication and citation) per citable year

After the early 2000s, the citation curve tended to decline slowly but maintained a relative height until around 2011. Around 2013–2016, there was a citation rebound along with the increase in studies that integrated digital technology more broadly into educational practices (Da Silva et al., 2011; Kennedy et al., 2014), while the themes of game-based learning and distance learning also began to appear (Mohd et al., 2020; Mustika et al., 2014). Entering 2018–2021, citations gradually decreased as the themes fragmented and the focus shifted to more specific applications (Fage et al., 2019; Zamry et al., 2022).

During 2022–2025, the number of publications continued to increase, although citation counts declined. This pattern is common because recent publications usually require more time to accumulate citations. During this period, research topics also became more diverse, including digital storytelling for early mathematics (Kumaş, 2024), multimedia applications in special education (Derbissalova et al., 2024), qualitative story-based approaches in inclusive classrooms (Shields et al., 2025), and the development of assistive e-learning environments (Kamid, 2025). Overall, the curve shows a foundational phase (1990s–early 2000s), a consolidation and diversification phase (mid-2000s to 2010s), and then a phase of cutting-edge thematic innovations that include VR/AR, mobile-assistive technology, storytelling, and e-learning, with the consequence of a delay in citations for the most recent works.



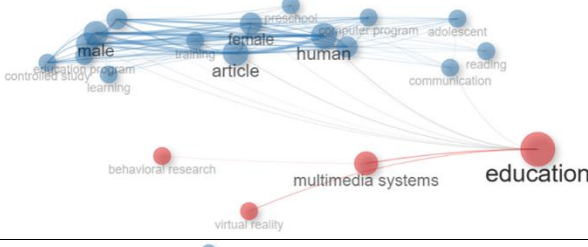
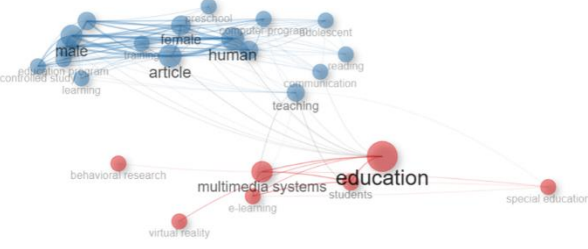
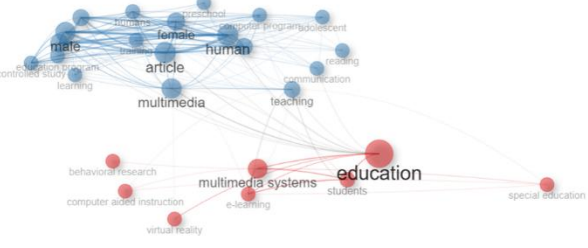
4.2 Trends and Thematic Evolution

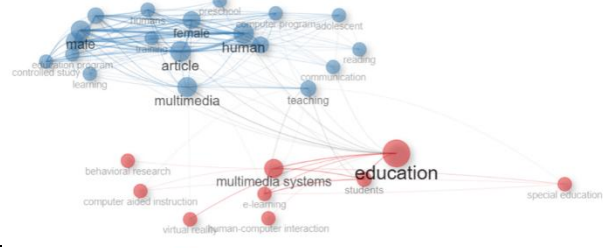
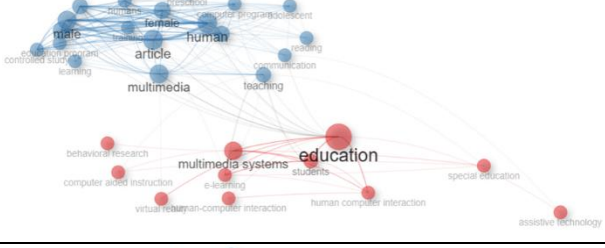
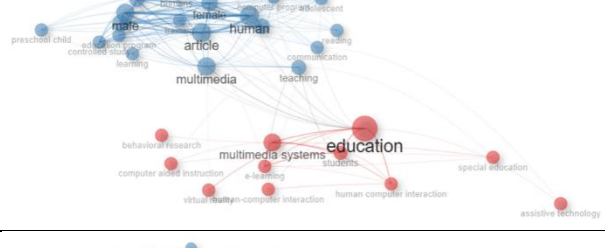
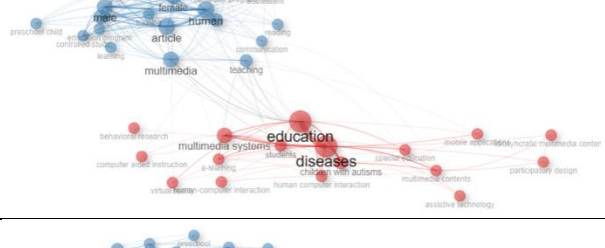
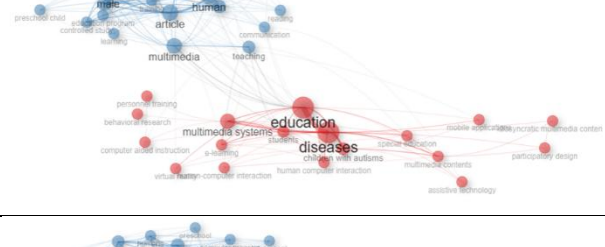
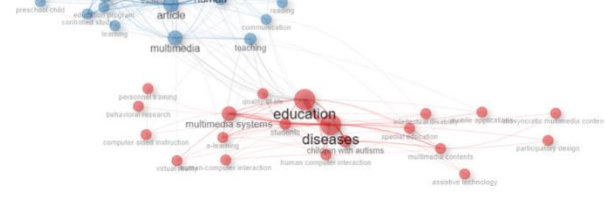
Figure 3 depicts a keyword-based network visualization showing the relationships between key concepts in scientific publications across the three decades of research. Two large clusters were clearly visible:

- (i) The blue group (Cluster 1) represents the human domain and research subject characteristics such as human, male, female, preschool child, and communication. This cluster was dominant in the early phase (1995–2005), when research focused more on studying the behavior and characteristics of autistic children, without a strong involvement of educational technology.
- (ii) The red group (Cluster 2) represents the technology and education domain, with keywords such as autism, education, multimedia systems, e-learning, human-computer interaction, and AR/VR. This cluster began to emerge

behavioral aspects in the early phase, and Cluster 2 (red), which depicts the transformation towards the technology and education domains, where the connection between autism and education nodes is strengthened along with the emergence of research based on interactive multimedia and VR (Kamid, 2025; Kumaş, 2024; Theodoropoulos et al., 2022).

Table 2: Visualization of the evolutionary network over the study period

Years	Network visualization	Evolution
1995–2000		The initial phase focused on the human/subject domain (human, male, female, child, communication, reading); the research was still descriptive-behavioral in nature without prominent educational technology.
2001–2003		The terms “education” and “multimedia” began to emerge – a transition from behavioral studies to the exploration of computer/multimedia programs to support early communication and literacy.
2004		“Education” was becoming a major node and was increasingly connected to “multimedia systems”, focusing on computer-assisted learning.
2005		Strengthening “teaching/students” – networks leading to pedagogical practice (implementation of media in the classroom, not just laboratory trials).
2006–2008		The emergence of “human-computer interaction” and “interactive computer systems” – a shift to interface design and usability for children with ASD.

Years	Network visualization	Evolution
2009–2010		Expansion into “e-learning” and “virtual learning” – the beginning of online-platform integration and multimedia content management.
2011–2014		Diversification of themes: “serious games/gamification”, “assistive technology” – multimedia was used for motivation, skill generalization, and accessibility support.
2015		The “virtual reality” (VR) node was starting to become clear – simulation of social situations and real-context exercises in an immersive environment.
2016		VR/AR enhancement and connection to education/teaching – focus on digital scenario-based emotional and social training.
2017		The network was getting denser in “multimedia systems–education–students”; games and mobile apps are starting to connect the social–language domains.
2018–2019		The consolidation of “augmented reality” with human–computer interaction; the emergence of measurement/analytics and parent/teacher involvement in design.

Years	Network visualization	Evolution
2020		Strengthening e-learning/LMS (distance learning adaptation) – connection to engagement/attention and adaptive content.
2021–2022		The term “autism” emerged as a central node linking education–multimedia–assistive; the focus of the theme was ToM/recognition of emotions.
2023–2024		The “child/children” node was becoming more prominent – age group specifications & inclusive school contexts, mobile–AR/VR–storytelling integration.
2025		Consistency of the term “ASD” as the center of the taxonomy; the network showed the integrative phase: AI-enhanced multimedia, personalization, and evidence-based school interventions.

Figure 4 displays a thematic map depicting the position and relationships between research themes based on two main axes: development degree (density) and relevance degree (centrality). The horizontal axis (relevance degree) indicates the level of connection or relevance of a theme to the overall research structure. The vertical axis (development degree) indicates the depth and maturity of the development of the topic (Nasir et al., 2020).

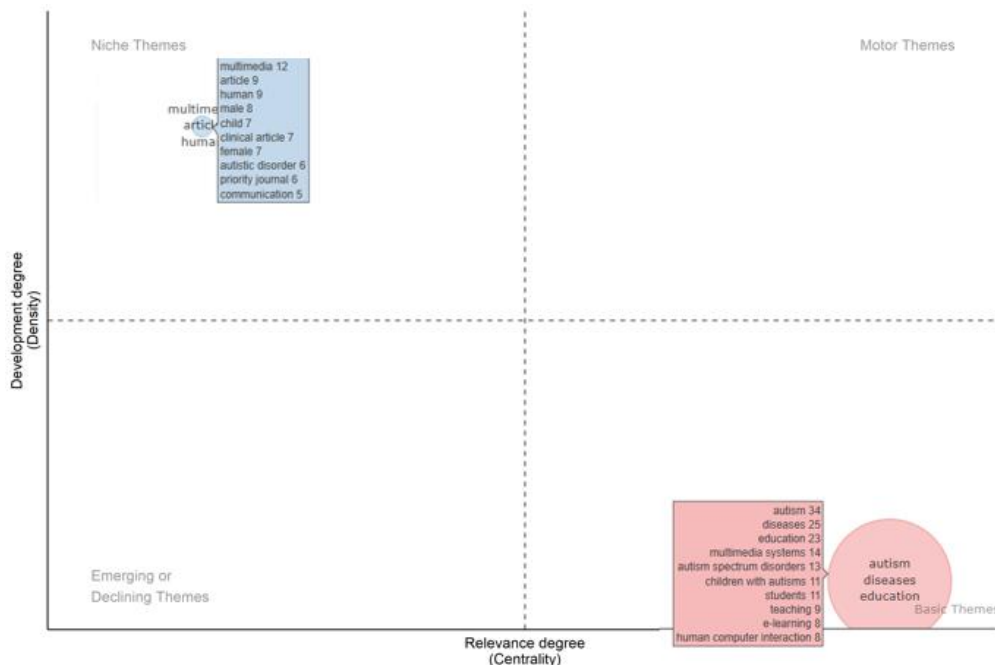


Figure 4: Thematic map of multimedia in learning for ASD research

Based on the data in Figure 4, research on multimedia in learning for children with ASD was divided into two major clusters, namely, *basic themes* and *niche themes*.

- (i) Basic themes (red cluster) were the main themes with high relevance and became the primary focus of the research. Based on the data in Table 3 (basic themes), this cluster included keywords such as *autism* (34 occurrences), *diseases* (25), *education* (23), *multimedia systems* (14), and *autism spectrum disorders* (13). These themes illustrated a research direction focusing on the relationship between autism, education, and the application of multimedia systems to support the learning of children with ASD. Topics such as *children with autism*, *students*, *teaching*, and *e-learning* indicate that multimedia was used not only as a therapeutic tool but also as a means of increasing teaching and learning effectiveness in inclusive education contexts. The presence of the keyword *human-computer interaction* (8 occurrences) shows that the design of interaction between users and systems was an important dimension in developing adaptive learning media appropriate to the characteristics of children with ASD.
- (ii) Niche themes (blue cluster) are specific themes that developed within particular research contexts but had not yet become the main focus of study. Based on the data in Table 4 (niche themes), this cluster consisted of keywords such as *multimedia* (12), *article* (9), *human* (9), *male* (8), *child* (7), and *communication* (5). These themes generally represented methodological approaches and research subject characteristics, such as gender, age, or the type of communication observed in multimedia intervention studies. These niche themes indicate that the research still placed the human dimension at the center of micro-level analysis to understand how multimedia influenced the social, communication, and cognitive abilities of children with ASD.

However, due to their low centrality values, these themes had not yet been strongly integrated into the main research structure, although they still played an important role in enriching an empirical understanding of multimedia use in populations with special needs.

Table 3: Basic themes on the use of multimedia in learning for children with ASD

No	Number of occurrences	Words	Cluster label
1	34	Autism	Autism diseases education
2	25	Diseases	Autism diseases education
3	23	Education	Autism diseases education
4	14	Multimedia system	Autism diseases education
5	13	Autism spectrum disorders	Autism diseases education
6	11	Children with autisms	Autism diseases education
7	11	Students	Autism diseases education
8	9	Teaching	Autism diseases education
9	8	E-learning	Autism diseases education
10	8	Human-computer interaction	Autism diseases education

Table 4: Niche themes on the use of multimedia in learning for children with ASD

No	Number of occurrences	Words	Cluster label
1	12	Multimedia	Multimedia article human
2	9	Article	Multimedia article human
3	9	Human	Multimedia article human
4	8	Male	Multimedia article human
5	7	Child	Multimedia article human
6	7	Clinical article	Multimedia article human
7	7	Female	Multimedia article human
8	6	Autistic disorder	Multimedia article human
9	6	Priority journal	Multimedia article human
10	5	communication	Multimedia article human

Overall, the data presented in Figure 4 and Tables 3 and 4 show that research on multimedia in learning for children with ASD developed in two complementary directions: (i) strengthening basic themes that emphasized the connection between autism, education, and multimedia systems as the main research framework; and (ii) exploring niche themes that examined human aspects and learning contexts to expand multimedia applications for the autistic population. This pattern confirmed that an interdisciplinary approach combining computer science, education, and developmental psychology was a key characteristic in the evolution of multimedia research for children with ASD.

Figure 5 displays the temporal evolution of key terms (term frequency over time), illustrating the development of research topics related to multimedia in learning for children with ASD over the past two decades. Each dot on the graph represents a term appearing in the literature within a specific timeframe, while the dot size indicates its frequency. The data demonstrate a clear shift from early descriptive themes to more applied and technology-based themes.

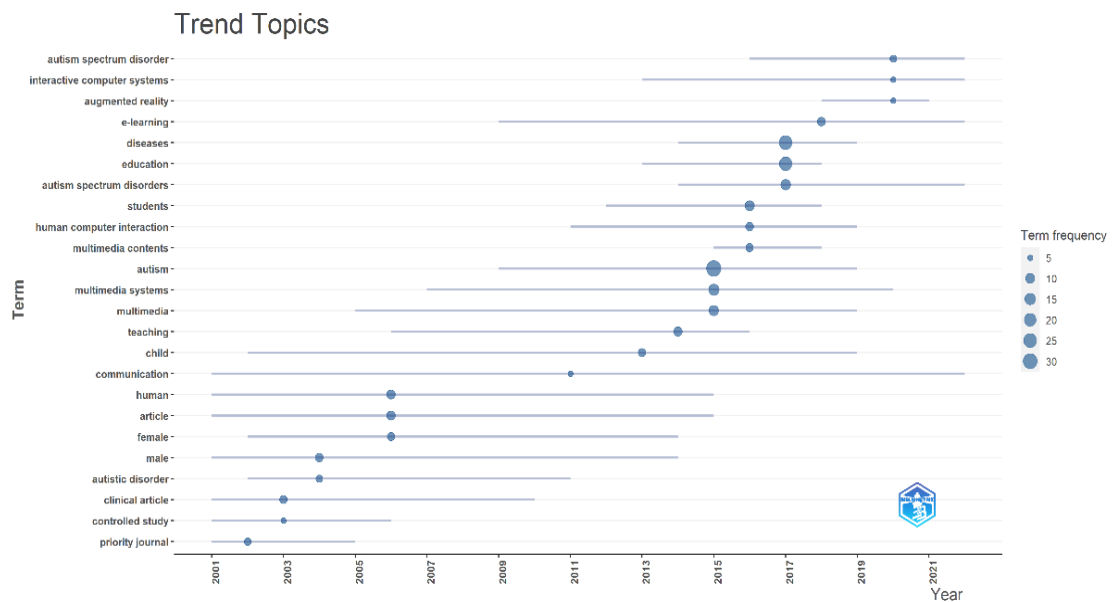


Figure 5: Term frequency over time

In the initial phase (2001–2006), research topics focused on human characteristics and clinical contexts, reflected in terms such as human, male, female, autistic disorder, communication, clinical article, and controlled study. This pattern indicates that research during this period emphasized behavioral observation and the documentation of traditional interventions before the widespread emergence of digital media. In the following period (2007–2014), terms such as multimedia systems, teaching, and education began to appear, indicating a shift toward the integration of computer-based learning technologies in the educational context of children with ASD. During this phase, the terms child and student also emerged, suggesting a transition from individual therapy to more inclusive school-based learning contexts.

Between 2015 and 2019, research topics expanded significantly, particularly around autism (34 occurrences), education (23), multimedia contents (7), and human–computer interaction (8). This development marked a period in which multimedia was increasingly recognized as an effective approach for supporting the learning of children with ASD. Several studies during this period highlighted the role of digital media in improving communication, social skills, and behavioral adaptation in children with autism (Derbissalova et al., 2024; Mostajo et al., 2023).

The current phase (2018–2022) was marked by the emergence of technologies such as AR and VR (5 and 6 occurrences, respectively), which were used to create more immersive learning experiences for children with ASD. This phase also coincided with the rise of the term autism spectrum disorder(s) ($n = 13$), which became more central in recent studies than earlier terms such as autistic disorder. In addition, the appearance of interactive computer systems and e-learning reflected a shift toward adaptive digital learning systems that supported personalized materials, student progress monitoring, and simulation-based social training (Fage et al., 2019; Kamid, 2025; Theodoropoulos et al., 2022).

Table 5 summarizes the trend topics of multimedia in learning for ASD research during the study period. Overall, the data confirm that high-frequency terms such as autism, education, diseases, autism spectrum disorders, and multimedia systems had median years of occurrence between 2015 and 2019, indicating a consolidation phase in multimedia research for children with ASD. Meanwhile, newer terms such as augmented reality, autism spectrum disorder, and interactive computer systems emerged more prominently after 2018, showing a trend toward advanced and personalized digital learning environments. As such, the data in Figure 6 and Table 5 demonstrate a consistent evolution from observation-based clinical studies to collaborative, interactive, and personalized digital learning approaches.

Table 5: Trend topics of multimedia in learning for ASD research

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
augmented reality	5	2018	2020	2021
autism spectrum disorder	6	2016	2020	2022
multimedia contents	7	2015	2016	2018
autism spectrum disorders	13	2014	2017	2022
diseases	25	2014	2017	2019
interactive computer systems	5	2013	2020	2022
education	23	2013	2017	2018
students	11	2012	2016	2018
human-computer interaction	8	2011	2016	2019
e-learning	8	2009	2018	2022
autism	34	2009	2015	2019
multimedia systems	14	2007	2015	2020
teaching	9	2006	2014	2016
multimedia	12	2005	2015	2019
child	7	2002	2013	2019
female	7	2002	2006	2014
autistic disorder	6	2002	2004	2011
communication	5	2001	2011	2022
article	9	2001	2006	2015
human	9	2001	2006	2015
male	8	2001	2004	2014
clinical article	7	2001	2003	2010
controlled study	5	2001	2003	2006
priority journal	6	2001	2002	2005

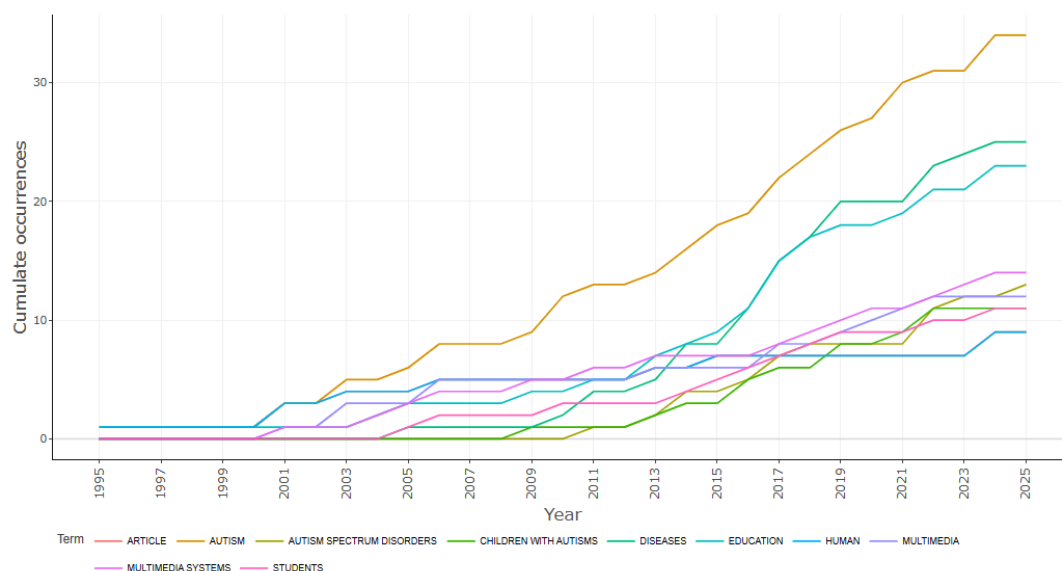


Figure 6: Word frequency trends

4.3 Map of Stakeholders and Influential Sources in Multimedia Research in Education for Children with ASD

Table 6 presents data on the local impact based on total citations (TC) of the top ten sources.

Table 6: Top ten sources' local impact based on total citations

No	Source	h-index	g-index	m-index	TC	NP	PY-start
1	Journal of Autism and Developmental Disorders	3	3	0.097	509	3	1995
2	Development and Psychopathology	1	1	0.050	442	1	2006
3	Computers and Education	2	2	0.167	70	2	2014
4	Journal of Physics: Conference Series	1	1	0.125	55	1	2018
5	International Journal of Inclusive Education	1	1	0.200	53	1	2021
6	ACM International Conference Proceeding Series	2	2	0.118	49	2	2009
7	Lecture Notes in Computer Science	2	2	0.091	48	2	2004
8	Autism	1	1	0.040	40	1	2001
9	Revista Brasileira de Engenharia Biomedica	1	1	0.100	38	1	2016
10	Multimedia Tools and Applications	2	2	0.222	37	2	2017

Note: NP: number of publications; PY: publication year start

Based on the data presented in Table 6, research on the application of multimedia in the education of children with ASD was published through various sources with varying degrees of influence. The Journal of Autism and Developmental

Disorders was listed as the most influential publication source, with a total of 509 citations, an h-index of 3, and 3 articles published. This journal has published important studies on interactive computer programs for reading and communication skills (Heimann et al., 1995), computer-animated tutors for vocabulary and language learning (Bosseler & Massaro, 2003), and the Visual Hybrid Development Learning System (VHDLS) for supporting children with ASD (Banire et al., 2015).

Furthermore, *Development and Psychopathology*, with a total of 442 citations and 1 publication, followed by *Computers and Education*, with a total of 70 citations and 2 publications, also had a high impact in research related to multimedia learning for children with ASD. The *Computers and Education* journal has published articles discussing the use of technology and digital media in learning for children with autism (Fage et al., 2019; Kennedy et al., 2014). The next position is occupied by the *Journal of Physics: Conference Series*, with a total of 55 citations and 1 publication, and the *International Journal of Inclusive Education*, with a total of 53 citations and 1 publication.

In addition, several proceedings and scientific publication series were also identified as having contributed to this field, such as the *ACM International Conference Proceeding Series* and *Lecture Notes in Computer Science*, each with 2 publications and a total of 49 and 48 citations, respectively. On the other hand, the journal *Autism* had 1 publication and 40 citations, while *Revista Brasileira de Engenharia Biomedica* had 1 publication and 38 citations. *Multimedia Tools and Applications* is in tenth place, with 2 publications and a total of 37 citations. This journal has several studies discussing the use of technology for learning for children with autism (Derbissalova et al., 2024; Wojciechowski & Al-Musawi, 2017).

Next, Table 7 presents the top ten most influential researchers in the field of study based on total citations. Simon Baron-Cohen and Ofer Golan emerged as the two most influential authors (TC = 442, h-index 1), known for their seminal research on emotion recognition and multimedia-based video modeling for children with ASD (Golan & Baron-Cohen, 2006). Both were from the University of Cambridge and have made significant contributions to social understanding and communication through psychologically adapted digital technologies. Next in line are Bosseler and Massaro (TC = 281), who in 2003 developed a computer-animated tutor to support language learning interventions for children with ASD (Bosseler & Massaro, 2003).

Interestingly, three other names, Heimann, Nelson, and Tjus (1995) (TC = 255, h-index 2), have emerged as pioneers of interactive computer-based research since 1995 in Sweden (Tjus et al., 2001). All three played a key role in introducing the use of multimedia to improve the communication skills of children with autism. In addition, Gillberg (TC = 215, h-index 1) also stands out as an early influential contributor in this field, particularly through work associated with autism research in Sweden during the mid-1990s. His contribution reflects the early scientific attention given to communication and developmental support for

children with ASD, which later became an important foundation for technology-assisted intervention research. Meanwhile, Consel and Fage (TC = 70, h-index 3) represented a new wave of researchers from France who focus on app regulation for inclusive schools for children with ASD (Fage et al., 2019).

Table 7: Ten most influential researchers based on total citations

No	Author	h-index	g-index	m-index	TC	NP	PY-start
1	Baron-Cohen S. B.	1	1	0.050	442	1	2006
2	Golan O.	1	1	0.050	442	1	2006
3	Bosseler A. N.	1	1	0.043	281	1	2003
4	Massaro D. W.	1	1	0.043	281	1	2003
5	Heimann M.	2	2	0.065	255	2	1995
6	Nelson K. E.	2	2	0.065	255	2	1995
7	Tjus T.	2	2	0.065	255	2	1995
8	Gillberg C. L.	1	1	0.032	215	1	1995
9	Consel C. Y.	3	3	0.250	70	3	2014
10	Fage C.	3	3	0.250	70	3	2014

Furthermore, Figure 7 illustrates the dynamics of researchers' productivity over time and reinforces the data in Table 7 by illustrating how each author's contribution developed chronologically in the field of multimedia learning for children with ASD. The productivity pattern indicates continuity between the early generation of researchers, who focused on psychological and linguistic approaches, and the more recent generation, who were oriented toward digital technology and adaptive learning systems.

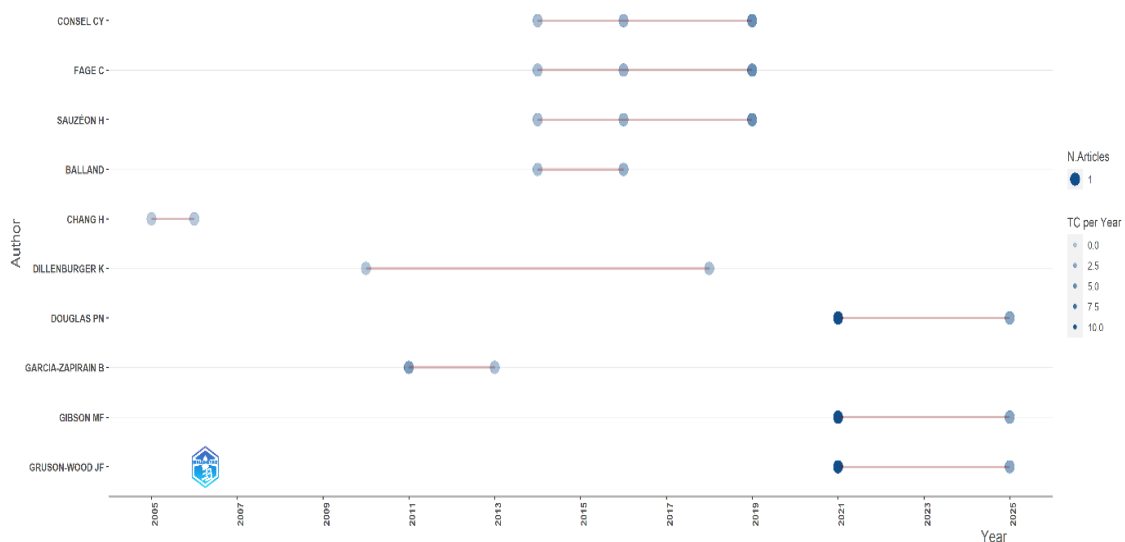


Figure 7: Authors' production overtime

As reflected in the graph, researchers such as Baron-Cohen S. and Golan O., who emerged as influential figures in Table 7, belonged to the early wave of studies that positioned multimedia as a tool to improve social skills and emotion recognition in autistic children through video modeling. This direction was further expanded by Bosseler A. N. and Massaro D. W. through the development

of computer-animated tutors for language learning. The graph in Figure 7 shows that these contributions appeared in the early 2000s, during the initial phase of computer-based learning for children with ASD.

After 2010, a new group of researchers, for example, Consel C.Y., Fage C., and Sauzéon H., emerged and remained productive between 2014 and 2019. They extended earlier research by integrating assistive technology and emotion regulation apps in inclusive education contexts (Fage et al., 2019). In addition, researchers such as Garcia-Zapirain, Gibson, and Gruson-Wood, who became active in 2021–2023, reflected more recent trends involving immersive learning and digital storytelling in multimedia-based educational environments (Bartolome et al., 2013; Shields et al., 2025). Overall, this pattern suggests that the field continued to evolve in a more collaborative and interdisciplinary direction.

Table 8 summarizes the collaboration between authors based on cluster network visualization results.

Table 8: Author collaboration based on cluster network visualization results

Node authors	Cluster	Betweenness	Closeness	PageRank
Lin C.	1	0	1	0.029
Tsai Y.	1	0	1	0.029
Consel C. Y.	2	0.667	0.2	0.035
Fage C.	2	0.667	0.2	0.035
Sauzéon H.	2	0.667	0.2	0.035
Balland B.	2	0	0.167	0.026
Pommereau L.	2	0	0.167	0.026
Amestoy A.	2	0	0.143	0.013
Garcia-Zapirain B.	3	0	0.5	0.032
Méndez-Zorrilla A.	3	0	0.5	0.032
Aresti-Bartolome N.	3	0	0.5	0.022
Heimann M.	4	0	0.5	0.029
Nelson K. E.	4	0	0.5	0.029
Tjus T.	4	0	0.5	0.029
Douglas P. N.	5	0	0.25	0.029
Gibson M. F.	5	0	0.25	0.029
Gruson-Wood J. F.	5	0	0.25	0.029
Rice C. M.	5	0	0.25	0.029
Shields R.	5	0	0.25	0.029
Banire B.	6	0	1	0.029
Binti Ahmad R. B.	6	0	1	0.029
Ahmad W. F.	7	0	1	0.029
Aziz N. S. A.	7	0	1	0.029
Aisulu S. A.	8	0	1	0.029
Avagimyan A. A.	8	0	1	0.029
Alias M. R. A.	9	0	1	0.029
Bahrudin I. A.	9	0	1	0.029
Bhatti Z. A.	10	0	1	0.029
Bibi M.	10	0	1	0.029
Dillenburger K.	11	0	1	0.029
Ala'i-Rosales S.	11	0	1	0.029

Node authors	Cluster	Betweenness	Closeness	PageRank
Amer A. M.	12	0	1	0.029
Baz H. M.	12	0	1	0.029
Ashburner J. K.	13	0	1	0.029
Bobir N. I.	13	0	1	0.029

The collaborative network analysis shown in Table 8 provides an overview of the relationship structure between researchers in this field. The network visualization identified 13 main collaborative clusters, each with distinct characteristics and research focuses. The most prominent were Cluster 2, consisting of Consel C.Y., Fage C. and Sauzéon H., with a betweenness centrality of 0.667 and the highest PageRank score of 0.035. These values indicate that these authors played an important role in connecting the global research network, particularly in studies on adaptive digital interventions.

The classic cluster consisting of Heimann, Nelson, and Tjus (Cluster 4) represents an earlier collaboration from Northern Europe on computer-assisted learning systems for improving the communication skills of autistic children. Meanwhile, the emergence of newer clusters, such as Lin C. and Tsai Y. (Cluster 1), shows the involvement of East Asian researchers in similar topics, while Banire B. and Binti Ahmad R. B. (Cluster 6) and Ahmad W. F. and Aziz N. S. A. (Cluster 7) reflect increasing contributions from Southeast Asia, especially Malaysia. Overall, these clusters indicate geographical and disciplinary diversification in multimedia research for children with ASD, with the research focus gradually expanding from the Euro-American context to Asian regions that were increasingly active in digital education innovation.

The country-level analysis, presented in Table 9, showed that the United Kingdom was the most influential country in multimedia research for children with ASD, as indicated by the highest total citations (TC = 456) and an average of 228 citations per article. This strong impact was influenced by the contributions of researchers such as Baron-Cohen and Golan, whose studies had a broad global influence. The United States ranked second (TC = 341; average citations = 68.20), with major contributions to the development of multimedia-based learning tools for behavioral interventions. Sweden placed third (TC = 262; average citations = 87.30), confirming its early role in interactive multimedia research since the 1990s.

Southern European countries such as Spain (TC = 69) and France (TC = 35) also showed consistent contributions, particularly in serious games and virtual learning environments, while the participation of Hungary, Argentina, and Greece indicates the expansion of research into Central Europe and Latin America. Overall, this pattern demonstrates that multimedia research for children with ASD has developed into a transcontinental field integrating psychological, educational, and technological perspectives, with Western Europe remaining dominant but other regions becoming increasingly active.

Table 9: Ten most influential countries in research on multimedia applications in the education of children with ASD based on TC

No	Country	TC	Average article citations
1	United Kingdom	456	228.00
2	United States	341	68.20
3	Sweden	262	87.30
4	Spain	69	34.50
5	Canada	56	28.00
6	Hungary	41	41.00
7	Argentina	38	38.00
8	Greece	38	38.00
9	Belgium	35	35.00
10	France	35	17.50

4.4 Mapping Research Related to Multimedia and the Abilities of Children with ASD

Table 10 illustrates the relationship between the types of multimedia technologies used in the publications and the abilities of children with ASD targeted for development. The number in each cell represents the number of studies examining a specific combination of multimedia and abilities.

In general, most publications use interactive multimedia applications (mobile/web/assistive) and general multimedia (text, images, audio, video), mainly to improve social-emotional, communication, and language skills. Virtual reality and serious games were also increasingly applied to develop social, cognitive, and adaptive skills through immersive and contextual learning experiences, while digital storytelling was used to strengthen conceptual understanding and learning focus.

In contrast, e-learning platforms appeared in only a small number of publications, indicating that inclusive online learning approaches for children with ASD were still relatively new and had potential for further development. Overall, this frequency pattern confirmed that most publications focused on social-communicative and linguistic development through interactive and accessible media, while attention and learning engagement remained less explored and represented potential directions for future research.

Table 10: Mapping of research related to multimedia and the abilities of children with ASD

	Social-emotional and communication	Language	Cognitive-academic	General cognitive/executive processes	Attention and engagement
Interactive multimedia applications (mobile/web/assistive)	11	5	2	1	0
General multimedia (text-image-audio-video)	7	6	2	1	2
Virtual reality/immersive	3	1	2	1	0
Digital storytelling/podcast	0	0	1	2	1
Serious games/gamification	2	0	2	0	0
E-learning platform/LMS	1	0	1	0	1

5. Discussion

5.1 Initial Phase: Psychological Perspectives and Basic Communication Skills

The initial phase of multimedia research for children with ASD was dominated by psychological perspectives, language development, and basic communication support. This phase was reflected in highly cited early studies that used interactive multimedia and computer-assisted programs to improve reading, vocabulary, and communication skills in autistic children (Bosseler & Massaro, 2003; Heimann et al., 1995; Tjus et al., 2001; Wong, 2001). In the bibliometric map, this phase was associated with the dominance of terms such as human, male, female, communication, and autistic disorder, indicating that the research focus was still centered on behavioral and clinical characteristics rather than educational technology integration.

These findings suggest that the earliest use of multimedia in ASD education was positioned primarily as a supportive intervention tool rather than as a pedagogical system. The emphasis on communication, literacy, and social understanding was understandable, since these areas represent core developmental challenges for children with ASD. This pattern was also consistent with the early structure of the literature, in which multimedia was mainly explored as a way to facilitate interaction and reduce barriers in basic learning and communication processes. Therefore, the initial phase laid the conceptual foundation for later developments by demonstrating that multimedia could support learning more effectively when it responds to the specific characteristics of autistic children.

The implication of this phase is that early multimedia research established the basic rationale for using digital media in ASD education, particularly in communication and language support. At the same time, the findings show that this phase remained limited in pedagogical scope, as most studies were still

oriented toward short-term intervention outcomes rather than broader instructional design or long-term academic development.

5.2 Transitional Phase: Computer-Assisted Learning and Multimedia Systems

The transitional phase marked an important shift from descriptive and clinical studies toward multimedia-supported learning systems. During this phase, keywords such as education, multimedia systems, teaching, human-computer interaction, and e-learning became more prominent, showing that research began to move from therapeutic use toward structured educational applications. This shift was reflected in studies on multimedia-based learning systems, teacher-supported digital practices, and more systematic instructional approaches for children with ASD (Banire et al., 2015; Kennedy et al., 2014; Matharaarachchi et al., 2023).

The synthesis of collected publications reinforced this pattern by showing that multimedia gradually developed from simple visual support into more interactive and adaptive learning tools. Research in this phase emphasized the use of instructional design models such as ADDIE, as well as user-centered design, to ensure that multimedia products addressed the needs of both autistic children and educators. Such findings suggest that the field was no longer focused only on whether multimedia worked but also on how multimedia should be designed to support meaningful and inclusive learning. This marked an important conceptual transition from technology as intervention to technology as pedagogy.

The broader implication of this phase is that multimedia began to be recognized as part of inclusive educational design rather than merely an assistive add-on. In other words, this period contributed to the emergence of multimedia as a structured learning medium that supported academic content, interaction, and engagement. This phase also strengthened the relationship between computer science, instructional design, and inclusive education, thereby expanding the knowledge base of ASD-oriented educational technology.

5.3 Recent Phase: Immersive, Adaptive, and Inclusive Technologies

The recent phase showed that multimedia research for children with ASD has increasingly focused on immersive, adaptive, and inclusive technologies. The bibliometric findings indicate the growing prominence of terms such as augmented reality, virtual reality, interactive computer systems, and autism spectrum disorder, while publication synthesis highlighted the use of emotion regulation applications, digital storytelling, assistive e-learning systems, and AI-supported multimedia environments (Fage et al., 2019; Kamid, 2025; Kumaş, 2024; Mostajo et al., 2023; Saibene et al., 2024; Shields et al., 2025; Theodoropoulos et al., 2022). These studies demonstrate that multimedia was increasingly used not only to support communication and literacy but also to enhance attention, engagement, self-expression, motivation, social-emotional skills, and conceptual understanding.

This development suggests a deeper conceptual shift in the field. Multimedia was no longer treated simply as a technological tool or therapeutic aid but increasingly functioned as part of an adaptive and inclusive pedagogical ecosystem. This

change could be interpreted through the integration of multimedia learning, inclusive education, and user-centered design perspectives, as recent multimedia systems were designed to respond more directly to individual learner differences. The use of immersive and intelligent technologies also reflected a broader move toward personalization, participation, and responsiveness in ASD education.

The implication of this phase is significant for both research and practice. It shows that multimedia has become a strategic medium for building more engaging, differentiated, and evidence-based learning environments for children with ASD. At the same time, the findings also contribute conceptually by clarifying the evolution of the field from therapeutic support to adaptive inclusive pedagogy. However, literature still shows important limitations, particularly the dominance of short-term intervention studies, limited attention to long-term academic outcomes, and underrepresentation of non-Western or less-resourced contexts. Despite these limitations, the consistency of findings across phases and studies supports the validity of the overall developmental pattern identified in this review. Future research should therefore examine longitudinal learning outcomes, broader cultural contexts, and the role of AI-supported multimedia systems in sustaining inclusive and personalized learning for children with ASD.

6. Conclusion

The bibliometric analysis showed that research on multimedia applications for children with ASD grew substantially over the past three decades. The field shifted from predominantly clinical and psychological approaches toward a digital education paradigm supported by interactive technologies and evidence-based practices. Core themes such as autism, education, and multimedia systems became central in literature, particularly in relation to improving social-emotional, communication, and language skills through computer-based interventions, e-learning, and immersive technologies such as AR and VR. This development reflected a broader transition from therapeutic exploration to pedagogical innovation and inclusive learning support through personalized multimedia environments.

The findings also indicate that new researchers, including Consel, Fage, and Sauzéon, expanded the field toward assistive technologies and emotion regulation applications in inclusive school settings, extending earlier studies focused on communication and literacy. In addition, stronger interdisciplinary collaboration among psychology, information technology, and inclusive education enriched the scientific understanding of the learning needs of children with ASD. Consequently, multimedia was recognized not merely as a therapeutic tool but as part of a digital learning ecosystem that supported engagement, attention, and cognitive development. This study contributed scientifically by mapping publication trends, thematic evolution, and influential contributors in the field, thus providing a clearer knowledge base for future research and practice. However, the study was limited to Scopus-indexed and English-language publications, so the findings should be interpreted as representing trends within the selected dataset.

7. Recommendations

Future studies should emphasize longitudinal evaluation, AI integration, adaptive learning analytics, inclusive design, and the ethical use of immersive technologies to ensure that multimedia innovations are effective, safe, contextual, and sustainable in supporting ASD education.

Conflict of Interest

The authors declare no conflict of interest.

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