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Early Generation Z Characteristics in Early Childhood Science Learning and Developmentally Appropriate Instructional Approaches

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Abstract
Early Generation Z children enter early childhood education (ECE) with distinct learning characteristics shaped by sustained exposure to digital media and interactive technologies. These characteristics present both opportunities and pedagogical challenges for fostering early scientific literacy, particularly in relation to fragmented attention and technology dependency. This study employs a qualitative systematic literature review of 30 international peer-reviewed studies published between 2019 and 2025 to synthesize emerging evidence on Generation Z traits and developmentally appropriate science instruction. The findings indicate that effective early science learning is best supported through play-based guided inquiry, experiential STEM activities, multimodal exploration, and the strategic use of digital tools as cognitive scaffolds rather than content substitutes. Instructional approaches emphasizing modeling, questioning, and reflective dialogue when aligned with developmental appropriateness are critical for nurturing early scientific reasoning. The review provides practical implications for educators and policymakers in designing science-rich learning environments responsive to the demands of the digital era.

Keywords: Early Scientific Literacy, Generation Z, Inquiry-Based Learning, Play-Based Learning, STEM in ECE

Introduction

Early childhood education (ECE) represents a critical developmental window for shaping children's cognitive, socio-emotional, and epistemic foundations. During this stage, learning is oriented toward the cultivation of curiosity, exploration, and meaning-making through active interaction with the physical and social environment. In recent years, early childhood classrooms have been increasingly populated by "early Generation Z" children those born into a world where experience is consistently mediated by digital interfaces. This early exposure to digital technologies and interactive platforms has fundamentally reshaped how young children engage with information and navigate learning experiences.

Generation Z is characterized as the first generation fully immersed in digital ecosystems, where access to information is immediate and visual (Chardonnens, 2025). While scholarly discussion often focuses on older students, emerging evidence suggests these characteristics manifest much earlier. Young children today demonstrate intuitive familiarity with digital interfaces, a preference for high-

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intensity visual stimuli, and an expectation of immediate responsiveness (Düzenli, 2021). These traits require careful pedagogical consideration in ECE, where learning must remain developmentally appropriate and grounded in play-based frameworks.

Science learning in early childhood is foundational for fostering early scientific literacy. Rather than emphasizing abstract concepts, early science education focuses on developing children's innate abilities to observe, ask questions, and make sense of everyday phenomena (National Research Council, 2012). Research consistently demonstrates that early engagement with science supports positive long-term attitudes and future learning trajectories (OECD, 2019). Consequently, designing effective science learning environments is a matter of both immediate pedagogical necessity and long-term societal importance.

The digital environment surrounding Generation Z presents a complex landscape of opportunities and risks. Digital media can significantly enhance visualization, providing access to diverse representations of natural phenomena, such as time-lapse plant growth or planetary movement (Brendel et al., 2024). However, unstructured digital exposure may contribute to fragmented attention and surface-level information processing (Elkatmış, 2024). These challenges are particularly salient in science, which requires sustained observation and hands-on exploration.

Traditional ECE pedagogy emphasizes play-based learning as the primary vehicle for development. Through play, children actively construct knowledge and negotiate meaning with peers (Hmelo-Silver et al., 2007). In science, play-based inquiry enables children to investigate phenomena in ways that align with their cognitive capacities. Guided inquiry strengthens this by providing adult scaffolding that supports children's questions without imposing rigid academic structures (Urdanivia Alarcon et al., 2023). Furthermore, developmentally appropriate STEM experiences, such as pattern recognition and simple problem-solving, can meaningfully support early scientific thinking when they integrate physical manipulation with digital supports (English, 2016; Yang et al., 2024).

Instructional design must also account for cognitive load. Young learners are susceptible to overload when exposed to fast-paced digital stimuli (Saxena, 2021). Therefore, modern approaches such as microlearning and short inquiry cycles allow children to engage deeply without overwhelming their cognitive resources (El-Thalji, 2025). Despite these developments, a gap remains between Generation Z research, which typically focuses on older learners, and ECE science literature, which often overlooks shifting media habits.

This study seeks to bridge this gap by synthesizing international research on Generation Z characteristics and early childhood science education. By mapping specific learner traits to instructional approaches, this review aims to provide a framework for designing science-rich environments that integrate play, social interaction, and purposeful digital scaffolding. Specifically, this analysis is guided by two research questions: 1) What defining characteristics of early Generation Z

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children influence their engagement with science learning in ECE?; 2) Which developmentally appropriate instructional strategies effectively support early scientific literacy and inquiry habits for this digital-native cohort?.

Method

This study employed a qualitative systematic literature review to synthesize contemporary research on Generation Z characteristics and early childhood science learning. A systematic review design was selected to ensure methodological transparency, rigor, and comprehensive coverage of relevant scholarship.

Electronic databases including Scopus, Web of Science, ERIC, ScienceDirect, and Google Scholar were systematically searched using combinations of keywords such as Generation Z, early childhood science, digital-native learners, and inquiry-based learning. Boolean operators were applied to refine search results and ensure relevance.

The selection process followed a multi-stage screening procedure:

1. Identification: A total of 124 records were retrieved through database searches.
2. Screening: After removing duplicates, titles and abstracts were reviewed, resulting in 58 articles eligible for full-text assessment.
3. Eligibility: Studies were included if they were peer-reviewed journal articles published between 2019 and 2025 and explicitly addressed Generation Z characteristics or digital learning within early childhood contexts. Studies focusing exclusively on secondary or higher education were excluded.
4. Inclusion: Following full-text evaluation, 30 international studies met the criteria and were included in the final synthesis.

Quality Appraisal Procedure To ensure the integrity of the findings, the quality of the selected 30 articles was evaluated based on the following criteria:

1. Methodological Soundness: Each study was assessed for clear research questions and appropriate data collection methods.
2. Relevance: Articles were prioritized based on their direct contribution to ECE science pedagogical frameworks.
3. Credibility: Only studies published in reputable, peer-reviewed international journals with transparent reporting were included.

Data Analysis Selected articles were analyzed thematically using an inductive coding approach, focusing on learner characteristics and instructional strategies.

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Results

Based on the thematic synthesis of the reviewed studies, a conceptual framework was developed to systematically map identified Generation Z characteristics onto developmentally appropriate instructional strategies for early childhood science learning. This framework integrates learner traits, associated pedagogical risks or opportunities, and corresponding instructional responses. The resulting model is presented in Figure 1.

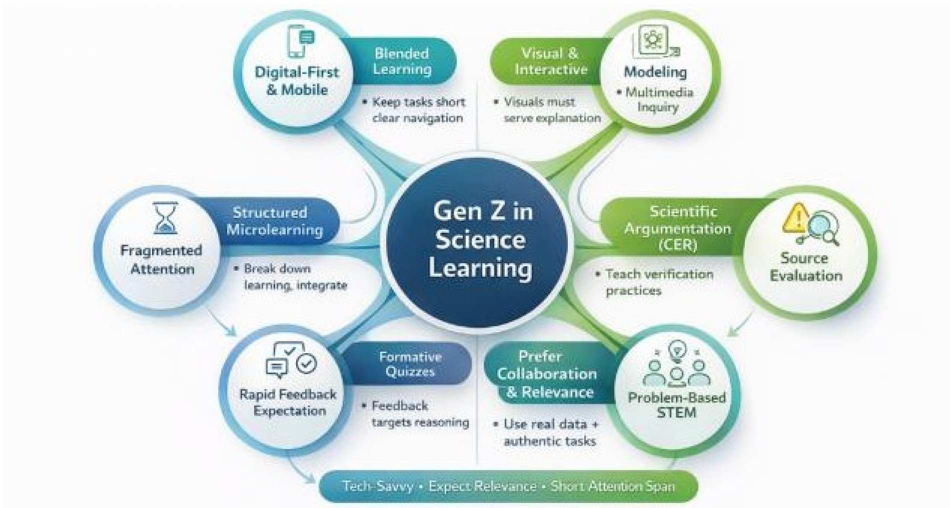

Figure 1. *Conceptual Framework Mapping Generation Z Characteristics to Developmentally Appropriate Early Childhood Science Instruction*

Figure 1 presents the conceptual framework derived from the thematic synthesis. The framework maps Generation Z characteristics to developmentally appropriate pedagogical strategies in early childhood science learning. To address digital-first and mobile familiarity, blended learning with short, structured tasks is recommended. Fragmented attention is mitigated through microlearning cycles that segment complex concepts. Visual and interactive preferences are supported through multimedia inquiry modeling, while rapid feedback expectations are addressed via formative assessment targeting reasoning processes. The model further emphasizes early scientific argumentation practices and problem-based STEM activities to foster collaboration, relevance, and critical thinking.

Identified Generation Z–Relevant Characteristics for Early Childhood Science Learning

Across the reviewed literature, consistent patterns were identified regarding characteristics of early Generation Z children that are highly relevant to science learning in early childhood education. One dominant characteristic is a digital-first orientation, marked by early familiarity with touch-based devices, visual interfaces, and interactive digital content. Studies indicate that young children increasingly

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engage with digital media as part of their everyday experiences, shaping their expectations for learning environments that are responsive, interactive, and visually rich (Düzenli, 2021; Brendel et al., 2024).

A strong preference for visual and interactive information was also consistently reported. Generation Z children respond positively to images, videos, animations, concrete models, and hands-on materials, particularly when these elements support exploration and meaning-making (English, 2016; Yang et al., 2024). This preference creates significant opportunities for engagement in early science learning, especially when instruction emphasizes observation, manipulation of objects, and sensory exploration.

Another prominent characteristic is the expectation of rapid feedback. Young learners naturally seek immediate responses from adults and their environment, which aligns with early childhood pedagogical practices such as dialogic interaction, modeling, and observation-based assessment (Fandrejewska, 2025). When feedback is timely and process-oriented, it supports motivation and emerging self-regulated learning skills.

The literature also highlights the importance of collaboration and social learning. Science learning in ECE frequently occurs through shared exploration, peer interaction, and guided play. Social interaction supports language development, reasoning, and the co-construction of understanding (Hmelo-Silver et al., 2007). Additionally, children show a strong demand for relevance and authenticity, engaging more deeply with science activities connected to familiar contexts such as plants, animals, water, weather, and everyday physical phenomena (OECD, 2019).

Despite these opportunities, several challenges were consistently identified. Fragmented attention and short attention spans are frequently associated with digitally rich environments, posing risks to sustained inquiry (Saxena, 2021). Children are also vulnerable to cognitive overload when exposed to overly complex or fast-paced stimuli. Moreover, early exposure to digital media increases the risk of superficial understanding or misinformation, particularly when representations of scientific phenomena are not mediated by adults (Elkatmış, 2024; Osborne et al., 2016).

Instructional Methods Most Frequently Recommended for Gen Z–Responsive Early Childhood Science Learning

The literature review identified several instructional approaches that are most frequently recommended for aligning Generation Z characteristics with developmentally appropriate science learning in early childhood education. The most prominent approach is play-based guided inquiry, which allows children to explore scientific phenomena through play while receiving scaffolding from

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educators (Urdanivia Alarcon et al., 2023). This approach supports curiosity, observation, and early explanation without imposing formal academic demands.

Simple STEM and project-based learning (PjBL) activities were also frequently recommended, provided they are designed at an appropriate level of complexity. Research emphasizes that STEM experiences in ECE should focus on exploration, pattern recognition, and problem-solving processes rather than product-oriented outcomes (English, 2016). Blended and experiential learning approaches combining hands-on activities with limited digital support, were found to enhance engagement when digital tools were used to visualize or extend real-world exploration (Brendel et al., 2024).

Gamified microlearning approaches were highlighted as effective for addressing short attention spans, as they allow learning to be segmented into brief, meaningful exploratory episodes (El-Thalji, 2025). While formal scientific argumentation is not developmentally appropriate in ECE, early forms of explanation, prediction, and justification were identified as foundational practices supporting later scientific reasoning (National Research Council, 2012; Osborne et al., 2016).

Model-based inquiry using physical models, drawings, and simple simulations was consistently recommended to support conceptual understanding in young children (National Research Council, 2012). Additionally, foundational computational thinking activities, such as sequencing, pattern recognition, and simple decomposition, were identified as appropriate for early childhood contexts when embedded in play and inquiry (Yang et al., 2024).

Table 2. *Mapping Generation Z Characteristics to Suitable Early Childhood Science Teaching Methods (Comparative)*

Gen Z Characteristic (ECE-Science Relevant)	Learning Risk / Opportunity	Suitable Science Teaching Methods	Key Design Notes
Digital-first & mobile familiarity	Opportunity for multimodal access	Blended learning, interactive visual exploration	Limit screen time; adult mediation required
Visual / interactive preference	High engagement potential	Concrete modeling, hands-on exploration, multimedia inquiry	Visuals must support meaning, not distraction
Rapid feedback expectation	Supports motivation & early SRL	Immediate verbal feedback, observation-based assessment	Feedback targets learning processes
Collaboration & social learning	Strong peer learning leverage	Collaborative play, group inquiry, STEM play centers	Guided interaction and clear roles
Desire for relevance	Enhances meaning-making	Contextual science learning, everyday phenomena	Use familiar and local contexts
Fragmented attention	Risk to sustained inquiry	Microlearning, short inquiry cycles	Segment then integrate experiences

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Gen Z Characteristic (ECE-Science Relevant)	Learning Risk / Opportunity	Suitable Science Teaching Methods	Key Design Notes
Misinformation exposure	Risk to early scientific literacy	Guided inquiry, adult explanation routines	Emphasize observation and evidence
Tool / AI exposure	Opportunity & dependency risk	Digital tools as scaffolds, not information sources	Prevent passive consumption

The following table presents an original synthesis by the author, rather than a direct adoption of existing models, by integrating international literature on Generation Z learning traits with pedagogical requirements in early childhood education. This synthesis specifically maps how innate digital-native characteristics, such as visual preferences and rapid feedback expectations, can be managed through guided inquiry and developmentally appropriate scaffolding. By aligning proposed teaching methods with the mitigation of cognitive risks like fragmented attention, this framework provides a tailored approach to building scientific literacy in the digital era.

Discussion

The findings of this review highlight that effective science learning for Generation Z children in early childhood education should be understood as a problem of pedagogical alignment rather than technological adoption. The characteristics identified are digital familiarity, preference for visual and interactive experiences, expectation of rapid feedback, and social orientation, do not automatically translate into meaningful learning outcomes unless they are intentionally matched with developmentally appropriate instructional structures.

First, the strong digital-first orientation and visual preference of Generation Z children create clear opportunities for engagement in early science learning. Visualizations, multimedia resources, and interactive tools can support children's understanding of phenomena that are difficult to observe directly. This finding aligns with prior research emphasizing that technology in ECE should function as a cognitive scaffold rather than a substitute for embodied learning experiences (National Research Council, 2012).

Second, the expectation of rapid feedback, often interpreted as a challenge in older learners can be reframed as a pedagogical asset in early childhood contexts. Young children naturally seek immediate responses from their environment and caregivers. When educators provide timely verbal feedback, modeling, and reflective questioning, this expectation supports motivation and emerging self-regulation. Importantly, feedback in early science learning should focus on processes such as observing, comparing, and explaining, rather than on correctness of answers.

Third, collaboration and social learning emerged as central characteristics that strongly align with early childhood learning principles. Science learning in ECE

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is inherently social, occurring through shared exploration, dialogue, and play. The findings suggest that collaborative inquiry and STEM play centers are particularly effective when educators establish clear roles, norms, and guidance.

Fourth, fragmented attention was identified as a significant challenge for Generation Z children, particularly in digitally rich environments. The review suggests that microlearning and short inquiry cycles can effectively address this issue when used strategically. In early childhood contexts, segmenting learning into brief exploratory episodes allows children to remain engaged while preventing cognitive overload.

Fifth, the issue of misinformation exposure, though often discussed in relation to older learners, is increasingly relevant in early childhood due to children's exposure to digital media. While young children may not critically evaluate sources, they are influenced by the representations they encounter. Guided inquiry, adult explanation, and questioning routines are therefore essential to help children distinguish between observation-based understanding and fictional or misleading representations.

Finally, the findings underscore the importance of positioning emerging digital tools including AI-based applications as supportive resources rather than authoritative knowledge sources. In early childhood science learning, digital tools should invite exploration, visualization, and discussion, while educators retain responsibility for framing meaning and guiding interpretation. This approach helps prevent early dependency on tools and supports children's agency as learners.

Conclusion

The findings of this review suggest that effective science learning for Generation Z children is a matter of pedagogical alignment rather than academic acceleration. By integrating contemporary learning traits with established early childhood principles, this study offers the following streamlined policy implications and directions for future research. Policy Implications: 1) Curriculum Integration: Shift focus from rote academic content to play-based inquiry that utilizes multimodal tools for visualization; 2) Professional Development: Train educators to act as mediators who scaffold digital interactions and provide process-oriented feedback; 3) Digital Literacy Standards: Establish ECE guidelines that prioritize digital tools as scaffolds for observation rather than content substitutes; 4) Environment Design: Promote science-rich environments that balance high-engagement digital stimuli with quiet spaces for reflection and hands-on manipulation.

While this review synthesizes existing literature, several gaps remain for further investigation: 1) Longitudinal Impact: Studies are needed to track how early exposure to digital-first science scaffolding affects long-term scientific reasoning and inquiry habits; 2) AI-Human Symbiosis: Future research should examine the specific impact of AI-enabled tools on early childhood curiosity, particularly regarding the risk

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of technology dependency; 3) Cross-Cultural Analysis: There is a need for comparative studies on how different socio economic and cultural contexts influence the manifestation of Generation Z traits in science learning; 4) Neurodevelopmental Focus: Investigating the relationship between microlearning inquiry cycles and cognitive load in the digital age to refine instructional pacing.

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Declaration on the Use of Artificial Intelligence (AI)

The authors declare that they utilized artificial intelligence (AI) tools during the preparation of this manuscript. Specifically, Large Language Models (LLMs) such as ChatGPT were utilized solely for language editing, grammar correction, and ensuring the concise synthesis of descriptive sections to meet the required word count. All core ideas, research frameworks, thematic interpretations, data analysis of the 30 included studies, and final conclusions were developed independently by the authors. The authors assume full responsibility for the accuracy, integrity, and originality of the entire content of this work.

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