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Rethinking Early Childhood Music Education in the Post-Digital Era: A Music Education 4.0 Perspective

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Abstract **Original Research Article**

Early childhood music education is increasingly shaped by post-digital conditions in which musical learning develops through the interaction of children, educators, bodies, materials, sounds, technologies, and social relationships. From a Music Education 4.0 perspective, digital transformation is approached as a pedagogical process that connects technological mediation with embodied exploration, creativity, participation, and musical meaning-making. Drawing on post-digital music education, constructionist and making-centered learning, multimodal musical literacy, STREAM-oriented approaches, and participatory pedagogies, the discussion examines how emerging, immersive, and AI-mediated technologies can support developmentally appropriate and meaningful musical experiences in the early years. Particular attention is given to music production, tactile interaction, creative coding, immersive media, and artificial intelligence as resources for listening, experimentation, representation, problem-solving, and collaborative creation. Their pedagogical value is considered in relation to accessibility, educator mediation, ethical awareness, and the opportunities they create for children's agency and multimodal participation. The discussion also proposes design principles for flexible post-digital music learning environments and illustrates their application through early childhood music scenarios. Music Education 4.0 is positioned as a human-centered perspective for connecting technological change with creativity, participation, inclusion, and shared musical experience.

Keywords: early childhood music education; Music Education 4.0; post-digital music education; STREAM education; artificial intelligence; musical agency.

Introduction

Recent technological developments have reshaped the ways in which children engage with and create music, expanding the possibilities for musical expression, interaction, and learning (Young, 2018). Digital platforms, mobile devices, interactive media, games, audiovisual environments, and networked cultural practices are increasingly embedded in children's everyday musical and play experiences, contributing to the development of musical, digital, and multimodal literacies (Chu et al., 2024). Prensky's concept of "digital natives" remains a historically influential point of reference, although familiarity with digital media should not be equated with critical, creative, or pedagogically meaningful engagement (Prensky, 2001). Emerging discussions of AI-mediated childhoods further suggest that generative technologies are entering children's play, storytelling, creative expression, and learning (Nikolopoulou, 2025). Children's musical activity therefore increasingly unfolds through hybrid and multimodal forms of participation in which sound,

image, movement, gesture, play, digital media, and AI-mediated practices intersect (Nikolopoulou, 2025; Young, 2018).

This evolving landscape invites music education to reconsider how children's everyday technological and musical practices can be meaningfully connected with formal and informal learning environments (Bell, 2018). More specifically, integrating digital technologies into early childhood music education requires pedagogical designs that are developmentally appropriate, inclusive, critically informed, and attentive to children's participation and agency (Charalambidou & Mygdanis, 2025; Mantilla & Edwards, 2019; Tunberg et al., 2025). Research on early childhood digital pedagogy emphasizes play-based, project-based, problem-based, cooperative, and collaborative approaches, while showing that the educational value of technology is shaped by the relationships among children, educators, tools, and learning contexts (Li et al., 2026). Within post-digital learning environments, technology acquires pedagogical value when it extends embodied and social forms of musical exploration, representation, transformation, and sharing without replacing them (Treß, 2026).

Building on these considerations, Music Education 4.0 provides a human-centered, post-digital framework for rethinking music teaching and learning through the deliberate pedagogical mediation of emerging technologies, immersive media, and artificial intelligence (Mygdanis, 2025a). Although it engages with broader discussions of Education 4.0 and digital transformation, it resists technology-driven interpretations of educational change (Mukul & Büyüközkan, 2023). The framework draws on constructionist and making-centered perspectives that position children as active makers who construct, test, revise, and share personally meaningful artifacts (Resnick, 2017). Research on maker music education and multisensory digital music learning likewise indicates that technological mediation can support participation when it is embedded in embodied, multimodal, and educator-mediated experiences (Lee & Liu, 2025; Treß, 2026).

Bringing together post-digital music education, STREAM-oriented learning, constructionist pedagogy, early childhood creativity, and technologically enhanced musical creativity, the discussion develops a set of design principles for inclusive, democratic, and post-digital STREAM music scenarios in early childhood education. These principles are developed through the lens of Music Education 4.0. Here, STREAM refers to Science, Technology, Reading and Writing, Engineering, Arts, and Mathematics, with literacy, communication, and reflection positioned as central dimensions of interdisciplinary learning (Sun & Zhong, 2024). The discussion first establishes the post-digital and interdisciplinary foundations of the framework, then examines relevant technological domains, and finally presents the design principles alongside illustrative music scenarios.

Early Childhood Music Education within Post-Digital Music Ecologies

Early childhood music education unfolds within post-digital musical ecologies in which children's engagement with music extends across domestic and educational settings, media environments, play practices, and everyday soundscapes (Deans et al., 2005; Jandrić & Knox, 2022; Young, 2018). Young children encounter and create music through family routines, toys, mobile devices, audiovisual platforms, games, movement, voice, and social interaction (Chu et al., 2024; Young, 2018). Their musical lives therefore take shape across overlapping contexts in which formal and informal experiences, as well as embodied and digital modes of engagement, increasingly intersect. Digital play is likewise embedded in children's communication, exploration, and meaning-making practices from an early age (Chu et al., 2024).

Within these ecologies, a post-digital orientation encourages music education to move beyond polarized distinctions between digital and non-digital practices and to foster more critical and self-determined forms of participation (Buchborn & Treß, 2023). It draws attention to the ways in which materials, bodies, sounds, tools, spaces, and social relations interact in the construction of musical meaning (Mygdanis, 2025a). In early childhood

settings, this entails integrating digital tools into familiar modes of learning, including play, movement, imitation, curiosity, repetition, experimentation, dialogue, and shared discovery (Edwards & Bird, 2017; Mantilla & Edwards, 2019). As these tools become increasingly embedded in such environments, intentional pedagogical support remains important for enabling children to exercise agency in how they engage with and use them (Wilson et al., 2024).

This orientation also broadens the conception of musical knowledge. Children may develop musical understanding by arranging sonic materials, responding to visual stimuli through movement, designing interactive graphic scores, creating digital sound stories, manipulating loops and samples, constructing simple sound objects, and using tactile interfaces to connect physical gestures with digital sound (Mygdanis, 2025b). Virtual musical instruments designed specifically for young children can further connect sound manipulation with movement, experimentation, improvisation, and collaborative activity (Mygdanis, 2021). Sound-based approaches similarly suggest that practices involving recording, amplification, augmented listening, and other sonic technologies can help children develop diverse and meaningful relationships with sound and the sonic environments they inhabit (Veloso & Foletto, 2025). Across these practices, musical knowledge is constructed through action, listening, design, experimentation, and reflection.

This expanded conception of musical knowledge aligns with constructionist and making-centered approaches to learning (Mygdanis, 2025a). In early childhood music education, personally meaningful artifacts may take the form of collaborative soundscapes, body-percussion sequences, visual representations of sound, classroom-made instruments, digital sound collages, and interactive objects. Through making, social exchange, and playful experimentation, children can construct musical understanding in tangible and shareable forms (Resnick, 2017).

Playful experimentation further connects making-centered pedagogy with digital play. Young children's engagement with technology through digital play can be understood as part of play-based learning, not as a separate technical activity (Edwards & Bird, 2017). This is particularly relevant to music education because children's interactions with microphones, tablets, tactile interfaces, sound applications, and recorded voices may be simultaneously exploratory, symbolic, social, technical, and musical (Edwards & Bird, 2017; Young, 2018). Pedagogical attention should therefore focus not only on the tools being used but also on the meanings children construct through their interactions with them (Edwards & Bird, 2017; Wilson et al., 2024). Educators can build on these experiences and develop them into pedagogically meaningful opportunities for listening, composing, moving, reflecting, and creating.

Multimodality constitutes another defining dimension of post-digital musical ecologies. Young children often experience music in close relation to gesture, image, movement, language, emotion, and social interaction. A musical idea may be expressed through sound, facial expression, movement, drawing, storytelling, rhythmic action, or interaction with digital media (Barrett, 1997; Suh & Jang, 2023; Young, 2018). This multimodal character provides an important foundation for inclusive music education by offering children with diverse sensory, linguistic, cognitive, cultural, and motor profiles multiple pathways for expression, engagement, and participation (CAST, 2024; Frid, 2019). Responsive and sensor-based technologies can further support musical participation when integrated into embodied, sensory, and educator-mediated experiences (Lee & Liu, 2025).

The relational dimension of post-digital musical ecologies is equally significant. A music classroom can be understood not only as a physical space for instruction but also as a relational configuration in which children, educators, materials, technologies, bodies, sounds, tasks, cultural references, and institutional expectations interact (Clement, 2019; Jandrić & Knox, 2022). Within such a configuration, maker-oriented music practices can foster participatory and empowering forms of music education when grounded in critical attention to

agency, accessibility, and technological constraints (Treß, 2026). Taken together, these dimensions frame post-digital early childhood music education as an embodied, multimodal, participatory, and critically mediated approach to musical learning. This conceptualization provides a foundation for examining how interdisciplinary STREAM structures can organize and support these forms of inquiry, representation, and making.

From STEAM to STREAM: Interdisciplinary Pathways for Early Childhood Music Education

The expansion of STEAM into STREAM provides a productive framework for conceptualizing early childhood music education as an interdisciplinary, creative, and participatory domain of learning. STEAM has developed as an integrated educational approach that brings together science, technology, engineering, the arts, and mathematics within connected learning experiences, addressing some of the limitations associated with fragmented disciplinary teaching (Mygdanis, 2025b; Perignat & Katz-Buonincontro, 2019). By incorporating reading and writing, STREAM extends this model and foregrounds the roles of literacy, communication, representation, and reflection in interdisciplinary learning (Sun & Zhong, 2024). Its interdisciplinary and inquiry-oriented character is consistent with early childhood pedagogies in which experimentation, construction, artistic expression, and play are interwoven within shared learning experiences (Veziroglu-Celik et al., 2026).

Music offers a generative context for this form of interdisciplinary integration. Exploring sound can prompt inquiry into vibration, resonance, timbre, and intensity, while rhythmic activities can make patterns, sequences, duration, and repetition perceptible and open to manipulation (Acosta et al., 2024; Deans et al., 2005). Constructing sound-producing objects can introduce elements of engineering thinking through material selection, testing, adjustment, and redesign (Mygdanis, 2025a; Resnick & Silverman, 2005). Digital sound manipulation can support technological exploration, while singing, movement, storytelling, and visual representation sustain the artistic, embodied, and expressive dimensions of the learning experience (Mygdanis, 2025b; Young, 2018).

The inclusion of the arts within integrated STEAM learning broadens its epistemological orientation by positioning imagination, expression, interpretation, and aesthetic judgment as integral to the construction of knowledge (Mygdanis, 2025a). In music education, this orientation recognizes that children think, inquire, and make meaning through sound, gesture, rhythm, image, space, and interaction. STEAM-oriented music learning can therefore engage cognitive, sensory, social, and affective dimensions of understanding. It also resonates with constructionist and making-centered perspectives, according to which knowledge develops through creating, testing, revising, and sharing meaningful artifacts (Resnick, 2017). More broadly, this orientation aligns with international perspectives that position culture and the arts as central to inclusive, creative, culturally responsive, and sustainable learning (UNESCO, 2024).

The additional “R” brings literacy, communication, reflection, and language more explicitly into interdisciplinary learning. Its emphasis on reading and writing helps explain how children represent, document, describe, communicate, and interpret their experiences (Sun & Zhong, 2024). This broader understanding of literacy connects communication, symbolic meaning-making, and critical reflection with inquiry and creative production (Makrakis, 2022). In early childhood settings, the “R” in STREAM can therefore be interpreted broadly to encompass oral language, emergent writing, symbolic representation, narrative thinking, visual marks, vocabulary for describing sound and music, gesture-based communication, and children’s attempts to articulate and interpret their experiences (Flewitt et al., 2015). Invented notations, for example, can function as early symbolic systems through which children communicate their musical thinking (Barrett, 1997). Research on children’s musical representations similarly shows how such notations can reveal the ways in which children organize and express musical ideas (Suh & Jang, 2023).

From this perspective, reading and writing extend

beyond decoding and encoding written language to include interpreting, representing, narrating, documenting, and communicating musical experience (Flewitt et al., 2015; Sun & Zhong, 2024). This understanding also aligns with conceptions of musical literacy as a multimodal and multicultural practice. Through singing, movement, drawing, invented symbols, storytelling, language for describing sound and music, and shared digital and non-digital forms of representation, young children can connect musical understanding with language, identity, culture, social inclusion, and collaborative participation (Argyriou, 2025).

Digital storytelling offers one practical expression of this expanded literacy by bringing together narrative voice, images, graphics, music, and sound within multimodal forms of expression (Rahiem, 2021). A soundscape project, for example, may involve collecting and classifying environmental sounds, constructing a story around them, arranging them into a sequence, developing graphic symbols, performing the resulting composition, and discussing how it evolved through collaborative decision-making. Such practices can deepen children's awareness of their sonic environment (Deans et al., 2005). A single musical project may therefore integrate scientific observation, technological mediation, engineering design, artistic decision-making, mathematical patterning, and emergent literacy.

Problem-oriented inquiry provides another productive connection between STREAM and early childhood music education (Perignat & Katz-Buonincontro, 2019; Veziroglu-Celik et al., 2026). Young children can investigate practical and imaginative challenges through sound, such as recreating a storm with classroom objects, composing music for a story character, or constructing an instrument that produces contrasting timbres (Argyriou, 2025). In addressing such challenges, children observe, test, listen, negotiate, revise, represent, and communicate. Making is therefore central to STREAM music education because it enables children to participate as creators, builders, performers, listeners, designers, and collaborators. Activities such as composing, recording, coding, constructing, arranging, improvising, manipulating materials, designing sound objects, and producing multimodal performances can support creativity, collaboration, computational thinking, and problem-solving through musical action (Acosta et al., 2024; Mygdanis, 2025b; Resnick, 2017).

The creative learning spiral and the 4Ps framework of projects, passion, peers, and play offer a complementary means of understanding these processes (Resnick, 2007, 2017). Early childhood music experiences may begin with children's curiosity, develop through playful experimentation, and gradually take shape as collaborative projects that lead to shared artifacts or performances. This cyclical process allows children to revisit, revise, and reinterpret their ideas through new sounds, movements, materials, and narratives without following rigid linear sequences (Resnick, 2007). Such an approach is consistent with early childhood learning because it connects musical inquiry with imagination, embodiment, peer interaction, and iterative exploration. Within the 4Ps framework, personally meaningful projects, intrinsic motivation, peer collaboration, and play operate as interconnected conditions for creative learning (Resnick, 2017).

Despite these possibilities, STREAM remains an emerging and comparatively underdeveloped field, particularly in early childhood research and practice (Phang et al., 2023; Sun & Zhong, 2024). Existing studies of STREAM in preschool settings offer useful insights into interdisciplinary integration, thematic module design, and implementation challenges, although they are not primarily situated within music education (Phang et al., 2023). Their relevance here lies in how they conceptualize interdisciplinary design in early childhood education. STREAM is therefore approached here as a flexible design orientation, not a fixed curricular formula. It organizes musical learning around exploration, communication, construction, reflection, and participation, while Music Education 4.0 provides the human-centered and post-digital pedagogical lens through which these interdisciplinary connections are developed.

Music Education 4.0 as a Human-Centered Design Lens

Music Education 4.0 can be understood as a human-centered, post-digital pedagogical lens for rethinking music teaching and learning within the technological, cultural, and social conditions of contemporary childhood (Mygdanis, 2025a). It contributes to broader discussions of Education 4.0 and digital transformation by foregrounding the pedagogical purposes that guide educational change (Mukul & Büyüközkan, 2023). Emerging technologies, immersive media, artificial intelligence, creative coding, tactile interfaces, and music production tools acquire educational significance when they strengthen children's musical agency, embodied exploration, collaborative creation, and reflective engagement (Bell, 2018). Their pedagogical use is situated within the interactions among the material, digital, social, and artistic dimensions of learning, with attention to the values, assumptions, and relationships embedded in technological choices (Jandrić & Knox, 2022). Digital technologies thus become part of children's musical ecologies through intentional designs that support hybrid forms of action, participation, and meaning-making (Buchborn & Treß, 2023; Treß, 2026).

Within this framework, children's agency is understood as a situated and relational form of participation through which children contribute as creators, makers, listeners, performers, designers, collaborators, and reflective meaning-makers (Correia et al., 2023; Madalozzo et al., 2025). This understanding is consistent with constructionist and making-centered approaches, according to which learning develops through the creation, testing, revision, sharing, and discussion of personally meaningful artifacts (Resnick, 2017). Children's agency is expressed through four interconnected dimensions involving creative autonomy, collaborative problem-solving, computational thinking, and sensory-emotional immersion (Mygdanis, 2025a). Creative autonomy becomes visible when children make musical choices, explore alternative possibilities, and develop individual or collective forms of expression (Madalozzo et al., 2025; Resnick, 2017). Through the negotiation of these choices, creative activity also develops as a process of collaborative problem-solving that involves distributing roles, exploring materials, and revising shared decisions. These processes engage computational thinking as children identify patterns, organize sequences, test procedures, and modify structures. Sensory-emotional immersion gives experiential depth to these creative, collaborative, and cognitive processes by connecting them with affective, embodied, and musically meaningful forms of engagement (Mygdanis, 2025b).

Positioning children as active agents also enriches the role of educators by emphasizing the design and responsive facilitation of learning environments. Educators create conditions for participation, introduce materials and provocations, observe children's responses, and adapt activities in relation to their needs, interests, emerging ideas, and forms of expression (Li et al., 2026; Scott & Lock, 2021). From this perspective, educational design develops iteratively through inquiry, observation, reflection, and pedagogical adjustment. Design thinking supports this process by connecting empathy and ideation with prototyping, implementation, evaluation, and redesign, while making-oriented approaches enable educators to investigate pedagogical possibilities through the creation and revision of concrete learning experiences (Mygdanis, 2025b; Scott & Lock, 2021). Early childhood digital pedagogy further strengthens this orientation by emphasizing participatory, play-based, and inquiry-oriented relationships among children, educators, technologies, and learning contexts (Li et al., 2026).

The human-centered orientation of Music Education 4.0 is grounded in children's voices, bodies, curiosity, imagination, sensory experiences, cultural backgrounds, social relationships, and their right to participate (Mygdanis, 2025a). Within this framework, technologies are selected and adapted according to their capacity to support meaningful musical engagement. Educational technology can therefore contribute to inclusion and equity when its design and pedagogical mediation are explicitly directed toward reducing barriers to musical participation and enabling diverse forms of

engagement and expression (Mygdanis, 2023). Flexible musical situations translate this commitment into practice by offering multiple entry points, modes of expression, and levels of pedagogical support. Children may participate through voice, movement, gesture, visual representation, physical materials, social interaction, or digital media in ways that reflect their interests, strengths, access needs, and preferred modes of participation (Tīģere et al., 2025). This flexibility aligns with Universal Design for Learning, which advocates multiple means of engagement and representation, as well as action and expression (CAST, 2024). Recent work in preschool music education further illustrates how assistive features such as gaze control, motion tracking, tactile interfaces, and chromesthesia-based mappings can create alternative pathways for musical interaction, expression, and participation (Mygdanis & Charalambidou, 2025). Research on accessible digital musical instruments likewise demonstrates how adaptable and customizable interfaces can broaden musical participation by accommodating diverse bodies, gestures, access requirements, and expressive intentions (Frid, 2019).

When children are positioned as co-creators, the framework also acquires a distinctly democratic character. Classroom music-making becomes a shared space in which choices, responsibilities, roles, and interpretations are negotiated collectively. In early childhood education, children's participation is increasingly understood both as a right and as a pedagogical condition that can benefit children, educators, and the wider educational community (Correia et al., 2023). Within music education, role rotation and shared decision-making allow children to experience different forms of contribution, while collective composition and performance can support agency, musical protagonism, interdependence, and shared authorship (Madalozzo et al., 2025). Musical learning is thereby approached as a social and relational practice shaped by the distribution of responsibilities, resources, and opportunities for expression.

Music Education 4.0 can therefore be approached as a flexible design orientation that brings together children's agency, multimodal and embodied making, purposeful technological mediation, collaborative creativity, reflective documentation, inclusion, and democratic participation. These commitments align closely with STREAM education. The following discussion examines how specific technological domains can be integrated within this human-centered and post-digital orientation.

Emerging, Immersive, and AI-Mediated Technologies for Early Childhood Music Learning

From a Music Education 4.0 perspective, emerging, immersive, and AI-mediated technologies should not be treated merely as an additional set of tools layered onto existing music education practices. Instead, they can be understood as forms of technological mediation that expand the ways in which young children listen, move, imagine, construct, represent, and share musical ideas (Mygdanis, 2025a). Previous research with students in Grades 3 to 5 explored these domains through *Digital Little Music Makers*, a 30-week music intervention focused on music production, maker practices, creative coding, artificial intelligence, and immersive technologies (Mygdanis, 2025a). A related study examined STREAM-based instructional scenarios with students in the same grade range, integrating emerging and immersive technologies, artificial intelligence, and interdisciplinary STREAM practices (Mygdanis, 2025b). These domains are reconceptualized here for preschool music education, with particular emphasis on developmentally appropriate, embodied, inclusive, and educator-mediated forms of musical participation.

Music production can be understood as the recording, editing, arranging, transforming, and creative sharing of sonic material (Bell, 2018; Mygdanis, 2021). Digital audio workstations, loop-based platforms, recording tools, and simple sound-editing applications allow children to record, repeat, organize, combine, and modify sounds (Bell, 2018; Mygdanis, 2025a). When adapted to children's developmental and musical needs, these practices

can connect classroom music with informal and participatory forms of music-making (Bell, 2018). A practical intervention with children aged 4–6 further indicated that age-appropriate music software can support active participation in authentic music teaching and learning situations and contribute to the development of musical and technological skills (Charalambidou & Mygdanis, 2025). A recorded voice, a repeated rhythm, an environmental sound, or a short loop can become material for listening, comparison, sequencing, movement, storytelling, and collaborative composition. Music production can thus function as making through sound, enabling children to develop musical understanding by manipulating, organizing, and reflecting on sonic materials, extending learning beyond the reproduction of predetermined musical content (Bell, 2018; Mygdanis, 2025a).

Tactile and maker-oriented forms of musical interaction extend this active engagement with sound. Invented instruments, sound objects, interactive installations, conductive materials, sensors, microphones, hydrophones, and interfaces that connect touch and movement with sound can transform everyday materials into musical resources (Frid, 2019; Mygdanis & Papazachariou-Christoforou, 2023). In early childhood settings, their pedagogical value lies in making the relationships among bodies, objects, gestures, tactile and haptic feedback, and sound perceptible through direct experience (Frid, 2019; Lee & Liu, 2025). A small-scale preschool intervention with Synth4kids indicates that combining gaze control, motion tracking, tactile interaction, and multisensory sound representation can support accessibility, agency, and collaborative creativity (Mygdanis & Charalambidou, 2025). Children can explore materials, test possibilities, listen to the results of their actions, modify the sounds they produce, and share their emerging constructions. Musical learning therefore develops through iterative exchanges among bodily action, material experimentation, listening, and collaborative reflection (Mygdanis & Papazachariou-Christoforou, 2023).

Creative coding offers another pathway for musical exploration when framed as a space for expression, not as an introduction to formal programming. In early childhood, it can position children as active creators in their use of technology by engaging them in problem-solving and imaginative activity, alongside social interaction, motor activity, emotional exploration, and meaningful decision-making (Bers, 2021). In music education, this orientation shifts attention away from programming syntax and toward musical play with sequences, patterns, repetition, variation, cause-and-effect relationships, and expressive choices (Acosta et al., 2024; Bers, 2021). Simple block-based and tangible programming environments can facilitate these forms of musical thinking when integrated with movement, storytelling, and collaborative play. Such environments can also support embodied learning, creative movement, iterative exploration, and social interaction in preschool settings (Sapounidis et al., 2026). Computational thinking can thus emerge through musical processes of ordering, testing, revising, debugging, listening, and sharing beyond programming instruction alone (Acosta et al., 2024; Mygdanis, 2025a).

Immersive technologies, including virtual and augmented reality, can extend spatial, embodied, and imaginative forms of musical learning when used selectively and for clearly defined pedagogical purposes (Alani et al., 2026; Mygdanis, 2025a). Virtual reality can provide opportunities to explore musical worlds, spatial sound environments, and simulated performance spaces, while augmented reality can connect digital sonic elements with physical objects and classroom environments (Alani et al., 2026; Poutiainen & Krzywacki, 2023). In early childhood education, these applications require developmentally appropriate, safe, accessible, and carefully mediated forms of use (Alani et al., 2026). Children might explore the apparent location of a sound within a virtual environment, move toward a physical object associated with a digital sound, or participate in a collaborative story that connects digital sounds with images, gestures, and classroom materials. In this context, immersion emphasizes musical presence, spatial awareness, and imaginative participation over technological spectacle (Poutiainen & Krzywacki, 2023).

Artificial intelligence introduces a distinct set of creative possibilities and pedagogical concerns. AI-mediated tools can generate musical ideas, suggest combinations of sounds, create accompaniments, provide musical prompts, and support activities involving listening, storytelling, and composition (Nikolopoulou, 2025; Shang, 2019; Väkevä & Partti, 2025). In early childhood music education, AI can function most productively as a pedagogically mediated stimulus for exploration, comparison, transformation, and discussion, with children retaining responsibility for musical choices (Väkevä & Partti, 2025). Generative AI can contribute to storytelling, multimodal creativity, and play-based learning when its use is developmentally appropriate, ethically safeguarded, and supported by educators (Nikolopoulou, 2025). Children might listen to an AI-generated musical idea and decide whether to imitate, modify, reject, represent visually, respond through movement, or incorporate it into a collaborative composition (Väkevä & Partti, 2025). Under these conditions, AI-generated output becomes material for creative response, not finished musical content accepted without question (Rohrmeier, 2022).

Beyond these creative possibilities, AI raises age-appropriate questions concerning transparency, authorship, bias, privacy, and agency (Berson et al., 2025). Addressing such questions does not necessarily require children to interact directly with an AI system or to use a digital device. Unplugged activities can represent basic algorithmic principles and decision-making processes through physical objects, movement, classification games, storytelling, and rule-based musical tasks (Lindner et al., 2019). Children might, for example, classify sounds according to a simple rule, predict which sound a fictional "music machine" would select, and then modify the rule to observe how its output changes. They can also discuss who established the selection criteria, whether different criteria would produce different results, and which suggestions the group wishes to retain, transform, or discard. Such activities connect algorithmic thinking with critical discussion without presenting AI as a mysterious or autonomous source of musical meaning. They can foster early forms of critical post-digital awareness by helping children recognize that technological outputs are shaped by rules, data, and design choices and subsequently interpreted through human judgment. This is particularly important in music education, where meaning remains relational, cultural, embodied, and affective and cannot be reduced to computational processes (Shang, 2019).

Across these technological domains, technology use should remain guided by clear pedagogical purposes. Technologies acquire educational value when they extend embodied, playful, relational, and socially shared musical learning and enable multiple forms of participation. Their selection and adaptation should therefore consider developmental appropriateness, sensory accessibility, openness to play, opportunities for collaboration, connections with embodied action, ethical transparency, data protection, educator mediation, equitable access, and musical meaning-making (Berson et al., 2025; Frid, 2019; Mygdanis, 2023). Within a human-centered Music Education 4.0 framework, technologies are selected according to their capacity to enable children to imagine, explore, construct, transform, and engage meaningfully with music and with one another.

Designing Inclusive, Democratic, and Post-Digital STREAM Music Scenarios

The preceding theoretical discussion can be translated into a set of design principles for developmentally appropriate STREAM music scenarios in early childhood education. Building on design-oriented research in music education, these principles bring together constructionist learning, Universal Design for Learning, children's participation, pedagogical documentation, making-centered pedagogy, and technologically mediated musical creativity (Mygdanis, 2025b).

Children's agency provides the central organizing principle of this approach. Inclusive STREAM music scenarios should position children as active co-creators by offering opportunities to make small but meaningful musical decisions concerning sounds, materials, movements, roles, sequences, and forms of representation (Correia et al., 2023; Madalozzo et al., 2025). Through these decisions, children

experience music not merely as content to be reproduced but as a form of expression and social action that they can actively shape (Madalozzo et al., 2025; Resnick, 2017). Participatory co-creation therefore depends on activities that remain sufficiently open to accommodate children's ideas while providing enough structure to sustain shared attention and collaborative work (Clement, 2019; Scott & Lock, 2021). Within such environments, children participate as musical agents whose expressions, preferences, and decisions contribute directly to the shared musical experience.

This emphasis on agency is closely connected with multimodal and embodied forms of making. A STREAM music scenario can provide multiple pathways for participation, including vocal play, body percussion, drawing, gesture, tactile exploration, movement, invented notation, storytelling, digital sound manipulation, object-based performance, and collaborative construction. Such multimodality is particularly important for inclusion because musical meaning can be created, represented, and communicated through different modes of action and expression (CAST, 2024; Frid, 2019; Young, 2018). A child who does not feel confident singing, for example, may contribute by selecting sounds, moving objects, triggering audio, drawing a graphic score, or helping to organize a sequence. Technologies support this process when they extend bodily and sensory engagement while preserving its central role. Tactile interfaces, accessible music software, and sound-triggering devices can help children establish tangible connections among touch, movement, gesture, and sound (Charalambidou & Mygdanis, 2024; Frid, 2019). In preschool music education, educational music software can be integrated into constructivist and collaborative learning environments in ways that preserve and extend embodied, social, and creative forms of music-making (Charalambidou & Mygdanis, 2025). This emphasis on material, embodied, and technologically mediated participation is also consistent with maker-oriented approaches to musical learning (Mygdanis & Papazachariou-Christoforou, 2023).

The democratic character of collaboration depends partly on how an activity is organized. Fixed roles can reproduce hierarchies related to confidence, language, technical fluency, musical experience, or perceived ability. STREAM music scenarios should therefore allow children to move among different forms of contribution by taking on roles such as performer, listener, sound collector, narrator, conductor, builder, recorder, mover, or designer. Role rotation can help prevent musical activity from being dominated by children who are more verbally expressive, technologically confident, or musically experienced. It can also create opportunities for collaborative decision-making, turn-taking, peer listening, collective problem-solving, and recognition of diverse contributions. Research on participatory pedagogies in early childhood education indicates that young children can act as planners, negotiators, problem-solvers, and co-designers when learning environments are deliberately structured to facilitate shared decision-making (Clement, 2019; Correia et al., 2023).

Accessibility should be embedded in each scenario from the outset. This requires technological choices to be evaluated according to their implications for equity and accessibility and their capacity to reduce barriers to musical learning, not simply according to novelty or technical capability (Mygdanis, 2023). A low-threshold, high-ceiling approach aligns with the constructionist principles of low floors and wide walls, according to which learning environments should be easy to enter while accommodating varied and increasingly complex forms of exploration (Resnick & Silverman, 2005). In STREAM music scenarios, this means enabling all children to participate with minimal technical or musical prerequisites while keeping the activity open to more complex forms of musical thinking and expression. A child may begin by recording a single sound, triggering a sample, repeating a rhythm, or drawing the shape of a sound. Over time, the same activity may develop into a more complex sound story, an interactive object, a movement sequence, or a collaborative composition. This gradual expansion allows children to experience success while also encountering appropriate levels of challenge. It supports differentiated participation within a universally designed learning environment, as

children can contribute at varying levels of complexity within the same shared musical experience (CAST, 2024).

Narrative and problem-based framing can give coherence to these varied forms of exploration and participation. Young children often engage meaningfully with learning experiences organized around stories, questions, missions, or imaginative problems, particularly when narrative structures are combined with play and multimodal expression (Rahiem, 2021). A lost sound, an animal in need of a musical home, a busy city, a story character searching for a rhythm, or an imaginary celebration requiring an instrument can provide a starting point for musical inquiry. Such prompts do more than make an activity appealing. They activate the "R" dimension of STREAM as children describe sounds, name characters, sequence events, invent symbols, negotiate meanings, and reflect on how a musical story changes (Rahiem, 2021; Sun & Zhong, 2024). Problems embedded within a narrative can also create opportunities for scientific inquiry, engineering design, mathematical patterning, technological exploration, and artistic decision-making, thereby connecting multiple disciplinary perspectives within a shared creative purpose (Perignat & Katz-Buonincontro, 2019; Phang et al., 2023).

Scaffolding and iteration help STREAM music scenarios remain responsive and avoid fixed linear sequences. Children may first explore materials freely, then organize sounds, perform, listen back, revise a sequence, add movement or narration, and present a new version. Each cycle can deepen musical understanding as children hear, see, feel, and discuss the effects of their decisions. Scaffolding supports the gradual movement from guided exploration toward more independent musical decision-making by adjusting pedagogical assistance to children's emerging confidence, understanding, and participation (Li et al., 2026; Scott & Lock, 2021). Educators may model careful listening, guide comparisons among sounds, demonstrate ways of recording samples or arranging sequences, and invite children to build on a peer's idea, gradually reducing support as they assume greater responsibility for the process. Within a design-thinking framework, iteration also shapes the educator's role, as activities are observed, assessed, adapted, and redesigned in response to children's reactions and evolving needs (Mygdanis, 2025b).

Artifacts and pedagogical documentation can make learning processes visible. In STREAM music scenarios, assessment should not be limited to the quality of a final performance but should also attend to the artifacts, processes, decisions, and reflections that emerge throughout the activity. Sound recordings, invented instruments, drawings, graphic scores, photographs of constructions, movement maps, short videos, digital sound collages, and children's verbal explanations can provide evidence of musical thinking, collaboration, experimentation, and revision. Pedagogical documentation in early childhood settings can contribute to formative assessment by making children's learning observable and strengthening communication among educators, children, and families (Buldu, 2010). It can also strengthen connections between the early childhood curriculum and families, particularly when children's creative processes and artifacts are shared in meaningful ways (Kakana & Gkloumpou, 2025).

Shared presentation extends this process by giving children's work a wider social presence. A classroom performance, sound walk, family-sharing event, or exhibition of sound objects can help children experience their work as socially meaningful. Research on music production highlights the value of connecting school music with authentic and participatory forms of musical creation (Bell, 2018). Previous work on making-centered and STREAM-oriented music scenarios similarly emphasizes authentic sharing and artifact-based participation, particularly when children's creations become part of wider classroom or community experiences (Mygdanis, 2025c).

Taken together, these principles frame inclusive, democratic, and post-digital STREAM music environments as relational learning spaces that move beyond sequences of isolated activities. Children's agency, embodied making, role rotation, accessible entry points, narrative inquiry, scaffolding, artifact-based documentation, and shared presentation

operate as mutually reinforcing dimensions of pedagogical design. Collectively, they enable young children to encounter music as a space for exploration, participation, imagination, negotiation, and shared authorship (Mygdanis, 2025b). This orientation aligns with international approaches that position culture and the arts as central to participation, inclusion, creativity, and the development of more equitable educational futures (UNESCO, 2024).

Illustrative STREAM Music Scenarios for Early Childhood Education

The scenarios presented below translate the preceding design principles into developmentally appropriate musical practices that serve as flexible entry points for STREAM-oriented learning. Each scenario brings together play, sound exploration, storytelling, embodied participation, tactile construction, simple immersive elements, AI-mediated prompts, and collaborative creation, while foregrounding children's agency, multimodal expression, cooperation, and musical meaning-making.

Imagined Forest Soundscape

Children may collaboratively create a soundscape inspired by an imagined forest, using their voices, bodies, classroom objects, small percussion instruments, paper, fabric, stones, wooden blocks, and recording devices. They can explore and compare sounds associated with wind, animals, rain, footsteps, rustling leaves, and imaginary creatures, before organizing them into a shared sonic environment.

As a post-digital extension, children may construct tactile sound stations by selecting objects that represent elements of the forest and, with careful guidance from the educator, connecting them to simple sound-triggering mechanisms or tactile interfaces. For example, touching a paper leaf might activate a recorded wind sound, pressing a stone might trigger a child's vocal imitation of an animal, and moving a strip of fabric might produce a rain-like sonic texture. Alternative access modes, including gaze control, motion tracking, and tactile sound triggering, can enable children with different motor and sensory profiles to contribute to the shared soundscape through varied forms of musical action (Mygdanis & Charalambidou, 2025). Where appropriate, a brief augmented-reality or projection-based component may introduce additional visual elements, while the children remain responsible for creating, selecting, and modifying the sonic material. The activity may culminate in a collective performance, an interactive sound installation, or a recorded soundscape.

Body-Sound Coding

The body can serve as a starting point for exploring rhythm, movement, pattern, and embodied musical thinking. Children may clap, tap, step, rub, breathe, vocalize, and move through space as they investigate the range of sounds their bodies can produce and explore how a rhythmic pattern might circulate within a group. By organizing sequences, repeating patterns, identifying changes, testing alternatives, and revising a collective performance, children engage in processes associated with computational thinking. Tangible coding may be introduced through cards depicting body-sound symbols, colored blocks representing gestures, or a floor pathway that functions as a rhythmic score.

A post-digital extension may incorporate simple recording, looping, and sound-triggering processes. Children can record a body sound, position it within a short sequence, and perform alongside the recorded pattern. Tactile pads or floor-based triggers may also activate sounds through stepping, touching, or other forms of movement. Where immersive media are appropriate, a brief spatial audio environment evoking a city, the sea, a jungle, or a playground may encourage bodily and rhythmic responses to what children hear and imagine. The scenario integrates music, mathematics, early symbolic representation, bodily awareness, technological mediation, and social coordination. It may also create opportunities for democratic participation when children contribute ideas, negotiate musical choices, and share responsibility for the collective outcome.

Everyday Object Orchestra

Everyday objects provide a productive starting point for musical exploration. Children may bring or select cups, boxes, paper tubes, spoons, pieces of fabric, stones, plastic containers, or toys and investigate the sounds these objects produce when tapped, shaken, scraped, blown, touched, or combined. Selected objects may then be connected to simple physical computing components, conductive surfaces, sensors, or sound-triggering interfaces, with careful educator guidance and appropriate safety measures. For example, a cardboard box may function as a bass drum, a spoon may trigger a recorded metallic sound, a paper tube may activate a child's spoken word, and a toy animal may produce a short melodic pattern.

Within this scenario, engineering is approached through construction and testing, science through the exploration of sound, technology through tactile interaction, mathematics through classification and sequencing, and the arts through performance and imagination. The literacy-related "R" dimension of STREAM may be addressed through object names, invented symbols, labels, short descriptions, and the collaborative creation of a story centered on the object orchestra. The resulting artifacts may take the form of a performance, an interactive classroom installation, or a short multimodal presentation shared with peers.

Multimodal Sound Story

Storytelling can integrate early literacy, sound design, and musical composition. Children may begin with a short narrative, a picture book, a classroom story, or a tale developed collectively, and then create sounds to represent characters, settings, actions, emotions, and transitions. For example, a monster may be represented by a low drum sound, a small bird by a high vocalization, a door by a scraping sound, and a magical object by a recorded or digitally transformed sound. Children may record and layer sounds, draw sound symbols beneath illustrated scenes, arrange cards into a sequence, and determine when each sound should enter the narrative.

Where appropriate, projected images, spatial audio, or a brief educator-guided virtual reality or 360-degree experience may support children's engagement with the imagined setting. Educators may also use artificial intelligence tools to generate short sound prompts, visual stimuli, or musical variations associated with the story. Children can then evaluate whether these materials reflect their narrative intentions, consider how they could be adapted, and compare them with their own creations. The scenario integrates narrative language, symbolic representation, sound exploration, sequencing, artistic expression, technological mediation, and collaborative decision-making. Democratic participation is further supported as children negotiate creative choices, decide how the story will be represented, and share responsibility for the collective presentation.

Interactive Classroom Sound Map

The classroom itself can be approached as a sonic environment for investigation. A listening walk may invite children to attend to sounds such as doors opening, footsteps, voices, chairs moving, running water, wind, bells, pencils tapping or scratching on paper, and sounds entering from outside. These sounds may then form the basis of an interactive classroom map to which children add drawings, symbols, QR codes, tactile markers, or sound-triggering points. Touching or scanning a point may activate a recorded classroom sound, a child's voice, a rhythmic pattern, or a short collaborative composition.

The scenario may culminate in a sound-walk performance during which children guide peers or families through the mapped environment while triggering or performing sounds in sequence. Through this process, the classroom is reimagined as a shared musical space, and children's listening and spatial exploration are recognized as meaningful ways of developing and communicating knowledge.

Across these examples, post-digitality does not imply greater technological complexity. Instead, the emphasis lies on creating meaningful relationships among bodies, voices, materials, digital tools, stories, images, sounds, spaces, and social

interactions. These practices may be implemented with minimal resources, such as a recording device and speakers, or extended through tactile interfaces, simple coding tools, augmented-reality sound triggers, brief immersive stimuli, or prompts generated through artificial intelligence. Across these configurations, children are invited to explore sound as material, organize it through play and inquiry, represent it through symbols and stories, transform it through physical and digital processes, and share it with others as a meaningful creative outcome.

Concluding Reflections and Future Directions

In conclusion, the discussion suggests that STREAM music scenarios can provide a meaningful framework for rethinking early childhood music education within inclusive, democratic, post-digital, and human-centered learning environments. Through the lens of Music Education 4.0, music learning is understood as a design-oriented process that foregrounds children's agency, multimodal participation, democratic collaboration, and critical post-digital awareness (Mygdanis, 2025a). This orientation is particularly relevant to early childhood because young children often encounter music through their bodies, senses, relationships, imagination, play, and engagement with materials before encountering it as a formal school subject. It also challenges narrow definitions of musical ability by recognizing movement, listening, touch, narration, drawing, construction, digital interaction, and collaborative decision-making as legitimate forms of musical participation. In this sense, post-digital music education is defined less by the presence of digital tools than by the relationships they mediate among bodies, materials, sounds, spaces, and social interactions.

Emerging, immersive, and AI-mediated technologies become pedagogically significant when they expand children's musical possibilities while maintaining opportunities for play, embodied participation, educator mediation, accessibility, and shared creation. Their value depends less on technological novelty than on their integration into participatory and inquiry-oriented pedagogies (Li et al., 2026). Digital technologies should therefore be adapted to children's musical, social, and developmental needs. Their presence alone should not be treated as an independent indicator of educational innovation. Within a human-centered Music Education 4.0 perspective, technological mediation becomes meaningful when it contributes to participation, creativity, reflection, and musical meaning-making.

Future research should examine how young children engage with STREAM music scenarios across diverse early childhood settings, including inclusive classrooms, community arts programs, multilingual environments, and culturally diverse educational contexts. The importance of examining these contexts is underscored by the role of music in supporting cultural identity, intercultural understanding, emotional expression, and social interaction during early childhood (Argyriou, 2025). Ultimately, inclusive post-digital transformation in early childhood music education depends on whether children can encounter music as a space for exploration, imagination, participation, and shared authorship. Through carefully designed STREAM music scenarios, music can become a way of listening to the world, making sense of experience, collaborating with others, and contributing creatively to more inclusive and socially responsive educational futures (UNESCO, 2024).

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