



From Screens to Sustainability: A Bibliometric Analysis of Digital Literacy Development Among Children for Inclusive and Sustainable Futures

Lim Seong Pek¹, Rita Wong Mee Mee^{2*}, Fatin Syamilah Che Yob¹, Yammuna Sivabalan³,
Geoffrey Rhoel C. Cruz⁴, Jameson Estrada⁵

¹ Faculty of Education and Liberal Arts, INTI International University, Negeri Sembilan 71800, Malaysia

² Centre for Language, National Defence University of Malaysia, Kuala Lumpur 57000, Malaysia

³ Faculty of Education and Social Sciences, Universiti Selangor, Selangor 45600, Malaysia

⁴ School of Multidisciplinary Studies-Social Science Area, De La Salle-College of Saint Benilde, Manila 1004, Philippines

⁵ Research and Development Centre, Pangasinan State University, Pangasinan 2401, Philippines

Corresponding Author Email: ritawong@upnm.edu.my

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ABSTRACT

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digital literacy, children's learning, educational technology, digital well-being, family engagement

This bibliometric study examines global research trends, intellectual structures, and thematic developments in children's digital literacy development between 2021 and 2025, with a specific focus on its role in advancing sustainable and inclusive education. A total of 216 articles were retrieved from the Scopus database using the search string TITLE-ABS-KEY ("digital literac*" AND "child*"). Using VOSviewer, co-occurrence, co-citation, and performance analyses were conducted to map scholarly networks and thematic evolution. The findings reveal a significant growth in publications, particularly after the COVID-19 pandemic, highlighting digital literacy as a critical competency for resilient and sustainable learning systems. Five major thematic clusters emerged: (1) digital competence and creativity, (2) digital divide and socioeconomic inequality, (3) family and home literacy practices, (4) computational thinking and STEM integration, and (5) digital well-being. Importantly, the results position digital literacy as a multidimensional construct closely linked to social equity, access to education, and long-term societal sustainability. The study contributes by reframing digital literacy as a sustainability-driven educational priority aligned with Sustainable Development Goal 4 (Quality Education). It further provides directions for policymakers and educators to develop inclusive, equitable, and future-ready digital learning ecosystems.

1. INTRODUCTION

A crucial ability in today's knowledge-based society is digital literacy, particularly for children growing up in the digital era. According to Gündoğmuş [1], digital literacy encompasses not just proficient use of technology but also the ability to locate, assess, produce, and distribute information on digital platforms. According to Wangui [2], children are spending more time in digital settings at younger ages due to the rapid growth of the internet, mobile devices, and educational technology. Because they provide access to information, dynamic learning environments, and opportunities to interact with people from different nations, these tools have transformed the way people learn [3]. Notwithstanding the noteworthy potential of integrating digital tools into education, there are drawbacks as well, including issues of accessibility, quality, and equality [4]. This changing environment makes the development of children's digital literacy a crucial research topic that requires in-depth examination.

Digital literacy gaps persist in children's development, despite the increased focus on digital skills in 21st-century

schooling [5]. According to Shi et al. [6], children from low-income households, those living in rural areas, and those from disadvantaged backgrounds often lack access to digital devices, reliable internet, and parental supervision when using digital platforms. Additionally, many schools lack the infrastructure, training, and resources needed for teachers to successfully incorporate digital literacy into the curriculum [7]. According to Shim et al. [8], there is also the problem of the "digital divide 2.0," which implies that children may be able to utilise technology for enjoyment but not for critical tasks like evaluating online information, managing their online personas, or interacting with others online in a moral manner. This disconnect between exposure and meaningful digital competency jeopardises children's academic performance, social lives, and future employment opportunities [9].

Children who lack digital literacy face far-reaching repercussions. Academic performance is higher for children who are proficient with technology than for those who are not. The reason for this is that students are struggling to adapt to technologically based learning environments. Children who lack basic digital skills may find it difficult to make online acquaintances, which can lead to exclusion or bullying [10].

According to Pratiwi et al. [11], children who lack knowledge about digital safety are also more susceptible to online dangers such as false information, cyberbullying, and privacy violations. Developmental theory suggests that children who lack basic digital skills have fewer abilities to think critically, solve problems, and express themselves creatively in digital spaces [12]. These impacts exacerbate already-existing disparities and prevent children from succeeding in knowledge-based societies that demand education and technological adaptation.

Schools and society at large should be aware of and responsive to children's levels of digital literacy. Strong digital skills training helps children think critically, perform better in school, and be more creative – all of which will help them land a job in an increasingly digital economy [13]. Teaching young people how to utilise technology can help society minimise socioeconomic inequalities and produce intelligent digital citizens who can engage in online communities responsibly [14]. The present study identifies trends, gaps, and future directions in children's digital literacy that are important for parents, educators, and policymakers to understand in order to develop interventions that are equitable, effective, and accessible to everyone.

Despite the growing body of research on children's digital literacy, limited studies have explicitly examined its role within the broader sustainability discourse, particularly in relation to inclusive education, digital equity, and long-term societal resilience. Existing bibliometric studies tend to focus on technological or pedagogical dimensions without critically linking digital literacy to sustainable development frameworks. This creates a significant research gap, as digital literacy is increasingly recognised as a foundational competency for achieving Sustainable Development Goal 4 (Quality Education) and reducing inequalities in access to knowledge. Therefore, this study extends beyond traditional bibliometric mapping by situating children's digital literacy within the sustainability agenda, offering a more holistic understanding of its educational and societal implications.

This study makes three distinct and verifiable contributions to the existing body of bibliometric research. First, it provides a focused dataset by deliberately restricting the search to studies explicitly using the term “digital literacy” in relation to children, ensuring conceptual precision compared to broader studies that combine heterogeneous constructs such as digital skills or ICT competence. Second, it introduces a multi-layered mapping approach by integrating performance analysis, co-citation, and co-occurrence techniques to simultaneously capture productivity, intellectual structure, and thematic evolution within a sustainability-oriented framework. Third, the study incorporates a sustainability-aligned analytical lens, explicitly linking digital literacy research to Sustainable Development Goal 4 (Quality Education), thereby extending prior bibliometric studies that primarily emphasised technological or pedagogical dimensions without sustainability integration.

This study is guided by the following objectives:

- To analyse publication and citation trends of children's digital literacy development.
- To identify the intellectual structure of children's digital literacy using co-citation analysis.
- To map emerging research themes in children's digital literacy through keyword co-occurrence analysis.

2. METHODS

Bibliometric analysis is a quantitative, methodical approach to examining all research on how children learn to utilise technology. Traditional literature assessments frequently fall short of capturing the subject's evolving breadth and relationships as the volume of relevant research continues to grow. Bibliometric approaches help fill this vacuum by identifying important writers, institutions, countries, and new research areas [15]. Using this methodology, the conceptual framework of research on digital literacy can be visualised, providing valuable insights into how educational, psychological, and technological perspectives interact to shape children's digital abilities [16]. According to Wider et al. [17], bibliometric mapping provides educators and policymakers with empirical evidence to support data-driven decision-making and equitable educational practices.

Co-citation analysis reveals important theories, important authors, and developing conceptual frameworks by identifying books that are commonly mentioned together, so illuminating the intellectual underpinnings of a discipline [18]. Co-occurrence analysis, on the other hand, charts the frequency and relationships among phrases to uncover interdisciplinary linkages and important themes such as digital learning, online safety, and 21st-century competencies [19]. These studies shed light on the conceptual and historical development of digital literacy research, particularly in light of emerging concerns such as fair access, AI literacy, and disinformation [20].

This study demonstrated these interactions using VOSviewer. It creates network, cluster, and link-strength graphs [21]. To enhance the validity of the co-occurrence analysis, a keyword cleaning process was conducted. Generic index terms generated by Scopus, such as “human”, “article”, and “controlled study”, were identified as non-conceptual noise and removed. A thesaurus file in VOSviewer was applied to merge similar terms and exclude irrelevant keywords. This process ensures that the resulting clusters reflect meaningful conceptual relationships rather than database indexing artefacts. Therefore, to guide future research and policy initiatives in digital education, the study offers a thorough, transparent assessment of the field's evolution through integrated techniques [22].

2.1 Search strategy

This bibliometric analysis's search technique was meticulously designed to ensure that every piece of literature on how children learn to utilise digital technology was included in Table 1. The information was obtained from the Scopus database using the search query TITLE-ABS-KEY ("digital literac*" AND "child*"). Publications from 2021 to 2025 were covered. This period was selected to compile the most current and pertinent study results demonstrating the expanding use of digital literacy in the classroom. Only English-language journal papers in all open access formats met the inclusion criteria in order to ensure quality and accessibility. In the initial search, 1,077 records were found. Based on the kind of document and the eligibility requirements, these were sorted and filtered. Following the application of inclusion and exclusion criteria, 216 articles were retained for bibliometric examination. In the investigation of the intellectual environment pertaining to children's digital literacy study, this methodological approach enhances the validity, reproducibility, and transparency of the

results.

Table 1. Inclusion criteria for bibliometric analysis

Scopus Database	ALL
Time period	2021 to 2025
Search field	TITLE-ABS-KEY
Search keywords	“digital literac*” AND “child*”
Document types	Article
Language	English

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart in Figure 1 shows how the bibliometric analysis methodically chooses and filters studies. The process started with 1,077 records found in the Scopus database. During the screening process, 434 records were eliminated because they were not published between 2021 and 2025, to maintain focus on recent advancements in digital literacy research. To ensure consistency, 219 non-research articles were excluded after 643 records were sorted by type. 424 full-text articles were left for evaluation of eligibility. At the eligibility stage, 208 papers were rejected for failing to meet open-access and language standards. In the end, 216 papers that satisfied all inclusion requirements were retained for bibliometric analysis. This rigorous PRISMA-based strategy enables a trustworthy, repeatable analysis of research trends, patterns, and thematic improvements in children's digital literacy development, ensuring openness in the data selection process and minimising bias.

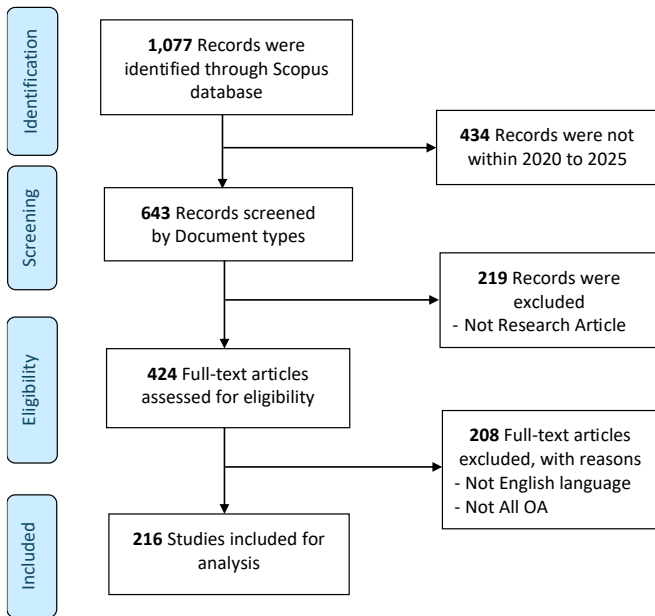


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart

The decision to retain a focused search string was intentional to ensure conceptual precision and to avoid diluting the dataset with loosely related constructs such as general ICT usage or media exposure. While broader terms such as “digital skills” or “media literacy” exist, the selected query prioritises studies explicitly grounded in digital literacy discourse. This enhances the internal validity of the bibliometric mapping and ensures that the resulting thematic clusters accurately reflect the evolution of the digital literacy construct in relation to children. Furthermore, the use of Scopus as the sole database

is justified due to its extensive coverage of peer-reviewed, high-impact publications across multidisciplinary domains, making it suitable for sustainability-oriented research synthesis.

It is acknowledged that broader terminologies such as “digital competence”, “digital skills”, “media literacy”, and “ICT literacy” are also widely used in related studies. However, this study intentionally adopts a narrower query to ensure conceptual specificity and avoid the inclusion of loosely related constructs that may dilute the analytical focus. Therefore, the findings should be interpreted as representing research explicitly grounded in the “digital literacy” discourse rather than the entire spectrum of digital-related competencies. Future research may extend this analysis by applying expanded search queries to examine thematic stability.

In addition, in the VOSviewer visualisations, nodes represent keywords or cited documents, while links indicate the strength of relationships between them. The size of nodes reflects frequency, and the thickness of links represents the strength of association. A minimum threshold of 48 occurrences and the total link strength of 3,549 was applied, resulting in the selection of the top 15 keywords. Clustering was generated using the VOSviewer modularity-based algorithm.

3. RESULTS

3.1 Performance analysis

Performance analysis in bibliometric research highlights important people, organisations, and countries that are advancing knowledge by analysing the output and impact of publications on a certain topic. To identify trends over time, it provides a quantitative overview of publication patterns, including active research groups, well-known journals, and prolific authors. Performance analysis helps us understand the global research dynamics shaping children's digital literacy development by revealing where and by whom significant academic contributions are being produced. Through this analysis, researchers can determine the primary centres of competency, assess the maturity of the topic, and suggest areas that require cooperation or additional research.

3.1.1 Performance by years

Research on how children learn to utilise technology has been continuously increasing, as evidenced by the number of papers published annually between 2021 and 2025. Based on Figure 2, 31 publications were made in 2021. It increased gradually, peaking at 59 documents in 2024 and then rising to 40 in 2025. Given that learning with technology has become more popular due to the pandemic, this trend suggests that digital literacy is becoming increasingly crucial in classrooms. The increase from 2021 to 2024 suggests growing interest in learning, consistent with global efforts to digitise education, policy changes, and children's internet use. Even a slight decline in 2025 might be more due to publishing delays than a decline in research interest. This upward trend reflects not only increased academic interest but also a structural transformation in global education systems, in which digital literacy has shifted from a supplementary skill to a core competency for sustainable learning environments. The surge in publications post-2022 aligns with global recovery strategies following the COVID-19 pandemic, where digital

inclusion and educational resilience became central policy concerns.

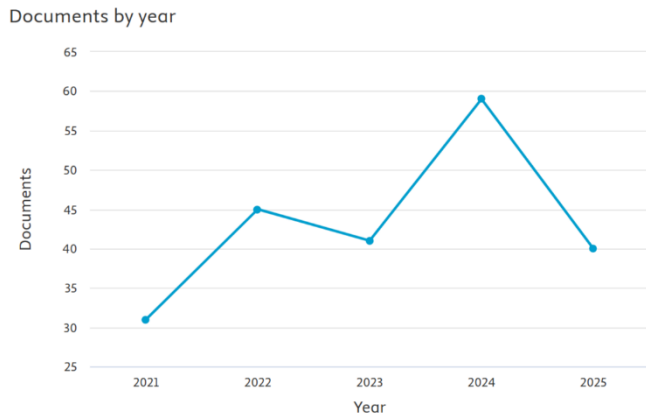


Figure 2. Performance by year
Source: Scopus Database

3.1.2 Performance by sources

The source analysis in Figure 3 reveals that research on children's digital literacy is supported by a broad range of fields and prestigious journals. The dedication to enhancing technology-based education is demonstrated by the six publications published in the Education and Information Technologies and the International Journal of Child-Computer Interaction. The Journal of Medical Internet Research and Frontiers in Education each have five publications that imply a close relationship between health, technology, and pedagogy in this area. By connecting educational theory, technology use, and child welfare, journals such as the British Journal of Educational Technology, Education Sciences, and BMC Public Health demonstrate the field's multidisciplinary nature. Publications from the fields of education and medicine are included to provide a comprehensive view of digital literacy that considers its social, cognitive, and health aspects. The variety of publication routes is proof of the field's interdisciplinary character and wide-ranging academic importance.

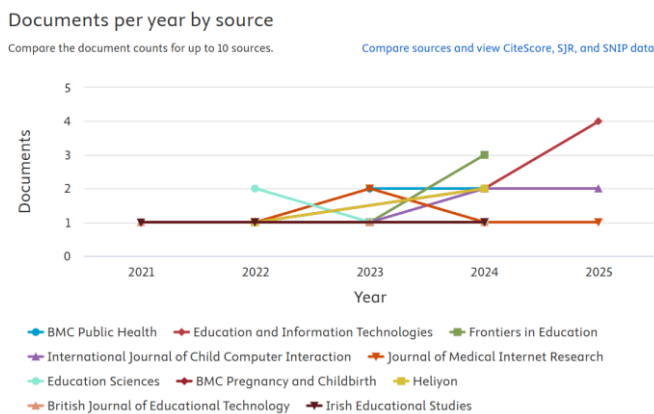


Figure 3. Performance by sources
Source: Scopus Database

3.1.3 Performance by authors

According to the author's performance analysis in Figure 4, 10 authors – among them Aarsand, P., Adigwe, I., Aram, D., Benton, L., and Botturi, L. – published two each. This highlights how much each of them contributed. This relatively

equal distribution highlights that the region benefits from the efforts of numerous scholars from diverse locations and academic disciplines rather than just one key figure. Numerous academic disciplines are represented in this distribution, including computer science, child psychology, and education. This highlights how research on digital literacy is becoming more cooperative. Given the moderate frequency of authorship, children's digital literacy remains a developing field, offering opportunities for new scholars to contribute to the conversation. A diverse spectrum of scholars from various educational systems, cultures, and teaching methods may be found in the field, as evidenced by the balanced authorship network. When examining children's digital skills, this is particularly valid.

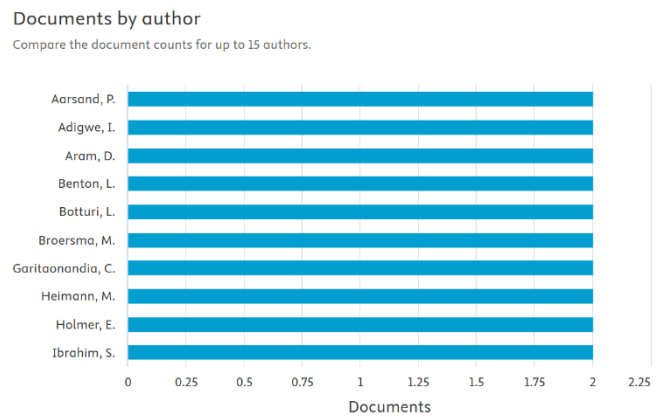


Figure 4. Performance by authors
Source: Scopus Database

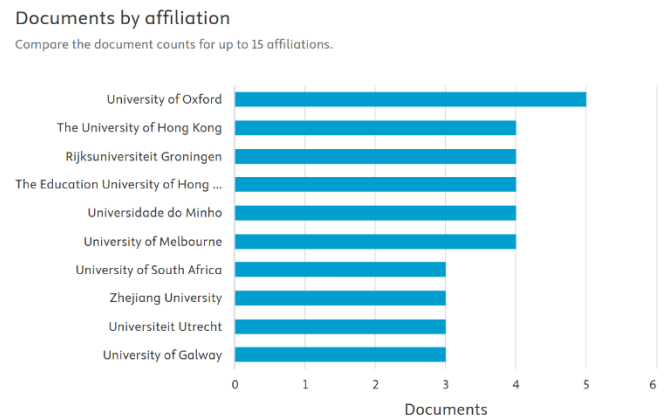


Figure 5. Performance by affiliations
Source: Scopus Database

3.1.4 Performance by affiliations

An analysis of institutional output reveals which leading universities are advancing the study of children's digital literacy. With five papers, the University of Oxford holds the record. Each of the following universities, as shown in Figure 5, has four papers: the University of Melbourne, Universidade do Minho, Rijksuniversiteit Groningen, The Education University of Hong Kong, and the University of Hong Kong. These partnerships have a robust presence worldwide, spanning Europe, Asia, Africa, and Oceania. The manner in which various educational frameworks handle children's digital participation varies. Research on digital literacy is becoming increasingly global, as evidenced by the presence of both Western and Asian colleges. Growing interest in developing and emerging environments is a trend among

universities such as Zhejiang University and the University of South Africa. This suggests a growing recognition of digital literacy as a critical competency for equitable education. According to these collaborations, there is a robust global academic community committed to advancing innovative teaching methods and child-centred digital learning initiatives.

Documents by country or territory
Compare the document counts for up to 15 countries/territories.

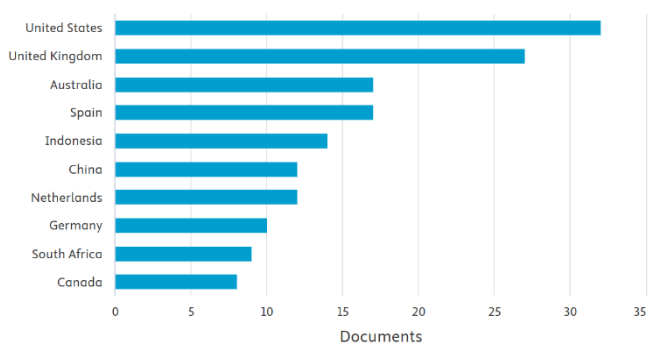


Figure 6. Performance by countries
Source: Scopus Database

3.1.5 Performance by countries

The distribution by countries in Figure 6 highlights the extensive global research being conducted on children's digital literacy. With 32 and 27, respectively, the United States and the United Kingdom are at the top of the list. These nations provide substantial funding due to their robust research

infrastructure and digital education legislation. Spain and Australia are second and third, respectively, with 17 articles. There are also several publications from China (12), Indonesia (14), and the Netherlands (12), indicating a high level of interest from both Asian and Western academic organisations.

As evidenced by recent publications from South Africa (9), Canada (8), and Germany (10), the topic is becoming increasingly relevant worldwide. While the growing number of Asian countries participating is a positive trend towards global inclusivity, the dominance of Western countries suggests that a significant amount of the theoretical framework has its roots in developed environments. Based on this regional distribution, the majority of individuals believe that digital literacy is a crucial educational objective that prepares children for a digital society.

3.2 Co-citation analysis

The fundamental research supporting children's digital literacy development is found in the top 10 co-cited papers (Table 2), which encompass theoretical, psychological, and pedagogical perspectives. Given their revolutionary work on thematic analysis, which offers a methodological basis for qualitative research in digital learning environments, Braun and Clarke [23] are at the top of the list. In their meta-analysis of print and digital reading, Delgado et al. [24] highlighted comprehension distinctions that are important for literacy studies. In digital learning contexts, Bandura's [25] idea of self-efficacy continues to influence research on children's motivation and confidence.

Table 2. Co-citations (Top 10 articles)

Rank	Authors	Title	Citations	Total Link Strength
1	[23]	Using thematic analysis in psychology.	5	25
2	[24]	Don't throw away your printed books: A meta-analysis on the effects of reading media on reading comprehension.	3	27
3	[26]	Advantages and challenges associated with augmented reality for education: A systematic review of the literature.	2	13
4	[25]	Self-efficacy: Toward a unifying theory of behavioral change.	2	16
5	[27]	Sharenting and parents' digital literacy: an agenda for future research.	2	17
6	[28]	The effective components of creativity in digital game-based learning among young children: A case study.	2	17
7	[29]	Coding as a playground: Promoting positive learning experiences in childhood classrooms.	2	18
8	[30]	Children learning to use technologies through play: A Digital Play Framework.	2	15
9	[31]	Defining digital literacy-What do young people need to know about digital media?	2	10
10	[32]	Ending the reading wars: Reading acquisition from novice to expert.	2	9

According to Behnamnia et al. [28] and Akçayır [26], the educational integration of digital game-based learning and augmented reality, respectively, emphasises creativity and participation. In addition to introducing the idea of parental digital literacy, Barnes and Potter [27] broaden the discussion to include family-mediated technology use through "sharenting." Two child-centred frameworks that are promoted by Bird and Edwards [30] and Bers et al. [29] are "Digital Play" and "Coding as a Playground." Additional definitions of digital literacy and reading acquisition can be found in foundational studies by Buckingham [31] and Castles et al. [32]. Together, these often referenced books provide the theoretical underpinnings that connect digital literacy, instructional technology, and children's cognitive development. The relatively low co-

citation frequencies observed in this study can be attributed to the limited dataset size (n = 216) and the recent publication window (2021-2025), where citation accumulation is still developing.

3.2.1 Co-citation analysis by clusters

In technology-integrated education, as seen in Figure 7, Cluster 1 emphasises teacher collaboration, fostering creativity, and developing frameworks for digital competency. Two examples of works discussing how digital game-based learning might assist students in understanding how to educate in the twenty-first century and foster creativity are Behnamnia et al. [33] and Caena and Redecker [34]. The growing emphasis on digital responsibility is evident in research by Blevins [35] and Akman et al. [36] examining teachers' and

parents' understanding of digital literacy and data security. According to Carayannis and Morawska-Jancelewicz [37], digital proficiency is essential for long-term educational futures, as they emphasise the rise of Industry 5.0 and Society 5.0. Through digital resources, the cluster advocates a comprehensive strategy in which educators, parents, and

schools collaborate to establish learning environments that foster innovation and creativity. It also highlights how the teaching movement is preparing students for lifelong digital use by shifting away from passive technology use and towards active, purposeful use.

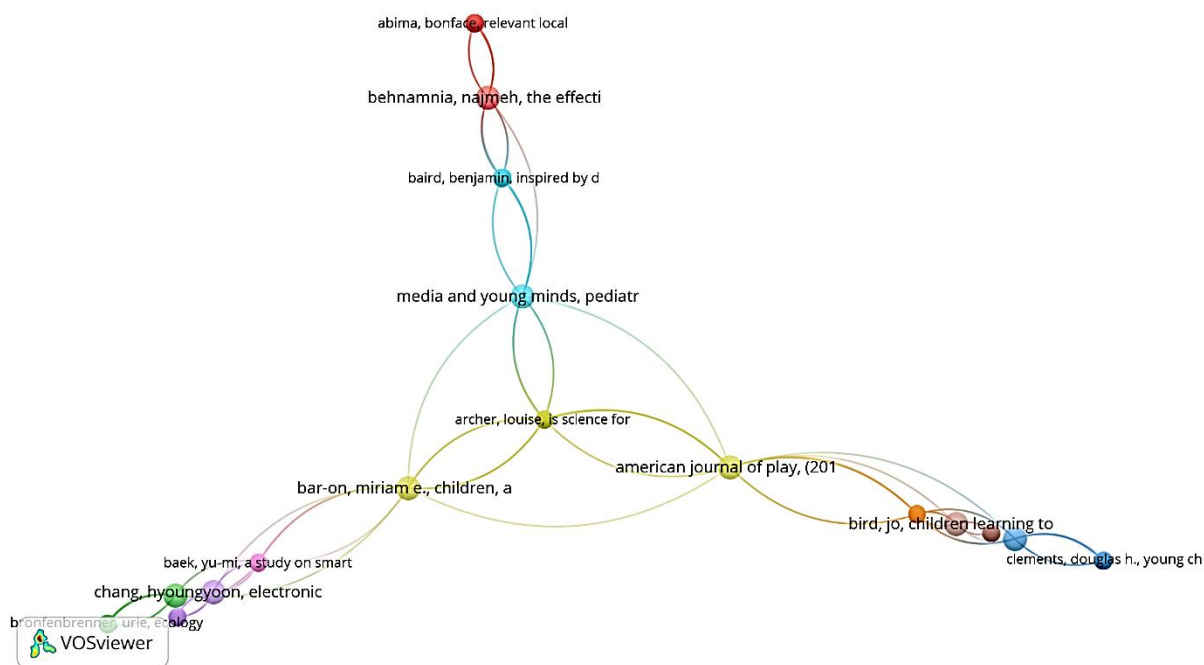


Figure 7. Co-citation analysis (VOSviewer visualization)

Cluster 2 examines how early literacy development is influenced by socioeconomic position, family dynamics, and digital inequalities. The ecological and familial process theories presented in Bronfenbrenner [38] and Conger et al. [39] are foundational works that clarify how socioeconomic status and the environment affect digital learning results. Children's digital competences and parental mediation vary by social class, according to research by Nikken and Oprea [40]. These conclusions are supported by meta-analytic data from Scherer and Siddiq [41], which links socioeconomic background and ICT literacy. Wang et al. [42] and Van Dijk [43] expanded the discussion to include systemic digital inequalities in access and equity, particularly in developing countries such as China. This cluster emphasises that digital literacy is a socially contingent phenomenon influenced by educational opportunities, family resources, and broader structural injustices. It emphasises the urgent need for inclusive policies that address socio-digital inequalities and advance fair educational outcomes in digital education.

Cluster 3 emphasises the crucial role of the home environment and family relationships in helping children learn to use technology. Two significant studies that highlight the value of informal, play-based learning environments for children when their parents are observing them use technology are Clements and Sarama [44] and Kervin et al. [45]. By analysing bilingual settings and literacy activities at home, Li et al. [46] and López-Escribano et al. [47] demonstrated how parental influence shapes early literacy practices both during and after the COVID-19 pandemic. While Ozturk and Ohi [48] investigated home-based digital engagement in Turkey, Staes et al. [49] proposed the concept of "grandsharenting,"

emphasising the intergenerational aspect of digital participation. Together, these works highlight the importance of the family in supporting children's digital development, where digital literacy permeates everyday life and transcends formal schooling. The cluster highlights how technology is now utilised as a social backdrop to family interactions and shared cultural norms, rather than as a teaching tool.

Cluster 4 investigates how STEM and computational thinking activities might support children's development of digital literacy. Science capital theory is strengthened by the seminal research of Archer et al. [50, 51], which shows how social and cultural resources impact children's science and technology learning paths. Bers [52] and Bower et al. [53] expanded on this concept by discussing how children may learn to utilise computers, be creative, and solve problems through robotics and coding platforms such as KIBO and ScratchJr. Ceci and Williams [54] placed gender inequities in STEM areas and highlight the need for fair digital pedagogies. These groups demonstrate the connection between identity formation in science, play, and computation and digital literacy. It promotes inclusive educational frameworks that spark children's interest in technology and critical thinking by allowing them to experience digital spaces from an early age, thereby preparing them for future STEM pursuits.

Cluster 5 examines how children's exposure to digital media affects their psychological well-being and behaviour. Studies like Chang et al. [55] and Domoff et al. [56] use interactional theory to examine media consumption patterns and the rise of harmful digital behaviours. Dresch-Langley [57] and Johnson [58] investigated digital health difficulties and online behaviours that impact early cognitive development, whereas

Sohn et al. [59] provided meta-analytic data linking excessive smartphone use to mental health problems in adolescents. By providing other parental viewpoints on the use of portable devices, Sergi et al. [60] highlighted the function of parental mediation in limiting digital exposure. This group combines education, psychology, and health to illustrate the benefits and drawbacks of early digital immersion. It highlights how crucial digital well-being literacy is for promoting balanced, healthful technology use and promoting children's overall development as presented in Table 3.

Table 3. Co-citation analysis by clusters

Cluster No. & Colour	Cluster Labels	No. of Articles	Representative Publications
Cluster 1 (Red)	Digital Competence, Creativity, and Educational Innovation	10	[33-37]
Cluster 2 (Green)	Socioeconomic Contexts and the Digital Divide	10	[38-43]
Cluster 3 (Blue)	Home Literacy, Family Practices, and Intergenerational Mediation	10	[44-49]
Cluster 4 (Yellow)	Computational Thinking and STEM-oriented Digital Literacy	9	[50-54]
Cluster 5 (Purple)	Screen Time, Digital Well-being, and Media Use in Early Childhood	9	[55-60]

3.3 Co-occurrence analysis

By examining the connections between 15 popular keywords, the co-occurrence analysis in Table 4 presents the conceptual landscape of research on how children learn to utilise technology. The central node that connects the field's conceptual network is the primary keyword "digital literacy" (59 occurrences, connection strength = 242). Related terms, such as "child" (33), "children" (13), "adolescent" (25), and "internet literacy" (26), highlight the importance of age-appropriate skills both online and in learning contexts. A growing number of people are interested in the differences between gender and development in digital learning settings, as seen by the use of demographic terminology such as "human" (41), "male" (28), and "female" (35). "COVID-19" (21) and "coronavirus disease 2019" (12) illustrate how the pandemic has advanced digital learning while highlighting disparities in access and participation. After filtering out generic index keywords, the analysis focused on conceptually meaningful terms relevant to digital literacy research.

Techniques such as "controlled study" (16) and "cross-sectional study" (14) reflect a shift in the field from exploratory research to evidence-based investigation. This reflects the practical rigour of the field. The co-word network (802 links; total strength = 3549) highlights how viewpoints from the fields of education, psychology, and health are interconnected within a multidisciplinary framework. In summary, the evidence points to a growing body of studies

aimed at understanding how digital literacy affects children's learning, behaviour, and overall well-being in rapidly changing digital contexts.

Table 4. The 15 most frequent keywords in the co-occurrence analysis

Rank	Keyword	Occurrences	Total Link Strength
1	digital literacy	59	242
2	human	41	552
3	female	35	496
4	article	33	465
5	child	33	409
6	male	28	400
7	internet literacy	26	394
8	adolescent	25	376
9	humans	24	368
10	covid-19	21	222
11	adult	19	306
12	controlled study	16	267
13	cross-sectional study	14	259
14	children	13	69
15	coronavirus disease 2019	12	221

3.3.1 Co-occurrence analysis by clusters

In the context of technology use, Cluster 1 examines how family dynamics, adolescent development, and digital literacy interact. The terms "digital literacy," "adolescent," "digital literacies," and "child-parent relation" in Figure 8 highlight the significance of comprehending how young pupils acquire and utilise technology both at home and at school. The terms "cross-sectional study" and "questionnaire" imply that the majority of the research in this category examines the relationship between parental mediation, learning outcomes, and teens' digital habits using either mixed-methods or quantitative approaches. This group also highlights the tendency to view teenagers as self-sufficient internet users capable of navigating intricate media environments. It reflects the growing interest among scholars in how digital tools impact teens' literacy practices, social interactions, and cognitive development. In general, the cluster emphasises a developmental approach to digital literacy, stating that collaboration between parents, schools, and digital ecosystems is necessary for children and teenagers to learn to read and write.

In digital literacy research, Cluster 2 examines human factors, gender, and early childhood participation. "Male," "female," "child," "children," "human," and "internet literacy" all indicate that the primary focus is on the behavioural and demographic variations among young students. This group discusses how social background, age, and gender all impact how people learn to use technology. The use of the words "article" and "literacy" suggests that studies in this field often combine analyses of basic literacy frameworks with gendered and developmental perspectives. Additionally, studies in this cluster examine how gender differences in children's cognitive and emotional use of technology affect academic outcomes. The discussion typically shifts to moral and parental concerns when it comes to regulating children's technology use. All things considered, this group highlights a child-centred approach to digital literacy, emphasising inclusivity and understanding gender-sensitive teaching strategies that consider the various ways children use, learn about, and experiment with digital media.

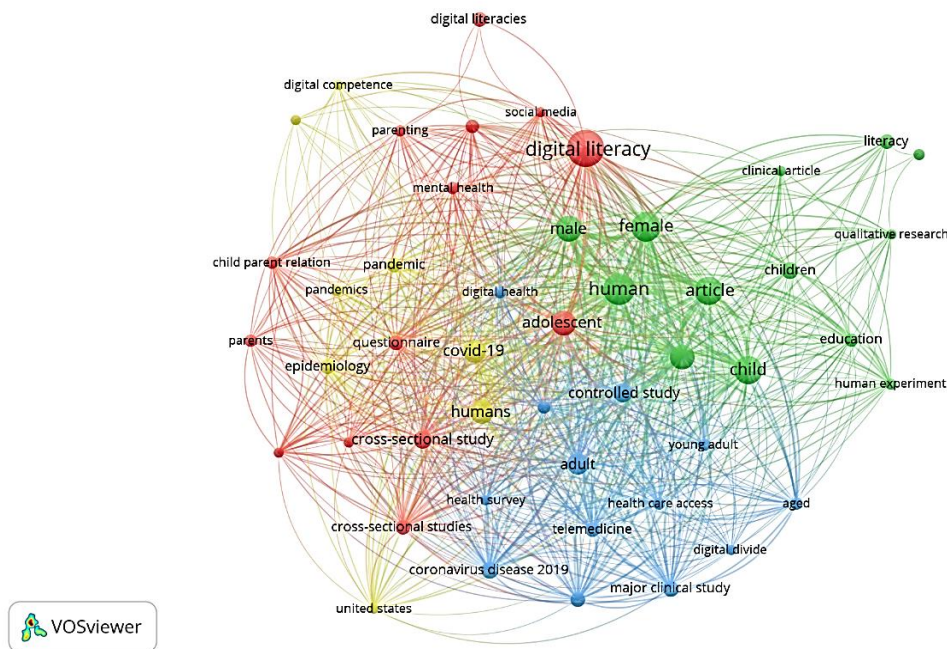


Figure 8. Co-occurrence analysis (VOSviewer visualization)

Table 5. Co-occurrence analysis of keywords on children’s digital literacy research

Cluster No & Colour	Cluster Label	Number of Keywords	Representative Keywords
Cluster 1 (Red)	Digital Literacy and Adolescent Learning Contexts	14	‘digital literacy’, ‘adolescent’, ‘cross-sectional study’, ‘cross-sectional studies’, ‘questionnaire’, ‘digital literacies’, ‘child parent relation’, ‘digital technology’
Cluster 2 (Green)	Gendered Dimensions and Child-centered Digital Literacy	13	‘male’, ‘female’, ‘article’, ‘human’, ‘child’, ‘internet literacy’, ‘literacy’, ‘children’
Cluster 3 (Blue)	Digital Health, Accessibility, and Technology Integration	13	‘adult’, ‘controlled study’, ‘coronavirus disease 2019’, ‘major clinical study’, ‘middle aged’, ‘telemedicine’, ‘health care access’, ‘digital health’
Cluster 4 (Yellow)	Pandemic-era Digital Competence and Educational Resilience	8	‘COVID-19’, ‘digital competence’, ‘early childhood education’, ‘epidemiology’, ‘humans’, ‘pandemic’, ‘pandemics’, ‘United States’

Cluster 3 examines the connections between digital literacy, healthcare, and technological access. Words such as "adult," "controlled study," "digital health," "telemedicine," "health care access," and "coronavirus disease 2019" suggest a thematic connection between digital literacy and public health. This group highlights how access to and use of healthcare technologies outside the classroom are influenced by digital literacy. The terms "middle-aged" and "major clinical study" in Table 5 suggest that this field of study frequently examines how adults and carers help children explore health-related topics on the internet, particularly during the COVID-19 pandemic. Additionally, the cluster emphasises the significance of digital literacy in fostering equitable health communication, particularly in telehealth contexts. This cluster essentially illustrates the increasing convergence of the domains of technology, health, and education. In an increasingly digital environment, it reflects how digital literacy improves access to health resources for children and helps adults make better health decisions.

Cluster 4 illustrates how digital literacy and education have evolved in response to the COVID-19 pandemic. Through the use of key terminology like "COVID-19," "digital competence," "early childhood education," "pandemic," and

"epidemiology," this group is associated with the global movement towards remote learning and digital adaptation. This field of study examines how educators, parents, and young learners swiftly acquired digital abilities to enable learning to continue during lockdowns. The terms "humans," "United States," and "pandemics" indicate that a significant portion of the data was derived from extensive research on the responses of various demographic groups to digital schooling. This group also discusses the concept of educational resilience, which holds that technological proficiency is now crucial to ensuring that everyone has access to education during disasters. The discussions focus on how this will impact policy and advocate for long-term adjustments to enhance technology-based early childhood education programs. Overall, by demonstrating how digital literacy can help people survive global shocks, this group emphasises the crucial role it will play in the long term in creating adaptable, future-ready educational institutions.

4. DISCUSSION

Beyond mapping publication trends, the findings reveal

critical structural imbalances within the field. The dominance of Western countries suggests that existing digital literacy frameworks may be shaped by socioeconomically advantaged contexts, potentially limiting their applicability in developing regions. This raises concerns about the global transferability of digital literacy models and highlights the need for more context-sensitive, inclusive approaches. Additionally, the heavy reliance on cross-sectional studies suggests a lack of longitudinal and intervention-based research, limiting the ability to understand long-term developmental impacts of digital literacy among children.

In addition to the overall mapping, a temporal interpretation of the dataset reveals a clear shift in research focus across the period analysed. Studies published between 2021 and 2022 primarily emphasised issues related to digital access, basic digital skills, and the initial integration of technology into learning environments. In contrast, publications from 2023 to 2025 demonstrate a transition towards more advanced and multidimensional themes, including digital well-being, computational thinking, and sustainability-oriented digital literacy. This progression reflects the maturation of the field from access-driven concerns to competence- and impact-oriented discourse. It also suggests that post-pandemic educational research has moved beyond emergency digital adoption towards more holistic considerations of quality, equity, and long-term educational sustainability.

The bibliometric analysis shows that between 2021 and 2025, research on children's digital literacy development grew dramatically worldwide, underscoring the topic's growing importance in education and society. Publication production increased, particularly in 2023 and 2024, in tandem with the shift to remote and hybrid learning approaches in schools worldwide following the pandemic. Digital education is becoming more inclusive, according to recent work from developing nations, while significant research from nations such as the US, UK, Australia, and China highlights the field's global reach. This temporal shift further reinforces the dynamic evolution of digital literacy research, highlighting how scholarly attention has expanded from foundational access issues to more complex dimensions of digital engagement and sustainability.

According to the co-citation analysis, the field's intellectual underpinnings were derived from multidisciplinary theories in education, psychology, and media studies. Prominent works highlight self-efficacy, creativity, and critical involvement, highlighting digital literacy as a multifaceted notion. Digital competence and educational innovation, which emphasises teacher creativity and readiness; socioeconomic inequality and the digital divide, which addresses equity and accessibility; literacy practices in the home and family, which emphasise intergenerational mediation; STEM and computational literacy, which connects digital engagement to inclusivity and problem-solving; and digital well-being and screen time management, which emphasises healthy and balanced technology use, were the five main research directions identified by thematic clustering.

Digital literacy, COVID-19, and educational resilience were found to be significantly correlated by the co-occurrence analysis, which designated the pandemic as a critical turning point. To demonstrate methodological rigour and identify prospects for longitudinal research, researchers are increasingly using quantitative, cross-sectional methods. As demonstrated by these findings, digital literacy is a fundamental 21st-century skill critical to learning, creativity,

and overall well-being. To continue advancing towards SDG 4: Quality Education and prepare children to be responsible and engaged in the digital world, future research must address equity gaps, improve relationships between families and schools, and incorporate digital ethics and well-being into the curriculum.

From a sustainability perspective, digital literacy must be understood not merely as a technological skill but as a critical enabler of equitable education, social inclusion, and lifelong learning. The integration of digital literacy into early education systems directly builds resilient societies capable of adapting to technological disruptions. However, without addressing persistent digital inequalities, the expansion of digital learning risks reinforcing existing socioeconomic disparities rather than alleviating them.

4.1 Theoretical implications

The results of this bibliometric study support the theoretical development of digital literacy as a multifaceted concept that includes cognitive, social, emotional, and ethical skills. According to the classification of co-cited works, children's digital literacy development is based on ecological and socioconstructivist viewpoints and emphasises learning through interactions within educational, technical, and family systems [38]. The influence of contextual and psychological factors on digital competence is demonstrated through the integration of frameworks such as the European Digital Competence Framework for Educators (DigCompEdu) and Bandura's Self-Efficacy Theory [34].

The study's theoretical underpinnings conceptualise digital participation as a societal phenomenon, going beyond simple technical skill [31]. Furthermore, the confluence of literacy, STEM, and digital well-being theories highlights digital literacy as a critical component of 21st-century learning and identity building [28, 29]. Therefore, by viewing digital literacy as a dynamic, context-dependent construct that engages with pedagogy, equity, and human development rather than as a static set of skills, this study advances theory.

4.2 Practical implications

The results highlight the pressing need for comprehensive educational policies and instructional practices that support children's digital literacy development in a fair and inclusive way. The adoption of pedagogical frameworks is necessary for educators to incorporate creativity, problem-solving, and ethical use of technology into early education curricula [33, 53]. To assist students use digital resources efficiently, teacher training programs should incorporate digital competency development that satisfies international criteria such as DigCompEdu [34]. Another crucial element is family engagement; initiatives that teach parents safe internet usage can help keep children safe online and limit their screen time [40].

In rural and impoverished areas, policymakers can help reduce the socioeconomic digital divide by facilitating access to resources and infrastructure [41, 43]. In addition, schools must strike a balance among screen time, mental health awareness, and responsible technology use to foster digital well-being [56, 59]. These approaches, when combined, ensure that children acquire not only technical skills but also the resilience and ethical consciousness necessary to succeed in a technologically dependent world.

4.3 Sustainability implications

The findings of this study position children's digital literacy as a key driver of sustainable development, particularly in advancing inclusive and equitable education. Digital literacy contributes to sustainability by enabling access to information, fostering critical thinking, and supporting lifelong learning pathways. In alignment with Sustainable Development Goal 4 (Quality Education), the development of digital competencies among children ensures that future generations are equipped to participate meaningfully in knowledge-based societies.

Furthermore, addressing the digital divide is essential for achieving social sustainability. The unequal distribution of digital resources and skills continues to marginalise vulnerable populations, reinforcing educational inequalities. Therefore, policymakers must prioritise equitable access to digital infrastructure, teacher training, and community-based digital education initiatives.

Finally, integrating digital well-being into literacy education supports sustainable human development by promoting responsible, balanced technology use. This ensures that technological advancement does not come at the expense of children's psychological and social well-being, thereby aligning digital transformation with long-term societal sustainability goals.

5. CONCLUSION

This bibliometric analysis offers a thorough overview of the international research landscape on children's digital literacy development, marked by its transdisciplinary growth and shifting conceptual underpinnings. The findings show that, in addition to technical competence, digital literacy today encompasses moral, creative, and cognitive participation in social and educational contexts. The discovered clusters demonstrate the complexity of children's digital learning experiences. These clusters focus on important topics, including family mediation, STEM integration, digital well-being, pedagogical innovation, and socioeconomic justice. The study also highlights how, since the COVID-19 epidemic, which altered our perception of digital skills as critical for social inclusion and sustaining learning, research on digital literacy has accelerated significantly.

In line with Sustainable Development Goal 4 (Quality Education), this study highlights the critical role that digital literacy plays in facilitating inclusive and equitable education. Promoting digital literacy in children enables them to participate in knowledge societies, overcome technological obstacles, and acquire lifelong learning skills. Teachers, families, legislators, and researchers must constantly collaborate to create robust educational ecosystems in the future. Teaching pupils to use technology from an early age will help create a more sustainable, inclusive, and informed society, while also preparing them for the demands of a digital future. Thus, fostering children's digital literacy is not only an educational priority but also a strategic investment in building sustainable, inclusive, and future-ready societies.

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