

Educational Digital Divide: A Mapping of Inequalities in Access to and Use of ICT in Public Schools in Latin America (2020–2025)

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ABSTRACT:

The article presents a systematic review of articles indexed between 2020 and 2025 that address the use of digital technologies to enhance research competence in high school students in science. In accordance with the PRISMA 2020 guidelines, 38 studies were selected, predominantly from Europe, Asia, and Latin America. The findings suggest that virtual laboratories, interactive simulations, data analysis, and collaborative platforms facilitate the development of scientific competencies, including hypothesis formulation, experimental design, and data interpretation. A substantial body of research suggests that these resources are most effective when incorporated into constructivist pedagogies and active approaches to learning. However, there are several challenges that have yet to be addressed, including the digital divide, infrastructure issues, teacher preparation, and difficulties in curricular integration. These barriers primarily affect public schools and environments with limited technological access. The research posits that the digital transformation of science education necessitates the implementation of policies that encompass infrastructure, continuous teacher training, and equity. Furthermore, the importance of longitudinal studies that analyze the long-term effects of technology-mediated inquiry learning cannot be overstated.

Keywords: Educational technology; science teaching; active learning; digital resources; research skills.

1. Introduction

In recent years, digital technologies have been incorporated into various aspects of education,

thereby gradually transforming the learning process, particularly in the scientific disciplines. In this stage, the cultivation of inquiry competence becomes

paramount. Students are expected to engage in active learning, inquiring into the subject matter, conducting independent research, meticulously analyzing data, and establishing connections between their observations and scientific explanations (Kang et al., 2023). A plethora of resources, including virtual laboratories, simulators, data software, and collaborative platforms, have emerged as potential supports for such purposes (Santos & Pérez, 2022). However, despite the prevailing optimism, there is still much to be learned about their actual impact: to what extent do they influence practice? Do the effects of these interventions depend on the context in which they are implemented, the manner in which they are administered, and the pedagogical support provided?

The advent of the pandemic precipitated the acceleration of these processes, as numerous institutions were compelled to mandate the incorporation of virtual platforms within a remarkably brief timeframe. This phenomenon served to underscore both the immense potential of technology and its inherent limitations (UNESCO, 2022). Some studies have identified enhancements in student engagement and the acquisition of scientific knowledge (Morales et al., 2023), while concurrently underscoring disparities in access, inadequate teacher preparation, and cursory utilization (García & Torres, 2024). Consequently, it is imperative to examine contemporary evidence, methodologies, and lacunae to facilitate sustainable progress.

This article explores studies published between 2020 and 2025 on how digital technologies support inquiry learning in secondary education. The PRISMA 2020 guideline (Page et al., 2021) was used to organize the review systematically. The study had three objectives: to map the main research lines in the field, identify the contexts of use and the most frequent tools, and determine the challenges faced by teachers. In doing so, the review organizes the available evidence and offers practical guidance for educators and educational policymakers.

2. Methodology

2.1 Research design

This systematic review of the literature employed a review design to synthesize and critically evaluate the most recent evidence on the use of digital tools to strengthen research competence in secondary education. The review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement (Page et al., 2021) to ensure methodological transparency and reproducibility. The PRISMA methodology is a systematic approach to the identification, selection,

and analysis of empirical studies, with the objective of identifying trends and gaps in the existing literature.

2.2 Research questions

The review addressed the following key questions:

1. What technologies favor the development of research capacity in secondary science education in the period 2020-2025?
2. What difficulties and limitations have been encountered when using them in the field of education?
3. What digital tools and pedagogical strategies develop students' research capacity?

2.3 Search strategy

A comprehensive search was conducted in Scopus, Web of Science, ERIC, ScienceDirect, and SpringerLink. Articles published from January 2020 to March 2025 were considered to capture post-pandemic educational changes and recent developments in virtual learning environments. The search terms included “digital tools,” “technology-enriched learning,” “research competence,” “science education,” “secondary education,” and “STEM learning.” Boolean operators (AND/OR) were used, and the search strings were adapted to the syntax of each database. Documents from recognized organizations, including UNESCO (2022), were also examined to complement the peer-reviewed evidence.

2.4 Inclusion and exclusion criteria

The selection process followed the four PRISMA phases: identification, screening, eligibility, and inclusion. The inclusion criteria were:

- Peer-reviewed journal articles published between 2020 and 2025 in English or Spanish.
- Studies focused on secondary education, particularly science and technology education.
- Empirical or review studies examining the use of digital tools to develop research competence or related constructs, such as scientific reasoning and experimental design.

The exclusion criteria were:

- Studies focused exclusively on higher education or primary education.
- Non-academic reports, theses, or conference abstracts not subjected to peer review.
- Studies addressing digital competence without incorporating inquiry-learning methodologies.

After duplicate records and studies that did not meet the eligibility criteria were removed, 38 studies were selected for the final analysis.

2.5 Data collection and analysis

A standardized data extraction form was designed for the following variables: authors, year, country, objectives, methodological approach, sample characteristics, digital tools used, and results found. The collected data were then subjected to thematic analysis, a process that led to the identification of relationships, challenges, and shared evolutions among the research participants (Santos & Pérez, 2022).

Quantitative data, including effect size and learning outcomes, were extracted. Qualitative data were coded to identify common themes, such as pedagogical cohesion, teacher training, technological limitations, and student engagement.

The findings were organized into two main areas: the convergence of digital tools with inquiry learning, and the emerging challenges and future research directions.

2.6 Ethical considerations

Because this study analyzed publicly accessible literature and involved no human participants, ethical approval was not required. The review nevertheless followed academic integrity standards through accurate citation, attribution to original authors, and transparent interpretation of the evidence (Page et al., 2021).

3. Results

3.1 Overview of the selection process

Following PRISMA 2020, the review was organized into four stages: identification, screening, eligibility, and inclusion. The database searches initially yielded 1,256 records. After duplicates were removed and the inclusion and exclusion criteria were applied, 38 studies remained in the final synthesis.

The step-by-step selection process is summarized in Table 1, and the study flow is presented according to the PRISMA structure in Table 2.

Table 1. Summary of the literature selection process (PRISMA 2020)

Stage	Description	Records (n)
Identification	Articles retrieved from Scopus, Web of Science, ERIC, ScienceDirect, and SpringerLink.	1,256
Duplicate removal	Duplicates removed using Mendeley and manual verification.	312
Screening	Titles and abstracts reviewed for relevance.	944
Excluded during screening	Non-relevant topics, primary education, or unrelated digital skills.	706
Eligibility	Full-text articles assessed according to the inclusion criteria.	238
Excluded during eligibility	Studies did not focus on research competence or lacked empirical evidence.	200
Final inclusion	Studies meeting all criteria and included in the synthesis.	38

Table 2. Flow of information through the PRISMA phases

PRISMA phase	Action	Result
Identification	Records identified (n = 1,256)	Initial database search
Screening	Records screened (n = 944)	Titles and abstracts reviewed
Eligibility	Full-text articles assessed (n = 238)	Inclusion criteria applied
Inclusion	Studies included in the synthesis (n = 38)	Final corpus for analysis

3.2 Characteristics of the included studies

The 38 selected studies were conducted between 2020 and 2025, reflecting a strong post-

pandemic emphasis on digital transformation in education. The majority of research came from Europe (34%), Latin America (29%) and Asia (26%),

while a smaller number originated from North America (11%).

The methodological distribution shows that quantitative (45%) designs slightly outperformed qualitative (34%) and mixed (21%) approaches. The

most recurrent digital tools included virtual labs, data simulation software, and learning management systems (LMS) such as Google Classroom and Moodle.

Table 3. Geographical and methodological distribution of included studies (n = 38)

Region	Studies, n (%)	Predominant methods	Representative digital tools
Europe	13 (34%)	Quantitative; mixed	PhET simulations; Moodle
Latin America	11 (29%)	Qualitative; mixed	Google Classroom; Edmodo
Asia	10 (26%)	Quantitative	Virtual laboratories; mobile applications
North America	4 (11%)	Quantitative	InquiryHub; Kahoot!; Labster

3.3 Thematic synthesis

The thematic synthesis identified four main trends and three cross-cutting challenges in the use

of digital tools to develop research competence. These themes were derived from coded data using a constant-comparison approach.

Table 4. Main thematic trends identified in the studies

Trend	Description	Illustrative studies
Integration of virtual simulations and laboratories	Greater use of interactive simulations and virtual laboratories to strengthen experimental reasoning.	Morales et al. (2023); Kang et al. (2023)
Collaborative research platforms	Use of digital environments that support peer collaboration and online research communities.	Santos & Pérez (2022); García & Torres (2024)
Data-based learning	Introduction of tools for data collection and visualization, improving analytical research skills.	Kang et al. (2023)
Post-pandemic innovation	Renewed curricular emphasis on hybrid learning and teachers' digital literacy.	UNESCO (2022); García & Torres (2024)

Table 5. Main challenges identified in the studies

Challenge	Impact on competence	Reported causes	References
Digital divide	Unequal participation and learning outcomes between schools.	Socioeconomic disparities and limited connectivity.	UNESCO (2022)
Teacher preparation	Inconsistent use of digital tools.	Insufficient professional development and digital training.	Santos & Pérez (2022)
Pedagogical integration	Fragmented or superficial use of technology.	Curricular rigidity and limited guidance.	García & Torres (2024)

3.4 Synthesis of the evidence

The extant research indicates that the integration of digital tools with constructivist pedagogies fosters enhanced research competence among students. The quantitative data demonstrated significant changes in the student's research

performance, particularly in the formulation of hypotheses and the interpretation of data. However, qualitative research consistently encountered barriers to teacher adaptation and contextual constraints, especially in public schools in developing countries. Therefore, although digital innovation is an engine

for research-based learning, its effectiveness is contingent upon the comprehensive training of teachers, the technological infrastructure, and pedagogical coherence.

3.5 Summary of findings

- The extant literature offers substantial evidence that the integration of digital tools into research processes leads to significant enhancements in research competence.
- The utilization of simulations and learning management systems (LMSs) emerged as the most efficacious technologies for facilitating learning through scientific discovery.
- The existence of disparities is evident in the domains of equity, infrastructure, and pedagogical alignment.
- It is recommended that subsequent studies employ longitudinal and comparative designs to ascertain the long-term implications on disparate education systems.

4. Discussion

This review indicates that the integration of digital tools in the secondary science classroom modifies the learning process for students. The synthesis of 38 studies indicates that technology facilitates students' hypothesis formation, data collection, and analysis, as well as the construction of scientific explanations, when incorporated with inquiry learning in a pedagogical context (Kang et al., 2023; Morales et al., 2023).

The findings also show that effectiveness depends on the local context, including teachers' ability to use digital environments and the availability of technological infrastructure (García & Torres, 2024; UNESCO, 2022). Consequently, the pedagogical value of digital tools does not arise from novelty alone; it results from their integration into a school environment that promotes autonomy, collaboration, and reflection.

The extant studies suggest that technology is a tool and not a replacement for the knowledge explored. Digital symbiosis, defined as the integration of technology into education to enhance students' scientific agency, design experiments, data manipulation, and in-depth discussions (Santos & Pérez, 2022), is a key component of effective teaching practices. Virtual laboratories and simulations have been developed as tools to facilitate the creation of safe and engaging environments in which students can experience science firsthand.

Consequently, numerous studies have identified the pedagogical advantages of digital collaborative spaces, including online consultation platforms and cloud-based tools, which facilitate collective work

and the exchange of ideas. These institutions serve as crucibles for scientific communities, fostering intellectual and social competition within the scientific realm (Morales et al., 2023).

However, there are still obstacles that prevent the equitable use of digital tools. Teacher training consistently demonstrates notable shortcomings; a significant proportion of educators encounter challenges in integrating digital technologies beyond a superficial level, primarily due to inadequate training or institutional support (Santos & Pérez, 2022). Consequently, technology is frequently incorporated as an informational instrument rather than a research instrument. Moreover, academic limitations and assessment methodologies impede the adoption of research-based digital learning methodologies. The existence of these structural barriers signifies the necessity for substantial modifications to the education system, encompassing the curriculum, assessment methodologies, and training protocols.

Educators therefore need institutional support to implement research-based learning objectives and integrate digital technologies beyond their use as simple information-delivery tools.

These results align with prior research emphasizing the constructivist potential of digital tools in fostering active learning and scientific inquiry (Santos & Pérez, 2022). However, in contrast to the pre-pandemic era, the 2020-2025 literature reveals a transformation in educational models, with a shift towards hybrid and mixed approaches. The global digital transformation of education and virtual labs was accelerated by the pandemic (UNESCO, 2022).

In the contemporary educational landscape, metacognition has emerged as a pivotal aspect of student learning, with digital tools playing a pivotal role in fostering autonomy and exploration in the learning process. This indicates that post-pandemic education does not entail an emergency digitalization, but rather a deliberate digital pedagogy, predicated on the capacity for inquiry and scientific thinking of the twenty-first-century society.

Furthermore, science curricula should integrate digital research skills, including problem solving, information analysis, and reflective thinking. Longitudinal studies are needed to establish the influence of digital tools on students' research competence, while comparisons across socioeconomic and cultural contexts could show how digitally mediated inquiry develops in different education systems.

Furthermore, the study necessitates a multifaceted research approach that integrates quantitative data on school performance with

qualitative narratives from students and teachers. This research would address how technology favors exploratory learning in complex classrooms.

The subsequent challenge confronting educators and policymakers is not to digitize research, but rather to humanize technology and ensure that technological innovation fosters the curiosity, creativity, and critical thinking that are integral to 21st-century science learning.

5. Conclusions

This systematic review of the literature, conducted in accordance with the PRISMA 2020 statement, examined the most recent trends and challenges associated with the utilization of digital tools in fostering research competence within the context of science education at the secondary level during the period between 2020 and 2025. A synthesis of 38 empirical and theoretical studies indicated that the integration of digital tools is conducive to the development of research competence in students. This effect is strongest when technologies are used for clear pedagogical purposes and are supported by teachers' experience.

Evidence indicates that technologies such as virtual laboratories, simulations, and online collaborative platforms engage students in active processes of exploring scientific concepts, designing experiments, and analyzing data, which are characteristic of inquiry learning. These results align with constructivist theories, which postulate that students should function as active participants in their own learning rather than as passive recipients of information.

However, the review identified systemic barriers that persist in impeding the full realization of the potential of digital research in education. The digital divide—the disparity in access to devices and connectivity—persists, particularly in economically disadvantaged educational institutions. However, the dearth of adequate teacher training and the rigidity of curricula impede the effective integration of technology in pedagogical practices. In the absence of training and institutional support, digital tools are merely conduits of information, rather than generators of research and knowledge.

A comprehensive approach to review policies and practices is required, integrating technological, pedagogical, and organizational dimensions. The sustainable digital transformation of science education is predicated on two fundamental investments: first, investment in infrastructure, and second, development of research-based curricula.

The establishment of continuous learning communities for educators is imperative. Ensuring equitable access to technology is imperative for students from all economic backgrounds to engage in technological learning opportunities.

A review of the extant literature reveals a paucity of longitudinal and comparative studies that examine the impact of digital tools on research competence in diverse cultural and educational contexts. The challenge lies in the transformation of research through digital innovation, with the objective of cultivating inclusive, reflective, and inquiry-based classrooms. These classrooms must be designed to stimulate curiosity, critical thinking, and scientific literacy in the 21st century.

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