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Digital Innovations in Science Education in the Philippines: A Scoping Review of Teaching Practices and Tools

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ABSTRACT

This scoping review examined digital innovations in Philippine K–12 science education during and after the COVID-19 pandemic. Guided by the PRISMA-ScR framework, 37 peer-reviewed studies published between 2020 and mid-2025 were systematically analyzed through thematic synthesis guided by defined inclusion and exclusion criteria. The analysis found that teachers relied heavily on accessible platforms such as Messenger, Google Meet, Zoom, and Canva, while learning management systems like Google Classroom and Quipper provided structure for content delivery and assessment. Locally developed innovations, including gamified applications, virtual laboratories, simulation-based modules, and home-based experiments, were also integrated to support conceptual mastery. These tools were embedded in pedagogical approaches such as flipped classrooms, online collaborative learning, and inquiry-based strategies, which improved engagement and flexibility but also raised concerns between simplifying content for accessibility and sustaining scientific accuracy. Reported benefits included strong motivation, participation, and self-efficacy, though evidence was often short-term and context-specific. Persistent challenges such as poor connectivity, unequal device access, and limited teacher preparation constrain effectiveness, particularly in rural and underserved schools. Findings highlight the need for sustained professional development in digital pedagogy, targeted infrastructure investment, and scaling of locally relevant content if digital instruction becomes not only an alternative solution during crisis but a pathway toward long-term equity and innovation in Philippine science education.

Keywords: digital science instruction, scoping review, educational technology, Philippine education, blended learning

INTRODUCTION

The digital transformation of education has significantly reshaped how science is taught and learned, particularly during and after the COVID-19 pandemic. In the Philippines, the sudden shift to remote and blended learning compelled science educators to utilize digital tools such as Facebook Messenger, Google Meet, PowerPoint, and Canva into their instructional practices (Abareta & Prudente, 2025; Rivera, 2024). While these platforms enabled instructional continuity through asynchronous access, real-time engagement, and flexible lesson delivery, their use also raises questions about how digital modalities align with the demands of science education, where experimentation, inquiry, and hands-on learning are central. In a digitally unequal structure like that in the Philippines, the reliance on such tools highlights concerns between accessibility and the integrity of scientific learning practices.

Yet the growing body of literature on digital learning in Philippine education remains fragmented, particularly with respect to K–12 science. Many existing studies concentrate on higher education or general online learning environments (Yeung et al., 2021; Momani et al., 2023), leaving limited insight into science-specific innovations in basic education. Systemic barriers like unequal access to devices, poor internet connectivity, and digital illiteracy among both teachers and students further complicate the task (Bustillo & Aguilos, 2022; Gonzales et al., 2022). These constraints not only limit participation but also disproportionately affect science practices that require experimentation, data collection, and collaborative inquiry. Compounding this challenge is the limited preparation of teachers for technology-enhanced pedagogy and the scarcity of longitudinal studies assessing the impact and sustainability of digital science instruction (Chin et al., 2022; Rondubio & Gantalao, 2025).

With this, the present study conducted a scoping review of 37 research articles published between 2020 and mid-2025, drawn from Scopus and ERIC databases, to systematically map the landscape of digital science teaching innovations in Philippine K–12 education. Guided by the PRISMA-ScR framework, the review examined the types of digital tools employed, pedagogical strategies adopted, benefits reported, challenges encountered, and gaps in the literature. By synthesizing these findings, this study seeks to provide a more grounded understanding of how digital tools are reshaping science instruction in basic education. Beyond cataloging practices, it identifies enabling approaches, structural constraints, and unresolved issues, offering insights to support the design of equitable, sustainable, and context-responsive digital science education strategies in the Philippines.

Statement of the Problem

1. What digital and remote teaching strategies and tools have been employed to deliver science instruction in Philippine K–12 curriculum?
2. What are the outcomes, benefits, and challenges in the literature regarding the effectiveness of digital innovations in science teaching?

METHODS

Research Design

This study employed a scoping review design to systematically map the breadth and depth of research on digital science teaching innovations in the Philippines. A scoping review was deemed appropriate because the field remains fragmented and rapidly evolving, particularly in response to the COVID-19 pandemic, and requires an approach capable of mapping diverse forms of evidence, clarifying conceptual distinctions, and identifying knowledge gaps (Peterson et al., 2017). The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018), which provided structured direction for conducting, documenting, and reporting the review with transparency and rigor. A PRISMA-ScR flow diagram was used to illustrate the process of identification, screening, eligibility assessment, and inclusion.

Using academic journals and other reputable sources, such as Scopus and ERIC databases, the researcher meticulously selected and reviewed thirty-seven (37) relevant literature and studies published, identified by the inclusion and exclusion criteria. The search terms included filters that were applied, combining keywords such as (“digital innovations” OR “digital learning” OR “online teaching” OR “remote learning”) AND (“science education” OR “science teaching”) AND (“K to 12” OR “high school”) AND “Philippines.” The timeframe filter was set to 2020–2025 to capture literature emerging during and after the COVID-19 pandemic. Studies labeled as 2025 publications were included if they appeared as early online releases accessible by mid-2025; publication date was defined as the date of online availability. Grey literature, editorials, and non-peer-reviewed sources were excluded to ensure credibility and replicability.

Thematic categorization was conducted through an inductive coding process. The researcher initially reviewed and coded all included studies, grouping findings into preliminary categories and themes. To enhance credibility, an expert independently reviewed the coding framework and sample excerpts from the dataset. Feedback from this review were the bases for refinements in theme development, ensuring consistency and reducing potential bias.

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Eligibility Criteria

The eligibility of studies was determined through a two-stage process. At the search stage, only studies published between 2020 and mid-2025 were considered, reflecting the period when digital innovations in education accelerated during and after the COVID-19 pandemic. To ensure accessibility and scholarly rigor, the review was limited to works written in English and indexed in Scopus and ERIC. The scope was also restricted to the Philippine K–12 education context, excluding studies conducted in other countries or those that did not explicitly address basic education.

At the screening stage, the full texts of retrieved articles were examined against more specific criteria. Studies were included if they addressed the use of digital, online, remote, or blended learning tools in science instruction and demonstrated clear relevance to classroom teaching practices or innovations in the Philippine context. Both qualitative and quantitative studies were accepted, provided that they offered sufficient methodological. Exclusion criteria at this stage covered studies focusing solely on non-science subjects, those limited to higher education unless directly tied to pre-service training or professional development relevant to K–12, and those lacking full-text access. Duplicate records across databases, as well as editorials, opinion pieces, and grey literature, were also excluded from the final review.

PRISMA-ScR Flow Summary

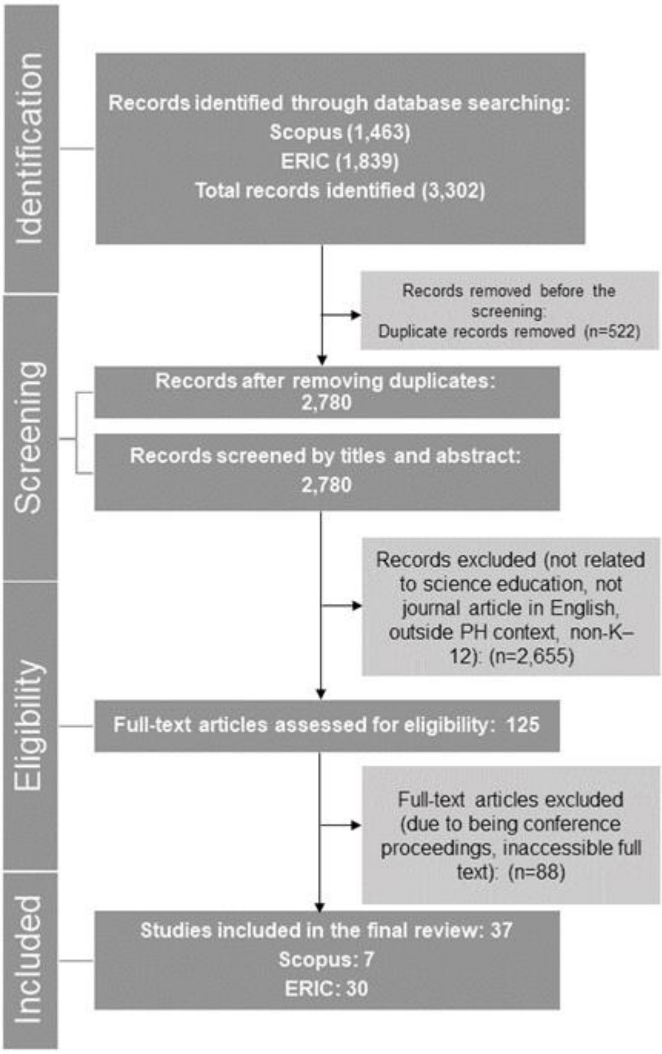

Figure 1. PRISMA-ScR flow diagram illustrating the identification, screening, eligibility, and inclusion process

RESULTS AND DISCUSSIONS

Theme 1. Digital Tools and Pedagogical Approaches in Philippine Science Education

The transition to online and blended learning during the COVID-19 pandemic compelled science educators in the Philippines to adopt a range of digital tools that varied in accessibility, cost, and pedagogical potential. Among the most widely used were communication platforms such as Facebook Messenger, valued for low data requirements and familiarity, along with presentation tools like PowerPoint and Canva, which teachers considered effective for creating visually engaging lessons (Abareta & Prudente, 2025; Balbin et al., 2025). Video conferencing tools such as Google Meet and Zoom supported synchronous interaction, though their utility was constrained by bandwidth reliability. Learning management systems (LMS) like Google Classroom and Quipper offered structured content delivery and assessment monitoring but were more consistently used in urban and better-resourced schools (Balbin et al., 2025).

Moreover, mobile phones, especially Android devices, emerged as the most accessible tool for both teachers and students, shaping the dominance of low-bandwidth and mobile-friendly platforms in science instruction. Locally developed innovations further supplemented instruction, including the WISE game for interactive learning (Ruiz et al., 2021), the Science-Inclusive Gamified Mobile Application (SIGMA) to support physics learning and inclusivity (Abenes et al., 2023), a genetics-focused virtual laboratory (Avelino, 2025), simulation-based modules on molecular biology (Cano et al., 2022), and digitized concept stories in biology (de Guzman & Magpantay, 2022). These resources, often developed within specific research or community contexts, demonstrated targeted benefits in conceptual mastery, motivation, and retention.

The effectiveness of these tools, however, depended largely on the pedagogical approaches through which they were embedded. Teachers redesigned lessons to balance synchronous and asynchronous methods, simplifying content to accommodate bandwidth and home-learning constraints while also modifying assessments to maintain inclusivity (Cahapay & Labrador, 2021; Laudencia, 2024). This often produces concerns between simplifying content for accessibility and maintaining the rigor of scientific inquiry. For instance, while inquiry-based learning remained a valued goal, teachers reported difficulties sustaining authentic experimentation online, leading to increased reliance on guided tasks, simulations, or home-based experiments (Cahapay & Labrador, 2021; Robledo et al., 2023).

Several pedagogical models emerged as particularly prominent. Online Collaborative Learning (OCL) encouraged critical thinking and peer exchange but relied heavily on stable internet and consistent participation (Pabores, 2024). Flipped classroom designs improved engagement and performance when students had reliable access to micro-content and when teachers provided structured feedback; in contexts lacking these supports, flipped instruction sometimes devolved into unsupervised content exposure (Villarica, 2023). Newer models, such as graphic organizer–integrated astronomy lessons (Endiape et al., 2023), mobile-based physics modules (Samosa, 2021), and computer-supported collaborative learning (CSCL) in Earth Science (Ramirez & Monterola, 2022), reported targeted gains in logical thinking, collaboration, and content retention, but these findings were generally bounded by short-term studies.

The success of these pedagogical shifts was closely linked to teachers' technological pedagogical content knowledge (TPACK) and their confidence in using digital tools (Cahapay & Anoba, 2021). Evidence suggests that limited training sessions were insufficient; more consistent, practice-based professional development produced deeper integration of digital strategies into classroom practice (Chin et al., 2022). In this sense, digital tools served not as standalone innovations but as enablers whose impact was dependent on pedagogical design and teacher capability.

Theme 2. Opportunities, Benefits, and Challenges of Digital Science Instruction

Digital innovations created new opportunities for enhancing science teaching and learning, though their benefits were uneven and often accompanied by persistent challenges. On the positive side, widely used platforms such as Facebook Messenger, Google Meet, and Canva supported continuity and interactivity, while digital games and STEAM-focused activities were linked to higher motivation, reduced absenteeism, and stronger teacher integration of technology into pedagogy (Hunter & Fitzgerald, 2021; Atilano-Tang & Cirilo, 2023). Purpose-built digital tools demonstrated specific learning benefits: simulation-based molecular biology modules improved student mastery of abstract processes (Cano et al., 2022), a genetics virtual laboratory supported understanding of heredity (Avelino, 2025), and home-based experiments promoted science self-efficacy and enjoyment (Robledo et al., 2023). The SIGMA app, in particular, showed promise in supporting inclusivity by improving physics performance among mainstream learners and those with hearing impairments (Abenes et al., 2023). Hybrid science learning models further generated positive student feedback and performance outcomes when implemented with clear scheduling and scaffolding (Gabor & Camano, 2023).

Yet the strength of evidence behind these benefits varied considerably. Many studies were exploratory, relying on self-reported engagement or short pre–post interventions rather than controlled or longitudinal evaluations (Robledo et al., 2023; Cano et al., 2022). As a result, claims of improved learning outcomes should be interpreted cautiously and recognized as context-specific rather than universally generalizable. Emerging technologies such as ChatGPT have also been noted for assisting teachers in lesson planning and personalization, though current evidence highlights efficiency gains more than direct learning outcomes, raising questions about academic integrity, learner autonomy, and instructional design (Ramos et al., 2024).

Balancing these opportunities are enduring barriers. Infrastructure limitations like poor connectivity, lack of devices, and resource scarcity in rural and underserved communities remain the most pressing issues, deepening inequities between urban and rural learners (Bustillo & Aguilos, 2022; Mae & Monteza, 2025; Kunjiapu et al., 2025). Capacity gaps also persist, as many teachers report limited ICT training, high workloads, and psychosocial stressors that impede consistent innovation (Fabito et al., 2020; Baticulon et al., 2020; Rondubio & Gantalao, 2025). Institutional constraints, such as weak digital governance and inefficient module distribution systems, further complicate the sustainability of digital instruction (Gonzales et al., 2022; Volante et al., 2025).

Importantly, these challenges are interrelated. Infrastructure gaps narrowed inquiry activities to low-bandwidth formats, while limited professional development left teachers without strategies to adapt inquiry-based practices under such conditions (Cahapay & Labrador, 2021; Chin et al., 2022). The result was often compounded disadvantage in rural and low-income settings. Nevertheless, coping mechanisms and localized solutions were documented: home-based experiments with accessible materials (Robledo et al., 2023), offline modules paired with periodic digital check-ins (de Guzman & Magpantay, 2022), and device-sharing or bandwidth-scheduling arrangements at the school level (Rivera, 2024; Volante et al., 2025). These demonstrate the resilience of educators and communities in sustaining science instruction amid structural inequities. Taken together, the opportunities and challenges reveal that digital science education in the Philippines is not simply a matter of tool adoption but of alignment between access conditions, pedagogical design, and teacher support. Benefits such as increased engagement, inclusion, and targeted learning gains are possible, but without systemic investments and context-responsive professional development, these gains risk remaining fragile and uneven.

CONCLUSION

This scoping review synthesized 37 studies on digital innovations in Philippine K–12 science education, highlighting both the opportunities and constraints of integrating technology into teaching and learning. The evidence shows that teachers demonstrated flexibility by adopting inclusive approaches such as flipped classrooms, online collaboration, simulations, and home-based experiments, but these strategies were not uniformly effective. Their success depended on contextual factors such as reliable connectivity, access to devices, sustained professional development, and supportive school leadership. In better-resourced settings, digital tools were associated with engagement gains and targeted learning improvements, while in disadvantaged schools, innovations often narrowed to continuity-focused practices rather than inquiry-driven science learning.

As a scoping review, the study surfaces the breadth of innovations but cannot establish causality or assess the overall quality of interventions. These limitations point to the need for further research that evaluates both the effectiveness and sustainability of digital science instruction in diverse Philippine settings. Further, the findings reveal that while digital innovations hold transformative potential for science education, their impact is fragile and uneven. The most urgent barriers, such as poor infrastructure, unequal access, and limited teacher capacity, must be addressed if digital instruction becomes not only an alternative solution during crisis but a pathway toward long-term equity and innovation in Philippine science education.

RECOMMENDATIONS

To advance digital science education in the Philippines, action is needed on four key areas: first, equip teachers through continuous, hands-on professional development that builds confidence in using digital tools for inquiry-based and inclusive science lessons; second, close infrastructure gaps by prioritizing disadvantaged schools in the rollout of affordable devices, reliable internet, and low-bandwidth solutions; third, scale up locally developed and culturally relevant digital resources such as virtual labs, gamified applications, and home-based experiments that align with curricula and learners' contexts; and fourth, establish stronger collaboration among government, schools, and private partners to pool resources and expand access. At the same time, policymakers and researchers may support longitudinal and equity-focused studies to ensure these innovations are sustainable and responsive to the needs of rural and marginalized communities.

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