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Digital Little Music Makers: Incorporating Emerging Technologies, Immersive Practices (AR, VR), Artificial Intelligence, and STREAM Methods into Music Teaching and Learning

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Abstract **Original Research Article**

Recent technological advancements have consistently redefined the ways in which individuals engage with music, fostering novel perspectives on expression, interaction, and learning. Children of the digital age are growing up in environments that expand their musical experiences and preferences, while also posing challenges to music education. This scholarly investigation explores the emergence and evolution of learning environments through the design and implementation of STREAM-based instructional scenarios in primary education. Specifically, it examines the experiences of students in grades three through five and analyzes the utilization of emerging technologies, including music production, ubiquitous and mobile music computing, creative coding, immersive technologies, and artificial intelligence. The intervention was conducted as a music club at a private educational institution over three academic years, each comprising thirty weeks. The research approach was based on Design-Based Research, which integrates theory, design, and practice through iterative cycles aimed at developing and continuously refining authentic learning experiences. The findings indicate that students enhanced their creative expression, autonomy, self-regulation, sensory engagement, and collaborative problem-solving capabilities, while also advancing computational thinking by integrating physical and digital musical realms. Overall, this study advocates for a pedagogically sound, human-centered, and post-digital framework for music education, emphasizing a paradigm shift that aligns with the new perspectives and opportunities presented by the contemporary digital landscape.

Keywords: STREAM education, immersive technologies, artificial intelligence, emerging technologies, post-digital music teaching and learning.

Introduction

The rapid development of digital technologies is transforming the field of musical engagement and education, creating new opportunities for creative expression and equitable access to knowledge (Mygdanis, 2025a). Today's children construct musical identities in environments that differ substantially from those of their teachers (Mygdanis & Papazachariou-Christoforou, 2023). The continuous interaction between technology and music, which begins at a young age, promotes digital musical literacy and sets new expectations for music education in schools (Young, 2018). In this context, contemporary pedagogical approaches emphasize the need for instructional practices that connect to cultures of creation and multimodal learning (Mygdanis, 2025a). The move toward a post-digital outlook, where analog and digital settings coexist in balance (Treß, 2024), guides music education toward a broader idea of the musical instrument and a reshaping of how music is created, listened to, and experienced, within frameworks that foster embodied and multisensory engagement (Buchborn & Treß, 2023).

The present study aims to develop and examine a coherent pedagogical model designed to promote creative autonomy and collaborative problem-solving in real school settings. The research approach was grounded in the methodological framework of Design-Based Research (DBR) (McKenney & Reeves, 2018), while the intervention was conducted with third- to fifth-grade students at Pierce – The American College of Greece, over three consecutive academic years. The pedagogical framework draws upon STREAM education principles, emphasizes learning through making, and incorporates practices that foster the exploratory nature of musical activity.

Contemporary music-technology approaches in music education

Music education is presently undergoing ongoing transformation, with a particular focus on fostering creativity, experiential learning, and multimodal pedagogical strategies (Mygdanis, 2025a). Current trends, such as music production, the maker movement, creative coding, immersive technologies including virtual and augmented reality, and artificial intelligence, cultivate a dynamic educational environment that promotes participatory and inclusive methodologies.

Music production encompasses a wide range of processes, including conception, recording, editing, and distribution, thereby forming a cohesive domain of artistic practice (Brown, 2015). Simultaneously, the DIY culture empowers creators to assume roles such as songwriter, producer, performer, and sound designer with notable flexibility and independence (Bell, 2018). Moreover, the availability of cost-effective tools and advancements in studio technology have shifted the focus of learning toward experiential practice and reflective production (Mygdanis & Kokkidou, 2021). In educational settings, Digital Audio Workstations (DAWs) facilitate this pedagogical approach by offering visual and auditory representations that assist students in understanding musical structure and texture, even in the absence of prior instrumental proficiency or notation literacy (Dammers & LoPresti, 2020). Consequently, active engagement in production, recording, mixing, and distribution encourages students to participate within authentic, collaborative workflows (Bell, 2018; Brown, 2015). Finally, these methodologies promote informal learning strategies wherein listening, performance, improvisation, and composition naturally coexist (Mygdanis & Kokkidou, 2021).

The maker movement signifies a pedagogical transition towards meaningful construction and collaborative exploration at the nexus of art, science, and technology (Huang, 2020). In this context, the focus on creative synergies and authentic projects shifts the student from a passive recipient to an active creator of artifacts with experiential value (Mygdanis & Papazachariou-Christoforou, 2023). Likewise, tactile interfaces, as tangible objects, establish a connection between bodily experience and the digital environment, fostering embodied and multisensory learning within the music classroom (Mygdanis, 2025a). In this paradigm, the notion of ubiquitous music computing underscores a landscape where mobile devices, networks, and sensors facilitate continuous musical engagement. Consequently, educational ecosystems can incorporate DIY materials, online platforms, and distributed resources with sociocultural sensitivity (Mygdanis & Perakaki, 2023).

Music coding transforms the computer into an expressive instrument and connects music with computer science, mathematics, and physics within creative environments (Aaron et al., 2016). In this context, tactile interfaces such as Makey-Makey and microcontrollers like micro:bit facilitate the development of interactive musical initiatives that employ sensors and conductive materials in conjunction with programming (Mygdanis & Papazachariou-Christoforou, 2023). The utilization of these tools is associated with computational thinking, which functions as a metacognitive framework for analyzing problems, developing algorithmic reasoning, and recognizing patterns in musical comprehension (Mygdanis, 2025a).

Immersive technologies establish multisensory environments where virtual content is seamlessly integrated with the physical classroom, providing a clear pedagogical orientation. Virtual reality (VR) enhances experiential learning and safe experimentation in areas such as theory, listening, and performance (Poutiainen & Krzywacki, 2023). The development of virtual musical worlds aligns with maker practices and promotes both metacognitive skills and twenty-first-century skills (Mygdanis, 2025a). Augmented reality (AR) provides a versatile interface that connects the physical and digital realms, utilizing commonplace mobile devices to deliver immediate information augmentation in space (Azuma, 1997). Finally, AR music applications facilitate natural and intuitive interactions with sound while simultaneously increasing motivation and accessibility (Guclu et al., 2021).

Artificial intelligence (AI) is revolutionizing music education and engagement by offering personalized and innovative experiences without necessitating advanced prerequisites (Merchán Sánchez-Jara et al., 2024). Within this context, AI tools facilitate composition, improvisation, and experimentation in interactive and playful manners (Pan, 2022). Furthermore, analytical support concerning structure, texture, and orchestration enhances comprehension of musical form and aesthetic evaluation (NAfME, 2024). Nevertheless, beyond these advantages, the absence of pedagogical grounding in certain AI applications underscores the importance of responsible and human-centered integration (Mygdanis, 2025a). Overall, this landscape underscores the significance of a strategy that combines technological proficiency with pedagogical discernment and respect for children's creative identity (Chen, 2020).

From the transdisciplinary STEAM model to STREAM in music education

Current trends in music education emphasize STEAM — Science, Technology, Engineering, Arts, and Mathematics — as a fundamental component in designing activities and scenarios, with a significant emphasis on creativity and engagement (Mygdanis & Papazachariou-Christoforou, 2023). As a transdisciplinary methodology, STEAM integrates science, technology, engineering, the arts, and mathematics, with the objective of creating cohesive learning experiences and providing a comprehensive perspective applicable across various disciplines (Psycharis, 2018). The incorporation of STEAM is exemplified through practices that foster imagination and enhance skills in creative problem-solving (Huang, 2020).

The STEAM framework is grounded in creative learning principles, as outlined in Mitchel Resnick's spiral model, and advances through iterative cycles encompassing idea conception, design, construction, feedback, and revision. These cycles establish a structural foundation for the organization and progression of scenarios (Resnick, 2007). Additionally, the framework of the 4Ps — projects, passion, peers, play — offers a pragmatic and relevant model by emphasizing the development of meaningful projects, collaboration among peers, and playful exploration. Collectively, these components shape a pedagogy focused on creativity and active engagement (Resnick & Robinson, 2017).

The STREAM approach—Science, Technology, Reading/wRiting, Engineering, Arts, Mathematics—represents a natural progression of the STEAM framework, augmenting it with a linguistic dimension. Essentially, STREAM is not an entirely new independent model but an extension of STEAM, emphasizing literacy, reflection, and engagement with real-world problems (Makrakis, 2022). Historically, reading and writing have served as fundamental pillars of education, while contemporary methodologies now redefine their roles through innovative, reflective, and multimodal practices that accommodate diverse learning styles. Research indicates that incorporating the "R" in STEAM contexts can enhance academic performance, particularly in science and technology disciplines (Sucheta, 2022). Consequently, literacy skills assume an expanded pedagogical function, fostering synthesis, creation, and multimodal expression (Makrakis, 2022). Nonetheless, it is important to note that STREAM education has not yet been fully institutionalized or scientifically established to the same extent as STEAM and remains subject to further clarification and investigation (Phang et al., 2023).

Rationale, aim, research questions, and participants

The study's rationale concentrates on the design and implementation of an innovative pedagogical intervention intended to develop a model that accurately reflects the needs and opportunities embedded in the contemporary digital music milieu. The primary objective of this research is the development and deployment of the Digital Little Music Makers intervention to exemplify the transformative potential and added value derived from the integration of emerging technologies and creative strategies. This intervention was conceived and executed with students from third to fifth grade at Pierce – The American College of Greece, within the context of music classes. The teaching initiative was founded upon the transdisciplinary STREAM framework, aimed at enhancing student engagement, collaboration, creativity, and active participation through experiential activities and technology-enhanced experiences. The research questions are outlined as follows:

1. How do students respond to STREAM-based teaching scenarios during the implementation of the intervention, and what features of engagement and participation are revealed?
2. What appears to be the added value of integrating emerging and immersive technologies, as well as the pedagogical practices that utilize them, in primary school music education?
3. Which teaching practices emerge, and what learning benefits are identified through the implementation of the intervention?

A total of forty-six primary school students from Pierce – The American College of Greece engaged in the optional music club Digital Little Music Makers during the academic years 2022–2023, 2023–2024, and 2024–2025. Each year, the club consistently included between twenty and twenty-three students from grades three to five, convening in the institution's music classroom. Participation was voluntary, based on the children's choice, and did not require specific entry prerequisites; moreover, parental or guardian consent was obtained. Of the forty-six students, some participated across two consecutive years, while four students attended all three sessions. Additionally, the distribution of participants was equitable in terms of gender and age groups, and the students demonstrated diversity in their musical and technological interests and backgrounds.

Methodology

The current study employed a qualitative methodology to investigate students' experiences, attitudes, and perceptions (Creswell & Creswell, 2018), utilizing Design-Based Research (DBR), which integrates theory, design, and practice through iterative cycles (Mygdanis, 2025b). Within this framework, the revised three-phase DBR model by McKenney & Reeves (2018) was adopted, encompassing initial design, implementation/data collection, and analysis/redesign, with the inclusion of a "maturation" phase.

The research process was systematically organized into three consecutive phases, culminating in a stage of maturation and dissemination. The first phase (2022–2023) involved conducting a needs analysis, alongside an exploration of existing practices, constraints, and dynamics, supported by literature on embodied learning, creativity, and technology (Miles et al., 2014). Within this framework, scenarios were developed based on the philosophy of STEAM (Mygdanis, 2024). During the second phase (2023–2024), data derived from the initial phase facilitated the redefinition of objectives and the reorganization of materials, leading to the evolution of the scenarios into STREAM, which integrates VR, AR, and AI technologies. The third phase (2024–2025) concentrated on expansion and gradual theorization. During this stage, design principles were applied in a more systematic manner, addressing complex pedagogical and technological issues tailored to the needs of the group (McKenney & Reeves, 2018), and revealing recurring patterns that contributed to the development of an emerging local theory. Following the completion of this three-year process, the final stage of maturation and dissemination involved a comprehensive evaluation aimed at consolidating the findings, identifying mechanisms of learning and design, and articulating clear design principles with the potential for transfer (McKenney & Reeves, 2018).

For data collection, a triangulation strategy was employed utilizing five instruments: (a) group-focused semi-structured interviews, (b) the field diary maintained by the teacher-researcher, (c) informal discussions, (d) a diary kept by a critical friend, and (e) student artifact portfolios (Cohen et al., 2018). The interviews (SI) captured attitudes and interpretations following each cycle, were conducted with audio recording, and included obtaining parental and student consent (Miles et al., 2014). The field notes (FN) were completed at the conclusion of each session, utilizing observation keys related to engagement, interaction, and skills (Miles et al., 2014). The informal discussions (ID) documented spontaneous narratives in non-formal settings, thereby enriching the comprehensiveness of the interpretation (Cohen et al., 2018). The critical friend served as an external observer, providing reflective feedback and enhancing the reliability of the study (Creswell & Creswell, 2018). Finally, the portfolios documented the progression of projects, supporting both self-assessment and peer assessment, while also contributing to the final analysis (Creswell & Creswell, 2018).

The analysis was organized into three levels: the organization and digitization of the material, thematic categorization, and reflective interpretation of patterns (Miles et al., 2014). Subsequently, thematic analysis was employed to identify, name, and interpret recurring themes (Braun & Clarke, 2006). The procedure incorporated both primary and secondary coding techniques. The initial stage concentrated on in vivo terminology, utilizing the participants' own words to emphasize authentic phrases and meanings, with particular focus on frequency, recurrence, and emotional intensity (Creswell & Creswell, 2018). In the secondary stage, the material was re-evaluated, and primary codes were consolidated into specific categories through focused coding (Miles et al., 2014; Saldaña, 2013). The entire methodology adhered to the codes-to-theory model, facilitating a seamless transition from descriptive codes to interpretive themes and principles (Saldaña, 2013).

Digital Little Music Makers: Practical Intervention

The Digital Little Music Makers teaching intervention was conducted as a thirty-week music club each school year, engaging third- to fifth-grade students at Pierce – The American College of Greece. The intervention was developed in three phases, aligned with the school years 2022–2023, 2023–2024, and 2024–2025. Weekly sessions lasted 45 minutes and took place in the music classroom, which was equipped with an interactive whiteboard, conventional musical instruments, construction materials, tablets, and the ability to be arranged as a makerspace. Additionally, each session was preceded by a brief reflection, allowing for minor adjustments to be made flexibly based on observations and group dynamics.

A fundamental principle of the design was the voice of the children, articulated through learner-centered and autonomy-supportive practices, integrating constructivist and constructionist principles (Papademetri-Kachrimani & Louca, 2022). Simultaneously, practices such as differentiated instruction (Tomlinson, 2014), inquiry- and discovery-based learning, authentic problem-solving, and formative assessment were incorporated within a creative learning framework that involved progressively increasing levels of difficulty (Resnick, 2007). The inclusion of digital media was regarded as an extension of informal learning, involving activities both within and beyond the classroom setting (Bell, 2018). Particular emphasis was placed on hands-on practices and maker philosophy, employing STREAM scenarios that held personal significance and provided opportunities for self-regulation and improvisation (Mygdanis, 2025a). Ultimately, the approach was aligned with elements of informal music learning (Green, 2017; Folkestad, 2006) and narrative frameworks that engaged students as co-creators (Mygdanis & Papazachariou-Christoforou, 2023).

The learning process occurred within a supportive and inclusive environment (Tomlinson, 2014), characterized by a spiral design, alternating roles and tools, concise activities lasting up to 20 minutes, and scheduled breaks to maintain attention and engagement. Furthermore, each academic year was concluded with a public "concert–artifact exhibition," serving as an authentic assessment method and providing a platform for showcasing students' work (Bell, 2018).

Design axes of the intervention

The intervention's focus was on creatively constructing artifacts with personal significance for students (Mygdanis, 2025a). The conceptual mapping (see Figure 1) delineates six interconnected axes that establish a cross-disciplinary, transdisciplinary, and holistic environment: (a) immersion through VR/AR, (b) artificial intelligence with applications such as generative AI, machine learning (ML), and big data, (c) mobile computing and the Internet of Things (IoT), (d) music production using DAWs, composition, and remixing, (e) creative coding involving applications, games, algorithmic music, and computational art, and (f) the maker movement combined with ubiquitous music computing. Rooted in DBR, Phase A (2022–2023) concentrated on DAWs, music coding, and ubiquitous computing, initially termed Little Music Makers & Producers (Mygdanis, 2024). In Phase B (2023–2024), the model was augmented by incorporating VR/AR, AI, and mobile computing (Mygdanis, 2025a). During Phase C (2024–2025), the six axes were finalized, acquiring a well-defined pedagogical focus and experiential technological application. In the figure, orange lines emphasize the core axes of the intervention, whereas dashed blue lines illustrate transversal interactions.

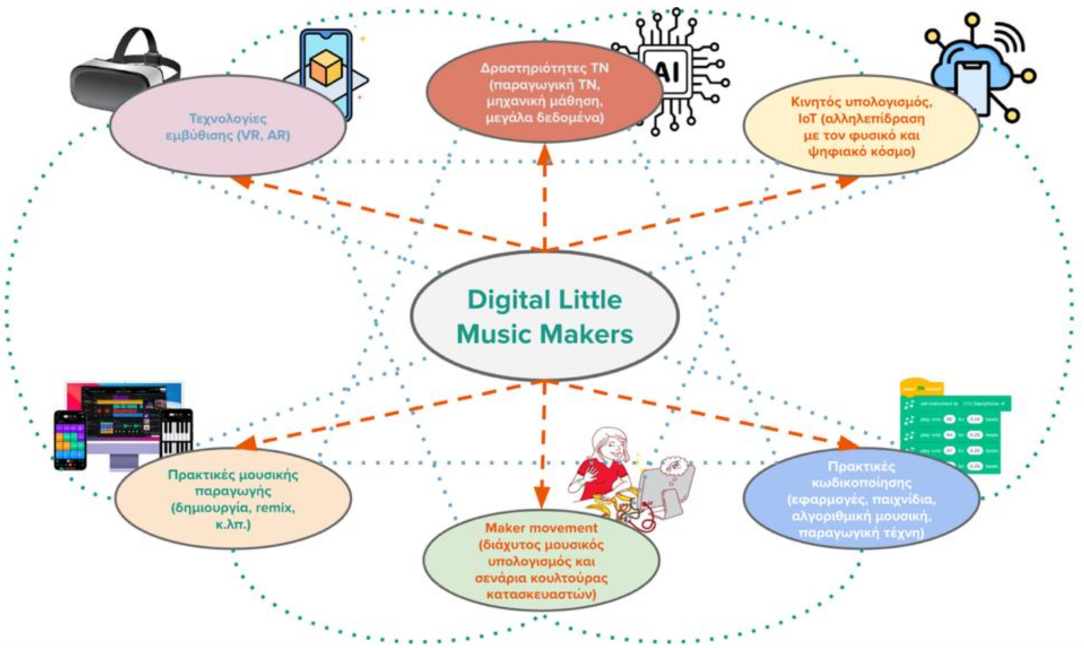

Figure 1. Design axes of the intervention.

In the field of music production, applications such as BandLab and Chrome Music Lab were utilized, offering opportunities for composition, recording, looping, sampling, and experimenting with sound effects. Open-ended narrative challenges—such as creating music for videos, designing sonic identities, or composing a "song of introduction" using rhythmic recitation of names—encouraged roles of composer, producer, and remixer, while also fostering multimodal literacy. The majority of work was conducted in pairs using tablets and headphones to facilitate collaboration without causing disturbance. Additionally, the principles of the maker movement were demonstrated through the creation of musical artifacts constructed from conductive or recyclable materials, including water, fruit, coins, and aluminum foil, utilizing Makey-Makey and micro:bit. Improvised microphones and hydrophones equipped with piezoelectric sensors were also developed, with particular emphasis on field sound collection. This hands-on learning approach enhanced computational thinking, environmental consciousness, and embodied interaction with physical space.

In the realm of ubiquitous music computing, students transformed physical experiences into digital applications by employing touch and motion interfaces that linked tangible materials with the digital environment. A notable example involved touching a banana, which triggered sound events within Scratch. The activities emphasized experimentation, genuine problem-solving, and collaborative learning. Creative coding was executed using Scratch in conjunction with Makey-Makey, leading to the development of musical games and virtual instruments. In this context, students applied core concepts such as variables, repetition, conditions, and randomness to produce automated compositions. Additionally, they established connections to physics and mathematics through timing, patterns, and rhythms. The projects were showcased during plenary sessions, thereby enhancing feedback mechanisms and fostering a sense of community among participants.

Concerning immersive practices, virtual reality (VR) and augmented reality (AR) functioned as tools for creative exploration and artistic expression. Students conducted experiments with virtual stages and orchestras employing spatial audio, as well as with augmented reality posters that activated segments of student compositions via QR codes. Moreover, they constructed micro-worlds within WebXR, generated from descriptive prompts in HTML/JavaScript with assistance from ChatGPT, integrating narrative, coding, and sound elements. Artificial intelligence was predominantly utilized as a catalyst for inspiration. Resources such as BandLab SongStarter and AIVA provided initial ideas or "sparks" for further creative development, while ChatGPT supported linguistic and narrative scenario development. Additionally, Teachable Machine was employed to train machine learning models capable of recognizing musical gestures, like Kodály hand signs or conductor movements, which were incorporated into Scratch. Reflective dialogues regarding the role and limitations of AI fostered students' critical and metacognitive skills awareness.

Overall, the proposal established a music-pedagogical microcosm, namely a flexible STREAM framework adaptable to specific contexts and serving as a foundation for new scenarios in music education (Mygdanis, 2024; 2025a).

Discussion

The analysis of the Digital Little Music Makers intervention data highlighted the transformative potential resulting from the integration of innovative strategies, practices, and technologies into music education, particularly at the primary level. The teaching intervention fostered a dynamic and inclusive environment in which students demonstrated flexibility, creativity, and a collaborative spirit. Their active participation illustrated the influence of these approaches on expanding musical and technological understanding, as well as cultivating a sustainable appreciation for music and learning. Four interconnected axes emerged, forming a framework for understanding the evolving learning dynamics. These axes emphasize the cultivation of creativity and autonomy alongside collaborative problem-solving and peer learning as mechanisms for shaping musical identity, developing computational thinking in relation to metacognitive accuracy, and engaging sensory and emotional experiences within a post-digital environment. Overall, they serve not merely as a depiction of the findings but also as a foundation for establishing the emerging local theory within the DBR framework (McKenney & Reeves, 2018).

The principles of constructionism and creative learning established the pedagogical foundation of the scenarios, emphasizing active engagement, autonomy, and innovative development through experimentation and collaborative inquiry (Resnick & Robinson, 2017). Instances of flow (Csikszentmihalyi, 2009) were frequently observed, such as when a child enthusiastically exclaimed, "I found it! Now it sounds like a song!" (FN 26). Furthermore, focusing on the creation of meaningful artifacts, whether physical or digital, served as a crucial method for developing knowledge (Mygdanis, 2025b). Simultaneously, the children's musical compositions and reflective activities demonstrated the efficacy of experiential, transdisciplinary, and holistic approaches consistent with the principles of STREAM and the maker movement (Papademetri-Kachrimani & Louca, 2022; Huang, 2020). Overall, these experiences illustrated the potential of hands-on creation and experiential learning, which are closely aligned with the principles of STREAM and constructionism (Mygdanis, 2025a; Resnick & Robinson, 2017; Hatch, 2014).

Fostering creativity, independence, teamwork, and problem-solving skills

Creative autonomy evolved within open learning environments and multimodal tools, which enabled students to cultivate personal styles and develop original expressions. In this context, children undertook an active role, transforming digital tools into artifacts imbued with personal significance (Mygdanis & Kokkidou, 2021; Dammers & LoPresti, 2020; Bell, 2018; Brown, 2015). Musical identity was characterized by the ability to make aesthetically meaningful decisions and substantiate them during public presentations, thereby reinforcing their sense of ownership over their work. Furthermore, this autonomy was demonstrated when students exceeded the initial objectives of the scenario and devised their own creative approaches.

Through digital audio workstations (DAWs), coding applications, maker practices, immersive technologies, and AI-based strategies, students recognized that musical creativity transcends mere sound production to include elements of daily life, adopting a universal and transdisciplinary perspective (Mygdanis & Papazachariou-Christoforou, 2023). From the initial stages of the intervention, they demonstrated a strong willingness to participate and gradually developed the confidence to surpass predetermined objectives and establish their own. As one student observed, "So, is it really that easy to make a rhythm?" (FN 7), while another articulated, "I want to make another [rhythmic pattern]… it will be better!" (FN 19). Similarly, the connection to informal practices was evident, as one child remarked, "What we did today reminded me of the music I make on my tablet with friends" (ID 2). Furthermore, a girl emphasized the expansion of her experience, stating, "Now I'm also thinking of images or movements to go along with it" (SI 16). Overall, the findings indicated an enhancement of autonomy, creativity, and active engagement, with musical creation functioning as an exploratory and self-directed process that extends beyond the boundaries of the classroom (Mygdanis & Papazachariou-Christoforou 2023).

During the process of artifact creation, students explored conductive materials and inventive combinations. "All of these can make sound… let's make music with everything!" (FN 22) observed one child, while another remarked, "Look what I found… it's mine and unique!" (FN 20). The sense of freedom became a fundamental aspect of the experience, exemplified by the statement, "I like that I can think of something crazy and try it… there's no right or wrong" (ID 5). The gradual increase in autonomy led students to assume greater responsibility for completing projects with minimal guidance, thereby fostering a sense of ownership and enhancing their comprehension of the connection between music and technology. As one student noted, "It's not just music, it's also a bit of science and a bit of art together" (SI 3).

Collaboration has emerged as a fundamental element of the learning process, as the sharing of ideas enhances creativity, engagement, and the collective construction of knowledge. "At first it seemed difficult to understand, but my friends helped me a lot" (ID 7), reported one student, while a peer remarked, "It's nice to make your own song, but it's even better when you work with others" (SI 25). "When we work together, it's easier to find solutions" (ID 26), according to one child, and another stated, "I was glad that someone listened to my idea and we included it in the song" (ID 14). Activities such as group pattern composition and the creation of collective artifacts further promoted experimentation, as evidenced by the remark, “Let’s combine all our patterns and see what happens” (FN 39). Additionally, collaboration played a vital role in fostering a creative classroom culture. The cycles of the 4Ps activated students’ intrinsic motivation and established an environment conducive to peer feedback (Resnick & Robinson, 2017).

The exchange of ideas was manifested through memorable phrases. “I hadn’t thought about bells, but my friend did and it turned out great” (FN 30), remarked one girl, while a classmate contributed, “In a group, one understands more quickly; someone always demonstrates the way” (ID 8). Similarly, another child observed, “It’s as if we borrow each other’s ideas and transform them into something new” (ID 17), and a girl added, “I did not create it alone, but I feel that this piece also belongs to me” (ID 20). These reflections underscore the significance of collaborative learning in nurturing creativity, empathy, and critical thinking (Mygdanis, 2024; Resnick & Robinson, 2017), which aligns with the principles of STREAM and cooperative learning. Concurrently, notable progress in technological competencies was observed. “I can operate BandLab at home” (SI 20), stated one girl, while a boy remarked, “I added rhythm and recording from home” (SI 24). The transition from guided to independent creation highlights the development of technological literacy, transdisciplinary thinking, and autonomy.

The utilization of immersive technologies notably highlighted students’ creativity within collaborative contexts, as they designed engaging musical environments and interacted with auditory and visual elements. “I felt like I was inside the music… it was magical” (ID 38), remarked one student, while a peer added, “I could change position and hear differently… like walking inside a song” (SI 21). Furthermore, in the project titled The Singing Chickens or Chickenophone, each chicken represented a musical note and was activated through hand movements, resulting in comments such as, “It’s like the music comes alive when I touch it” (SI 9) and “It’s like I’m conducting a humorous orchestra” (ID 18). The multisensory approach enhanced comprehension of spatiality and the integration of technology, movement, and storytelling within the principles of STREAM (Mygdanis, 2025a; Psycharis, 2018; Resnick & Robinson, 2017). Overall, the collaborative nature of these experiences acted as a catalyst for learning, as students recognized that creation in VR and AR becomes more meaningful when shared, ideas are integrated, and diverse contributions are pooled and coordinated.

Developing musical, technological skills, and emerging technologies

Music production served as a pivotal domain for experimentation utilizing BandLab, which was employed for composition, remixing, and editing. In activities centered on exploration and experimentation, students familiarized themselves with features, samples, and rhythmic patterns. “I didn’t know I could make something like this” (SI 5), remarked one student, while another queried, “How many times can I change the sound?” (ID 46). In collaborative projects such as Rip Time, they integrated pre-recorded samples with acoustic instruments: “I felt like a real music producer” (ID 11), commented one student. By the conclusion, they were able to associate sound with specific contexts within a transdisciplinary framework, composing music for videos, creating remixes of popular songs, and stating, “I changed the rhythm so it would match my style” (FN 45). They also crafted personal gifts, as one student articulated: “I wanted to make something for him/her by myself” (ID 23). This methodology supported learning through making and constructionism, providing an authentic and engaging environment where technology functioned as a tool for creativity and divergent thinking (Mygdanis & Kokkidou, 2021; Dammers & LoPresti, 2020; Bell, 2018; Brown, 2015).

The concept of the maker movement was demonstrated through activities that integrated everyday objects with digital interfaces. Employing Makey-Makey and conductive materials such as fruit, water, coins, or aluminum foil, students created sound-producing objects. “The banana makes a sound” (FN 12), exclaimed one child, while another remarked, “Water, wire, and a spoon… it became a drum” (ID 28). The water drum emerged as a favored project, with one girl describing it as “like playing music with magical water” (SI 42). They also conducted experiments with microphones and hydrophones, alongside field recordings such as rain: “I never imagined that rain could become music… now I hear it differently” (ID 35), shared one student. These hands-on interfaces provided an accessible and immersive method for experimentation, fostering imagination and a sense of mastery without requiring advanced electronics (Mygdanis & Papazachariou-Christoforou, 2023; Huang, 2020).

Creative coding has served as a vital instrument for integrating music, mathematics, and logic. By employing concepts such as loops, conditions, and patterns, students developed problem-solving and algorithmic skills, thereby establishing a connection between artistic creation and logical structure (Mygdanis & Papazachariou-Christoforou, 2023; Rohrmeier, 2022; Pan, 2022). In this context, Scratch was employed to build connections between code and sound, enabling experimentation with rhythms and interactions. As one participant remarked, “When I press space, the drum plays! I made it do that” (FN 14), while another inquired, “Can I also add lights to turn on?” (ID 59). A female participant described the experience as, “It’s like painting music with blocks” (SI 67). Subsequently, students engaged in the development of games, such as a dragon chasing notes with speed based on pitch. “Like a real game” (SI 43), observed one student. Furthermore, emphasizing the process—through documentation, functional prototypes, and adherence to community standards—enhanced accuracy, responsibility, and computational thinking skills. Simultaneously, the metacognitive dimension was exemplified through explicit reflection on decisions and outcomes, with assessment serving as a pedagogical tool rather than a means of control (Mygdanis, 2025a). Live coding was also showcased as a creative activity. As one student stated, “We had to find repetitions in the right order… like solving a puzzle” (ID 54), while a female participant added, “The computer does what we tell it, like magic tricks” (SI 22). In this manner, the integration of music and code fostered problem-solving, critical thinking, and teamwork, thereby promoting the dissemination of computational thinking through artistic practices (Mygdanis & Papazachariou-Christoforou, 2023; Psycharis, 2018; Brown, 2015).

Immersive technologies like VR and AR, combined with tactile interfaces, have introduced an innovative dimension to musical practice by integrating sound, space, and movement. Embodied understanding and the sense of “presence” enhance children’s persistence, imagination, and resilience (Yang, 2024; Poutiainen & Krzywacki, 2023; Azuma, 1997). These technologies additionally provide a framework for agency, experimentation, and unrestricted exploration. VR-facilitated safe trials and visualizations of abstract concepts improve problem-solving, collaboration, and critical thinking skills (Yang, 2024; Poutiainen & Krzywacki, 2023). Simultaneously, AR seamlessly combines the physical and digital domains. In the Chickenophone project, students activated musical notes through hand movements. As one participant noted, “The chicken is singing!” (SI 10). Similarly, an interactive poster featuring QR codes allowed audiences to listen to student compositions. As one student observed, “People can hear it just by scanning!” (FN 21). Overall, AR provides authentic and engaging experiences, characterized by robust kinesthetic and emotional engagement (Mygdanis, 2025a; Azuma, 1997). The utilization of AI tools has opened new avenues for creativity and exploration. Children have created personalized compositions. As one girl emphasized, “AI gave me a melody, I added the rhythm… now it’s my song” (SI 23), while a classmate contributed, “You start from a skeleton and fill it with your own ideas” (ID 21). Concurrently, through Google Teachable Machine, students trained machine learning models to recognize Kodály hand signs. As an individual explained, “I taught the computer to understand my hand movements” (ID 16). “Virtual interviews” with historical figures stimulated inspiration but also raised pertinent questions, such as “Can we trust AI?” (ID 13) and “It told me about its ideas… it was amazing” (SI 19). Furthermore, tools such as ChatGPT and Copilot facilitated the creation of texts and visuals within transdisciplinary projects. As one girl remarked, “I added two of my own instruments and it really became mine” (SI 36), while a boy observed, “AI helps you, but it doesn’t do everything by itself… you also need imagination” (ID 24). In this manner, AI expanded the scope of practices, thereby enhancing imagination, understanding of musical concepts, composition skills, and computational thinking (Merchán Sánchez-Jara et al., 2024; Rohrmeier, 2022; Pan, 2022; Peppler et al., 2016).

Concurrently, the STREAM perspective, with a balanced emphasis on Reading and Writing, introduced a narrative framework and multiliteracies that linked music with writing, documentation, and storytelling (Psycharis, 2018; Resnick & Robinson, 2017). Notably, the sensory and emotional dimensions were integral in enhancing creativity and deepening understanding of the musical experience. Of particular interest were AI applications, which, within the context of STREAM, supported projects involving patterns, improvisations, and personal narratives, thereby transforming AI-based production into an authentic educational experience that fosters autonomy, reflection, and a child-centered approach.

The significance of informal practices was prominently underscored throughout the intervention, which seamlessly integrated formal and informal learning modalities and encouraged children to extend their experiences beyond the temporal and spatial constraints of the classroom—an essential objective of the study. As one child observed, “I made patterns at home that I didn’t have time to do in class” (SI 62), while a girl remarked, “I wrote music for my favorite game at home and I felt like I was creating something meaningful!” (SI 1). Concurrently, the completion of the intervention functioned as a genuine assessment through project presentations, reflections, and a sense of artistic ownership. As one child articulated, “It was our orchestra… like a real band!” (ID 19), and a girl added, “It was wonderful to perform something we created collaboratively… it was our music!” (SI 8). These instances demonstrated that technology-supported and child-centered pedagogical strategies positively influenced artistic participation and personal engagement.

Overall, the integration of emerging and immersive technologies with creative, child-centered strategies within a constructionist and experiential framework appears to provide valuable insights for music education. Engaging creatively with various technological tools and practices enhances both technical and artistic competencies, while also fostering a more profound relationship with music as a medium of personal expression, exploration, and collaboration. Furthermore, active participation in creation, experimentation, and transdisciplinary methodologies promotes creativity and supports profound learning, thereby equipping students with essential skills for thriving in an increasingly digital and culturally diverse musical landscape (Mygdanis & Kokkidou, 2021). Ultimately, transforming the classroom into a space dedicated to creation, inquiry, experimentation, and co-design enriches the educational experience with new and expanded dimensions (Mygdanis, 2025a).

Findings and connection to the research questions

Regarding the initial research inquiry, students demonstrated substantial motivation and active participation across three distinct levels. At the behavioral and attitudinal tiers, perseverance, role adoption, and compliance with mutually agreed procedures were observed. At the cognitive tier, experimentation, comparative analysis of various solutions, and systematic documentation of choices were recorded. At the emotional tier, enthusiasm, instances of “flow,” and a sense of ownership regarding their work were expressed. Digital Audio Workstations (DAWs), Scratch, and tactile materials served as accessible entry points, whereas VR, AR, and AI applications broadened opportunities for exploration and sensory comprehension. Furthermore, micro-cycles of work—including clear objectives, brief reflective pauses, and public presentations—contributed to maintaining momentum and motivation. A gradual transition from guided to autonomous actions was evident, as students established their own sub-goals, sought targeted hints rather than pre-existing solutions, and justified aesthetic choices. Simultaneously, collaboration functioned as a reinforcing mechanism through the exchange of ideas, problem-solving, and mutual skill modeling. Equally significant was the connection to informal contexts, including ongoing activities at home and the development of gifts for peers.

Concerning the second inquiry, the added value of emerging and immersive technologies, as well as the associated pedagogical methodologies, was apparent on multiple levels. Firstly, participation and access were broadened, as DAWs and tactile circuits facilitated immediate engagement with composition and production without the necessity of prior instrumental proficiency. From the initial session, students were able to assume an active role in creation, thereby enhancing their sense of belonging. At the same time, VR and AR technologies, in conjunction with sensors, promoted embodied and spatial comprehension, transforming abstract musical concepts such as form, texture, and spatiality into tactile experiences. Furthermore, AI served as a tool for creative acceleration and personalization, providing ideas and targeted feedback as students learned to select, adapt, and refine their work. Lastly, authenticity and dissemination were augmented through public performances, AR posters, and the sharing of projects with audiences external to the classroom, thereby increasing accountability and improving the narrative quality and coherence of their work. Overall, when these practices were critically examined—through discussions on transparency, AI limitations, documentation, and sources—motivation, creativity, technical skills, and multiliteracies were reinforced, transforming the music classroom into a contemporary post-digital production environment.

The exploration of the third research question revealed a consistent set of pedagogical practices that substantially enhanced the learning process. Cognitive apprenticeship was employed through explicit modeling of skills, targeted scaffolding, and the gradual removal of support, thereby enabling students to assume greater responsibility over time. Concurrently, iterative cycles of creative learning—encompassing ideation, design, construction, feedback, and redesign—fostered dynamic conditions conducive to growth. Equally important was the systematic documentation utilizing short narratives, audio clips, and "decision sheets," which augmented metacognitive awareness. Collaboration was promoted through protocols involving role rotation, brief public trials, and clear delineation of responsibilities, while assessment was based on artifacts evaluated against jointly established criteria such as functionality, aesthetic coherence, and clarity of explanation. The attainment of learning outcomes included enhanced creative independence, improved aesthetic judgment, development of computational thinking through pattern recognition, repetition, and conditional reasoning, in addition to strengthened problem-solving and teamwork skills. Overall, a deeper understanding of music was achieved through multimodal representations, the transfer of learning to real-world contexts, and the reinforcement of metacognitive strategies via goal-setting, self-assessment, and reflective practices. A pivotal factor was the progressive increase in difficulty levels and the explicit connection between tools and meaning, which sustained high levels of engagement and consistent progress.

Conclusion

In a broader context, the Digital Little Music Makers initiative highlighted the potential of integrating technological methodologies with creative strategies to facilitate a paradigm shift in music education. This approach aims to provide students with innovative and enriched methods of engagement with music. Rooted in the principles of constructionist learning, the process demonstrated how the adoption of emerging and immersive technologies can enhance creativity, collaboration, and participation, while also expanding children's musical understanding and competencies. The pedagogical proposal sought to bridge formal and informal music learning, fostering continuous musical exploration beyond the confines of the school environment, and opening new avenues for profound experiences. Within this framework, the findings underscore pedagogical implications that support a broader transformation of music education, the advancement of musical and technological knowledge, and the development of critical twenty-first-century skills. Consequently, technological innovations function simultaneously as means for novel experiences, tools for reflective learning, and catalysts for creative expression, thereby redefining music education as a dynamic and evolving discipline within the contemporary pedagogical landscape.

Nevertheless, despite the encouraging outcomes, the study exhibits certain limitations that influence the generalizability of its conclusions and their applicability. The sample size was limited and derived from a private educational institution; hence, the findings cannot be broadly generalized. Furthermore, the intervention was executed within the context of a music club rather than the compulsory curriculum, which affected the level of participation. The researcher simultaneously acted as designer, facilitator, and observer, thereby enhancing internal comprehension but potentially introducing biases. Moreover, the absence of long-term data impedes a reliable assessment of the sustainability and transferability of skills across different domains. Future initiatives should focus on implementing the model across diverse settings, particularly within public education, to evaluate its adaptability. Integration into the official curriculum and collaboration with educational institutions may foster sustainability. Continued research is essential to verify the durability of learning outcomes and to explore the integration of emerging technologies—such as wearable devices, 3D printing, and blockchain—within a human-centered pedagogical framework.

In summary, it appears that the utilization of emerging technologies represents not merely an educational innovation but potentially serves as a catalyst for the reformation of music pedagogy. The post-digital pedagogical framework mandates the incorporation of digital cultural elements as fundamental components of contemporary musical practice, rather than as mere ends in themselves (Treß, 2024). Furthermore, there exists a necessity for a pedagogical paradigm that encourages active participation, experimentation, embodied experience, and reflective meaning-making in musical engagement (Mygdanis, 2025a). From this perspective, the objective is not to establish a "digital music classroom" but to develop music education capable of addressing the cultural and pedagogical challenges of the twenty-first century—empowering every student and emphasizing a new paradigm in music pedagogy: "Music Education 4.0" as a horizon of transformation and paradigm shift.

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