Table S1. Detailed characteristics of included studies.

Reference (country; language)	Study setting and sample	Methodology	Aim	Main findings	MMAT-based methodological quality appraisal / potential sources of bias
Abylkassymova et al. (2025) (Kazakhstan; English)	200 secondary students	Quantitative	1) To analyze the effectiveness of digital resources in developing spatial thinking among secondary school students during geometry instruction.	The experimental group showed a significant improvement in spatial thinking (M = 3.5 to 4.3, $p < .001$), confirming the effectiveness of the digital methodology.	Quantitative design aligned with the aim of assessing spatial thinking in geometry instruction; main limitations: single-country sample, subject-specific intervention, and limited information on longer-term effects.
Alabdulaziz & Alhammadi (2025) (Saudi Arabia; English)	64 second grade secondary students	Quantitative	1) To evaluate the effectiveness of infographic-based DE in developing visual thinking skills and improving mathematics performance among secondary school students.	The experimental group showed statistically significant improvements in visual thinking skills and mathematics performance compared to the control group. A strong correlation was also found between both factors.	Quantitative design with a clear intervention focus and comparison of visual thinking and mathematics outcomes; main limitations: relatively small sample, specific subject context, and limited information on longer-term transferability.
Álvarez-Herrero & Hernández-Ortega (2021) (Spain; Spanish)	447 secondary students (13–14 years) and 32 teachers	Mixed	1) Assess secondary school students' acceptance of teaching plan for enhancing learning, digital competence, and environmental awareness; 2) Compare acceptance levels of environmental education activities versus others in didactic itineraries; 3) Evaluate differences in acceptance based on gender and age of secondary school students.	(DE): 1) Students demonstrated increased competence levels; 2) Reported greater interest and motivation; 3) Findings highlight the need for teacher training; 4) Participants showed improved awareness of environmental issues.	Mixed-methods design allowed examination of acceptance, motivation, digital competence, and environmental awareness; main limitations: reliance on participant perceptions and limited detail on the integration of qualitative and quantitative evidence.
Bicer & Capraro (2017) (USA; English)	563 primary and secondary students	Quantitative	1) Analyze students' mathematics growth and changes in scores after the implementation of the MathForward program.	1) The MathForward App improved middle school math performance; 2) Improvements were consistent across genders and ethnicities; 3) Lower socioeconomic students performed lower but showed similar academic gains.	Quantitative design with a relatively large student sample and outcome data on mathematics performance; main limitations: intervention-specific context and possible influence of contextual variables beyond the digital program itself.
Castaño-Muñoz et al. (2022) (Spain; English)	83,185 school leaders, teachers, and students	Quantitative	1) Assess whether the SELFIE tool attracts schools with low digital capacity and if broader digitalization programs influence its self-selection.	1) Confirms the need for digital improvement over other inhibiting factors in schools with low digital capacity in Spain; 2) The Matthew Effect favors already digitized schools, creating a cumulative advantage.	Large-scale quantitative design provided relevant evidence on school digital capacity and participation in SELFIE; main limitations: self-selection of participating schools and limited capacity to establish causal relationships.

Table S1 *(continued)*

Characteristics of included studies (I)

Castro-García et al. (2016) (Colombia; English)	470 secondary students (average age 16.1 years)	Qualitative	1) Explore the relationship between technology use that fosters communication and problem-solving and meaningful learning in the classroom.	1) Communication and problem-solving activities mediated by technology were associated with improved learning; 2) Participants reported development of logical and pragmatic skills through computer use; 3) Students expressed increased motivation; 4) Use of technology was linked to improved application of knowledge in problem-solving tasks.	Qualitative design provided contextual evidence on technology-mediated communication, problem solving, and meaningful learning; main limitations: reliance on reported classroom experiences and limited transferability beyond the specific educational context.
Chust-Pérez et al. (2025) (Spain; Spanish)	40 first grade secondary students	Mixed	1) To evaluate the impact of Flipgrid and Copilot on students' motivation and oral expression in English	1) Significant improvement in fluency, vocabulary, grammar, and motivation. Reduced anxiety. No substantial improvement in pronunciation.	Mixed-methods design captured both language-learning outcomes and motivational aspects of digital tool use; main limitations: small sample, short-term intervention, and limited generalizability.
Crook & Sharma (2013) (Australia; English)	1,245 Grade 10 science students and 47 science teachers	Qualitative	1) Examine the use of computers in promoting deep learning.	1) Teachers often maintained a teacher-centered, lower-order approach despite using digital tools; 2) Commonly used tools were low-order in Bloom's Digital Taxonomy; 3) Both groups preferred low-processing activities such as web searches and presentations.	Qualitative design offered rich classroom-level evidence on technology use and cognitive demand; main limitations: context-specific interpretation and limited transferability to other educational systems or subject areas.
Crook et al. (2015) (Australia; English)	967 secondary science students	Quantitative	1) Investigate correlations between 1:1 laptop use and student performance in science subjects.	1) 1:1 programs positively impacted student achievement in physics, biology, and chemistry; 2) Improvements in academic performance were linked to a paradigm shift, not just technology use; 3) Simulators and spreadsheets were particularly useful in physics.	Quantitative design examined associations between 1:1 laptop use and science achievement in a sizeable sample; main limitations: difficulty isolating the specific contribution of technology from broader pedagogical and contextual changes.
Faria et al. (2019) (Portugal; English)	131 primary students (8–11 years) and 8 teachers	Qualitative	1) Evaluate an educational app ('Roteiro dos Descobrimentos') for primary students exploring historical and cultural contexts.	1) Use of the app was associated with development of environmental interaction, collaboration, autonomy, and interpretation of text and images; 2) Teachers played a key role in guiding student learning.	Qualitative design provided detailed evidence on app-based learning in a primary-school context; main limitations: context-specific intervention, small teacher sample, and limited information on sustained effects.
Gigantesco et al. (2019) (UK, Bulgaria, Poland, Italy, and Lithuania; English)	283 middle school students (aged 10–15 years)	Qualitative	1) Examine students' preferences for technology tools and digital activities for supporting mental health promotion in classrooms.	1) Smartphones were preferred for communication, tablets for classroom use; 2) Students perceived collaborative games as more supportive of their learning compared to other digital activities.	Qualitative multi-country design captured student preferences across diverse contexts; main limitations: reliance on self-reported preferences and limited evidence on actual learning outcomes.

Table S1 *(continued)*

Characteristics of included studies (II)

Guillén-Gámez et al. (2018) (Spain; English)	50 high school music students	Quantitative	1) Analyze the impact of mobile devices (e.g., tablets) on students' academic performance in music.	1) Electronic devices did not negatively impact academic performance.	Quantitative design addressed academic performance in a specific music-education context; main limitations: small sample, narrow curricular focus, and limited evidence on broader educational effects.
Holguin-Alvarez et al. (2024) (Perú; English)	189 fifth grade primary students	Quantitative	1) Analyze the impact of feedback (adaptive/non-adaptive) and gamification on the academic performance of low-achieving students.	1) Students who received adaptive feedback combined with gamification showed greater improvement than the other groups. Significant results were observed in mathematics and communication. Students who received dynamic feedback showed greater academic improvements, suggesting its potential role in learning gains.	Quantitative design examined the effects of feedback and gamification on low-achieving students; main limitations: specific target population, intervention-dependent findings, and possible influence of implementation conditions.
Janssen & Phillipson (2015) (Australia; English)	112 secondary schools (number of students unspecified)	Qualitative	1) Identify schools implementing a 1:1 BYOD model and analyze the information communicated to stakeholders for safe and equitable implementation.	1) Lack of communication with families about BYOD programs impacts program success, safety, and equity; 2) Mobile phones were not considered useful learning tools.	Qualitative design provided policy- and school-level evidence on BYOD implementation and communication; main limitations: absence of student-level outcome data and reliance on available school communication materials.
Jeong et al. (2024) (International; English)	355,746 secondary students (average age 15 years)	Quantitative	1) To investigate how the accumulation of digital capital in schools, teachers, and students is related to academic performance in reading, mathematics, and science.	1) School digital infrastructure (software) is positively associated with academic performance; 2) Students' digital competencies show a strong positive relationship with academic achievement; 3) Teachers' use of ICT alone has no direct impact, but becomes effective when combined with high student digital competence; 4) Investment strategies should align with national ICT development levels—focusing on infrastructure in low-development countries and on digital skills in more advanced contexts.	Large-scale cross-national quantitative design provided robust evidence on digital capital and academic achievement; main limitations: observational design, possible measurement variability across countries, and limited causal inference.
Kastner-Hauler et al. (2022) (Austria; English)	45 students (8–14 years, 19 female, 26 male)	Quantitative	1) Evaluate newly designed teaching materials using the micro:bit and Physical Computing in primary education.	1) The BCTt (Beginners Computational Thinking test) is a valid tool for assessing lower-order computational thinking and problem-solving skills; 2) Teaching block-based coding with Physical Computing fosters computational thinking in primary students (ages 8-10).	Quantitative design used task-specific measures to examine computational thinking in primary education; main limitations: small sample, narrow age range, and limited information on longer-term retention.

Table S1 *(continued)*

Characteristics of included studies (III)

Keane & Keane (2017) (Australia; English)	135 student questionnaires (7–12 years)	Mixed	1) Explore expectations, concerns, and perceptions of students and teachers when implementing a 1:1 program.	1) Delegated leadership and collaborative professional learning are key to successful 1:1 programs.	Mixed-methods design provided evidence on expectations and perceptions during 1:1 implementation; main limitations: modest sample size and reliance on self-reported perceptions.
Kerslake & Hannam (2022) (UK; English)	360 individual children and 120 groups of three from five schools in southern England	Mixed	1) Understand English primary-school children's attitudes toward the internet and their ability to find, use, and evaluate information.	1) Students access information according to their beliefs, affecting how they interpret content (e.g., Harry Potter); 2) Findings indicate that students struggled to evaluate online information reliability, highlighting a need for improved digital literacy instruction.	Mixed-methods design offered evidence on children's online information evaluation and attitudes across several schools; main limitations: context-specific sample and limited evidence on changes over time.
Kuo et al. (2025) (Taiwan; English)	123 4th-grade elementary students in Taiwan (10-11 years)	Mixed	1) To improve oral expression skills in English through technology-supported peer assessment.	1) Peer assessment using tablets improves confidence, fluency, pronunciation, and the structure of oral discourse. Significant correlations were found between peer evaluations, teacher assessments, and final grades.	Mixed-methods design combined peer, teacher, and performance-related evidence on technology-supported oral expression; main limitations: single educational context and limited information on the durability of learning gains.
Lee & Kim (2023) (Republic of Korea; English)	3,420 elementary students (5th grade)	Quantitative	1) Determine the usage of computers and smart devices for studying and completing homework, and measure the time spent on these activities.	1) Computer-supported learning has a modest positive effect on math performance; 2) Outcomes vary by income, infrastructure, and individualized instruction; 3) Effective CSDL relies on educational hardware and personalized practices.	Quantitative design used a relatively large sample to examine computer- and smart-device-supported learning and achievement; main limitations: observational nature and possible confounding by income, infrastructure, and individualized instruction.
Llorent-Vaquero et al. (2024) (Spain; English)	1,882 Primary and Secondary School (mean age 12.31 (SD = 2.305), with a range from 7 to 20 years old)	Mixed	1) To explore the factors that facilitate the integration of digital technologies in public schools with successful practices and to design a dynamic model for public policy.	1) Digital divides persist by gender and socioeconomic status; 2) Teachers engaged in innovation and professional development show improvements in instructional practice; 3) Active engagement by the educational community was associated with better integration of digital practices; 4) Authors proposed a policy model characterized as participatory, ethical, flexible, and responsive to local context.	Mixed-methods design connected digital integration with policy and school-level factors in a relatively large sample; main limitations: complexity of contextual variables and limited ability to isolate the effect of specific digital practices.
Nieto Moreno de Diezmas & Dondarza Manzano (2016) (Spain; English)	17 primary students (5th grade)	Qualitative	1) Explore learners' emotions and conceptions about digital learning environments using the IPA (Interpretative Phenomenological Approach) approach in the LEX (Learners' EXperiences of e-Learning) project.	1) Students have mixed feelings about technology in learning, appreciating it but still valuing traditional books; 2) Although motivated by ICT, students underappreciate its importance for their future training, viewing technology as mainly for entertainment.	Qualitative design provided in-depth evidence on learners' emotions and conceptions of digital learning; main limitations: very small sample and limited transferability.

Table S1 *(continued)*

Characteristics of included studies (IV)

Panesi et al. (2020) (Italy, English)	31,912 participants (24,715 Primary/Secondary students, 5,690 teachers, 1,507 school leaders)	Quantitative	1) Investigate how SELFIE supports school communities in reflecting on students' well-being and inclusion through technology at different educational levels.	1) Lower secondary students report the most positive feelings about well-being and inclusion through technology, followed by primary and upper secondary students; 2) Socio-emotional development should be integrated with inclusion via technology.	Large-scale quantitative design provided evidence from students, teachers, and school leaders; main limitations: reliance on self-reported perceptions and limited capacity to establish causal relationships.
Rajabion et al. (2019) (Iran; English)	384 secondary students	Quantitative	1) Examine the impact of ICT on students' beliefs and the role of ICT in improving knowledge interpretation.	1) A positive relationship exists between ICT use and students' thoughts and beliefs; 2) Digital knowledge (skills, system availability, awareness) positively impacts student beliefs; 3) Findings suggest that students with access to digital training (e.g., internet use, PC skills) showed more positive beliefs about technology and learning.	Quantitative design examined relationships between ICT use, digital knowledge, and student beliefs; main limitations: correlational design and reliance on self-reported measures.
Rong et al. (2022) (China; English)	31 first-year high school students	Quantitative	1) Determine the concentration and creativity levels of middle school students.	1) AI-enhanced learning fosters entrepreneurship and boosts attention and creativity in students; 2) Human-AI interaction positively contributes to student learning.	Quantitative design explored AI- and VR-related outcomes in attention and creativity; main limitations: small sample, exploratory focus, and limited information on educational transfer or longer-term effects.
Scippo et al. (2025) (Italy; English)	35 fourth-grade primary students	Quantitative	1) To evaluate whether digital tessellation activities enhance geometric learning in primary education.	1) The experimental group showed significant improvement in the post-test; Students reported higher motivation following the use of GeoGebra and 3D printing; digital activities were associated with improved engagement and learning. The study suggests that these interventions may be beneficial for inclusion in school curricula.	Quantitative design examined a clearly defined digital geometry intervention; main limitations: small sample, specific curricular focus, and limited information on longer-term retention.
Sejdiu (2017) (Kosovo; English)	50 EP students (9–10 years)	Quantitative	1) Compare the effectiveness of multimedia in developing listening comprehension.	1) Multimedia-based (MMB)-enriched instruction benefits both learners and teachers in various educational aspects.	Quantitative design focused on multimedia-supported listening comprehension; main limitations: small sample, narrow skill focus, and limited information on follow-up effects.
Selwyn et al. (2020) (Australia; English)	1,174 high school students (11–18 years)	Mixed	1) Develop an understanding of how students experience digital technologies in school.	1) Students find technology useful for daily tasks (e.g., homework, coursework); 2) Digital tools are central to research, writing, and submitting work; 3) Students tended to interact with prescribed digital study tasks in a passive and reactive manner, according to self-reports.	Mixed-methods design provided rich evidence on students' everyday digital technology use in school; main limitations: reliance on self-reported experiences and limited direct measurement of learning outcomes.

Table S1 *(continued)*

Characteristics of included studies (V)

Slussareff & Boháčková (2016) (Czech Republic; English)	27 secondary students (14–15 years)	Mixed	1) Compare the effectiveness of learning by designing versus playing educational location-based games.	1) Location-based game design aids factual learning with no difference in interest levels between groups; 2) Active design participation positively impacts fact acquisition.	Mixed-methods design compared active game design with game playing in a classroom-based intervention; main limitations: small sample, specific intervention context, and limited generalizability.
Tallvid et al. (2015) (Sweden; English)	500 students and 60 teachers	Mixed	1) Investigate the relationship between sanctioned and unsanctioned laptop use in a 1:1 classroom, and how laptop use evolves over time.	1) No evidence that gaming students in 1:1 classroom use laptops less; 2) 1:1 classrooms require integrated pedagogy, content, and technology; 3) High unauthorized device use with varied teacher responses; 4) Students adapt behavior to classroom conditions.	Mixed-methods design provided classroom-level evidence on sanctioned and unsanctioned laptop use in a 1:1 setting; main limitations: context-specific implementation and possible variation in teacher management practices.
Varier et al. (2017) (USA; English)	18 teachers and 42 elementary, middle, and high school students	Qualitative	1) Identify key factors for selecting appropriate devices for 1:1 implementation.	1) Tablets are more effective in lower grades than higher ones; 2) Parental attitudes influence technology use; 3) Findings indicate uncertainty regarding the educational impact of the 1:1 model; teacher attitudes emerged as a key factor influencing implementation outcomes.	Qualitative design captured teacher and student perspectives on 1:1 device implementation; main limitations: small sample and limited evidence on objective learning outcomes.
Xia et al. (2023) (China; English)	323 middle school students	Quantitative	1) Examine the mediating effects of needs satisfaction in SDT (self-determination theory) on the relationship between students' AI and English knowledge and self-regulated learning, using an AI chatbot.	1) Chatbots are better for knowledge consolidation than exploration; 2) The study found a positive association between support for competence and autonomy and the promotion of SRL among students; 3) Professional development should include the mediating effects of needs satisfaction.	Quantitative design examined mediating relationships between prior knowledge, need satisfaction, and self-regulated learning using questionnaire and test data; main limitations: short intervention period, partial reliance on self-reported measures, and limited information on longer-term academic outcomes.
Yan & Li (2023) (China; English)	18,978 middle school students	Quantitative	1) Analyze the development of students' cognitive abilities through emerging DE technologies.	1) DE technology can enhance cognitive abilities with controlled variables; 2) Students demonstrate cognitive improvement with digital tools; 3) Higher cognitive capacity correlates with greater technology impact.	Large-scale quantitative design examined associations between digital education technologies and cognitive ability; main limitations: observational design and possible influence of unmeasured contextual variables.

Note. DE = Digital Education. Mixed = Mixed methods. BYOD = Bring Your Own Device. SRL = Self-Regulated Learning. SELFIE = Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies. MMAT = Mixed Methods Appraisal Tool. The appraisal was used to inform the interpretation of the evidence rather than to exclude studies.