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The potential of technologies in educational and inclusive processes for Music Learning and Specific Learning Disorders

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Abstract: This study analyzes the potential of music and music technologies as educational tools to support students with Specific Learning Disabilities (SLD) in higher education, particularly in conservatories. Thanks to the rhythmic, symbolic, and multisensory nature of music, benefits on phonological awareness, working memory and performance functions are highlighted. Customizable digital tools, such as AI-powered music generators and simplified notation software, are examined. These technologies facilitate inclusion by adapting to different cognitive styles. The work proposes strategies for a more inclusive music education, suggesting a paradigm shift in the pedagogical models of conservatories.

Keywords: Specific Learning Disorders; music; technologies; inclusion; digital technologies

1. Introduction

In recent decades, Higher Education has shown growing attention to educational inclusion for students with Specific Learning Disorders (SLD). Defined by Law 170/2010 as persistent difficulties in reading, writing, and calculation not attributable to intellectual or sensory deficits, SLDs pose significant challenges in traditional learning contexts. This has prompted a rethinking of teaching strategies, highlighting music as a transversal and inclusive educational tool. This research explores the potential of music as a resource for the prevention and compensation of SLDs, with reference to Higher Education and Conservatories. Thanks to its multisensory, rhythmic, and symbolic nature, music can support cognitive, metalinguistic, and executive functions, especially in neuroatypical learners. Its inclusion responds not to aesthetic aims but to pedagogical and neuroscientific needs, offering alternative learning environments that enhance cognitive styles and brain plasticity. Music can function both as a second-level preventive tool and as a compensatory device for diagnosed students. Scientific literature confirms strong correlations between musical

[1] The work is the result of scientific collaboration between the authors; however, the attribution of the paragraphs is as follows: Alessio Di Paolo is the author of full paper; Michele Domenico Todino is the scientific director of the work.

activity and the development of phonological working memory, metalinguistic awareness, and spatio-temporal coordination (Hande and Hedge, 2021; O'Leary and Bannerman, 2025; Chiappetta Cajola and Rizzo, 2016). In Conservatories, inclusive strategies and accessible technologies can foster personalized, motivating, and sustainable educational pathways.

2. Music Education and Specific Learning Disorders in the Higher Education dimension

Specific Learning Disorders (SLD), within the broader field of neurodevelopmental disorders, involve specific limitations in reading, writing, or calculation despite normal or high intelligence and adequate educational opportunities. These difficulties emerge in contexts requiring systematic learning and call for targeted intervention and prevention strategies across all educational levels, including Higher Education. In this framework, music emerges as a transversal educational tool capable of supporting compromised cognitive and socio-emotional functions. Law 170/2010 and the MIUR Guidelines (2011) emphasize the importance of early identification of risk indicators and personalized teaching strategies, highlighting how timely intervention reduces long-term academic and emotional consequences.

Music education functions not only as an artistic discipline but also as a didactic device for stimulating early skills whose neglect may lead to consolidated deficits (Dewey, 1958; Walker, 2001). Rhythm enhances temporal organization, motor coordination, and phonological memory, singing strengthens phonemic awareness, and active listening promotes sustained attention and auditory discrimination. Longitudinal studies show that lack of early intervention can seriously compromise educational trajectories, increasing the risk of dropout and secondary emotional disorders (Trisciuzzi and Zappaterra, 2005; Penge, 2010).

Music thus assumes a second-level preventive role, particularly effective in preschool and primary education, acting on protective factors such as motivation, emotional regulation, socialization, and language development (Descamps et al., 2025; Cremades-Andreu and Lage-Gómez, 2024). Teachers must be trained to recognize early warning signs such as difficulties in sequential memory, fine-motor coordination, phonological discrimination, and spatio-temporal organization (Aiello et al., 2013; Di Tore, 2016).

Music teaching integrates cognitive, emotional, and motor dimensions, offering alternative learning pathways aligned with students' cognitive styles. Melodic and rhythmic repetition reinforces the phonological loop and auditory working memory (Baddeley et al., 2011), while singing and musical rhyme stimulate both linguistic and musical neural circuits. Educational neuroscience confirms strong links between musical development, neuroplasticity, and executive functions (Frauenfelder, 2000).

An inclusive, laboratory-based, and cooperative approach to music education enhances residual potential, promotes self-efficacy, and supports participation, positioning music as a vicarious factor for learning and inclusion (Berthoz, 2015; Sibilio, 2017; Di Paolo and Sibilio, 2024). Music thus acts as a didactic catalyst for prevention, compensation, and inclusion, deserving full recognition within educational and pedagogical frameworks.

3. The potential of music in educational intervention with university students with Specific Learning Disorders

Within inclusive education processes in Higher Education for students with Specific Learning Disorders (SLD), music emerges as an effective pedagogical mediator for the development of cognitive, motor, and communicative skills. Its value lies both in its emotional dimension and in its symbolic and structural complexity, which makes it a transversal and multidisciplinary tool capable of fostering learning transfer across cognitive domains. Musical experience, characterized by rhythmic, melodic, and harmonic elements, supports perceptual-kinesthetic abilities, fine and gross motor skills, and higher cognitive functions. Owing to its sequential and symbolic structure, music shares fundamental traits with verbal language, acting as a bridge between interconnected communication systems. As highlighted by the MIUR (2012), music stimulates reasoning, communication, and meaningful learning.

Research on musical learning transfer shows that music is not only an expressive experience but also an empowerment tool for learners who struggle with traditional educational models (Scaglioso, 2008). Scientific literature confirms positive effects of music education on transversal skills such as reading, logical-mathematical reasoning, and spatio-temporal abilities (Vilde, 2021; Blanco-García et al., 2025; Sharofiddinovich, 2025; Yoho, 2011). These benefits are particularly relevant for students with SLD, who often present deficits in phonological decoding, auditory working memory, and metalinguistic awareness.

The close phylogenetic relationship between musical and verbal language (Brown, 2000) provides a strong theoretical foundation for inclusive musical interventions. Both systems rely on symbolic sequences organized according to syntactic principles, a connection evident in singing and in neuropsychological phenomena such as dysprosody. Consequently, experiential activities based on musical and verbal listening can enhance rhythmic perception, auditory working memory, and phonological awareness through embodied and multisensory learning.

Rhythm education plays a central role (Fraisse, 1979), as rhythm is a key component of both music and language prosody. Approaches based on body movement, such as those proposed by Dalcroze (1907), support the internalization of rhythmic patterns and facilitate phonological processing. Training echoic memory through rhythmic practice further strengthens phonological awareness and activates the phonological loop (Huron and Parncutt, 1993; Baddeley et al., 2011). Empirical evidence also shows that early musical training positively impacts verbal intelligence (Rizzo and Pellegrini, 2021). Therefore, integrating music into Higher Education pathways for students with SLD represents a pedagogically grounded strategy that promotes inclusion, participation, and the development of individual potential.

4. The value of Conservatories in intervening with learners with Specific Learning Disabilities

In recent years, the growing attention to Specific Learning Disorders (SLD), in particular dyslexia and dysorthography, has led to a profound revision of teaching methodologies, particularly in the field of music education within the Conservatory institutions. The role of music conservatories, institutions responsible not only for the training of professional musicians but also increasingly involved in innovative ped-

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agogical and didactic paths, is becoming central in supporting the phonological and cognitive development of students with learning difficulties. Scientific and pedagogical evidence, starting from the Recommendations of the Consensus Conference (2011), in fact emphasizes how metaphonological skills represent a key indicator in the development and early detection of SLD. In this context, the use of music as a compensatory and enabling tool has proved to be extremely promising. Several experimental and quasi-experimental studies (Bolduc, 2008, 2009; Piro and Ortiz, 2009) have highlighted that musical activity, especially if structured and integrated into long-term educational paths, can facilitate the acquisition and consolidation of linguistic-phonological skills, with significant effects in particular on the ability to discriminate phonemes, phonological awareness and sequential auditory memory. In this sense, the Conservatories, through their preparatory schools, pre-academic courses and initial and continuing education activities, can be configured as highly favorable environments for the creation of educational paths that aim not only at instrumental teaching, but also at the enhancement of music as a transversal educational resource, capable of directly affecting the cognitive and linguistic development of students with dyslexia and dysorthography. The principle that underpins this synergy between music and language is the common temporal, rhythmic and prosodic structure of both codes, which makes it possible to stimulate shared neural circuits. According to Dehaene (2004; 2007), the sonority of words and their phonological organization can be enhanced through musical exposure that favors brain plasticity, activating new learning paths in subjects with difficulties. The integration between phonological and musical activities allows a perceptual-phonetic enhancement, acting on two fundamental processes: categorical perception and phonemic restoration. The first allows you to recognize linguistic units (words, phonemes) or musical units (notes, intervals) in a sound continuum, while the second allows you to reconstruct missing information, thus offering a unified perception even in the presence of interruptions or segmentations of the sound flow. It is therefore evident that music, by acting on these mechanisms, can promote better coding and decoding of written and oral texts in children with dyslexia and dysorthography. The Conservatories, thanks to the specificity of their teaching based on listening, repetition, imitation and rhythmic-melodic internalization, represent an ideal context for the consolidation of these skills, as they promote the acquisition of auditory-verbal skills in a natural and progressive way. Furthermore, as Sloboda (1985) points out, early exposure to music stimulates children's innate ability to learn language rules and structures through listening, a process that, if well guided, can significantly reduce the barriers related to SLD. It is important to remember that phonological awareness, according to the distinction proposed by Morais (1989), is divided into two levels: the *global*, earlier one, which allows the recognition of whole words in the verbal flow, and the *analytical*, more mature one, which implies the ability to segment, manipulate and classify individual phonemes. The latter dimension is closely related to the ability to read and write accurately and fluently. Music, especially through learning an instrument, intonation, rhythmic and singing solfeggiation, stimulates both components, offering constant, motivating and customizable perceptive-auditory training. The Conservatories, equipped with methodological skills and advanced teaching tools, can therefore structure targeted paths, which integrate linguistic-musical games, rhythm and prosody activities, sound discrimination exercises and musical reading, to strengthen phonological awareness and reduce difficulties related to reading and spelling. A particularly relevant aspect

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concerns brain plasticity in the first years of life: according to Parncutt and Marin (2006), if musical learning begins very early, even before the start of reading and writing, neural mechanisms similar to those of language acquisition are activated, enhancing the areas responsible for phonemic processing and favoring the development of compensatory strategies in subjects with predispositions to the disorder. The Conservatories, through collaborations with kindergartens and primary schools, could therefore intervene early in a preventive perspective, offering structured preparatory courses that aim to develop basic phonological and rhythmic skills, which are fundamental for subsequent access to the written language. Another element of interest concerns the involvement of executive and visual-temporo-spatial functions, often compromised in subjects with dyslexia and dysgraphia. According to the Cerebellar Deficit Theory (Nicolson and Fawcett, 1999), the difficulty in automating cognitive processes, including reading and writing, would derive from an alteration in cerebellar functioning, which also involves implicit learning and motor sequences. In this framework, music education can be a powerful ally, thanks to its ability to simultaneously integrate motor, perceptual and cognitive aspects. Playing an instrument, for example, requires precise bimanual coordination, the organization of time and space, motor planning and procedural memory, all skills that, if systematically enhanced, can also have positive effects on writing and reading. The Conservatories, as places of daily exercise of these functions, could therefore structure musical workshops of a habilitative nature, in which musical learning is used as a vehicle for the strengthening of executive functions and spatial perception, through the use of easily accessible instruments, rhythmic practice, musical reading and guided improvisation. These paths, if conducted continuously, would allow students with SLD to develop effective strategies of selective attention, inhibition of distracting stimuli, visual-spatial organization and temporal management of actions. In particular, the ability to exclude *noise* (Sperling, 2005) and focus on relevant information, fundamental in reading and writing, can be trained through musical exercises that require precision, fine discrimination and attentional regulation. Furthermore, for those with dysgraphia, musical activity can improve fine motor skills, management of space on the sheet and tonic-postural control, favoring a more harmonious and conscious approach to writing. It is therefore desirable that the Conservatories increasingly develop an "inclusive vocation", which is not limited to technical and interpretative training but opens up to a pedagogical and neuroeducational dimension, capable of responding to special educational needs through music. This perspective requires a reformulation of curricula and methodologies, specific training of teaching staff on SLD and active collaboration with schools, families and multidisciplinary teams. Music can no longer be considered an ancillary or decorative activity but must be recognized as a powerful and scientifically based tool for learning, recovery and inclusion. Conservatories, with their history, their resources and their human potential, are in ideal conditions to take on this role, contributing not only to artistic growth but also to the cognitive and educational development of young people, with particular attention to those who live in situations of fragility or difficulty (Colazzo, 2022). Therefore, integrating musical paths into personalized educational plans for students with dyslexia and dysorthography, promoting phonological and visual-motor enhancement programs within Conservatories, enhancing teacher training in the neuro-educational field and consolidating territorial support networks between school, family and musical institutions

today represent not only an opportune choice but a real pedagogical and social necessity.

5. Educational tools for the enhancement of musical skills in Higher Education with Learners with Specific Learning Disorders

Within inclusive education in Higher Education for students with Specific Learning Disorders (SLD), music functions as a powerful pedagogical mediator for cognitive, motor, and communicative development. Its effectiveness derives from both its emotional impact and its symbolic and structural complexity, which make it a transversal and multidisciplinary tool capable of supporting learning transfer across domains. Musical experience, grounded in rhythmic, melodic, and harmonic elements, enhances perceptual-kinesthetic abilities, fine and gross motor skills, and higher cognitive functions. Due to its sequential and symbolic organization, music shares core features with verbal language and acts as a bridge between interconnected communication systems, fostering reasoning, communication, and meaningful learning (MIUR, 2012).

Research on musical learning transfer highlights that music is not merely expressive, but also an empowerment tool for learners who struggle with traditional educational models (Scaglioso, 2008). Scientific literature confirms positive effects on transversal skills such as reading, logical-mathematical reasoning, and spatio-temporal abilities (Vilde, 2021; Blanco-García et al., 2025; Sharofiddinovich, 2025; Yoho, 2011), particularly relevant for students with SLD, who often present deficits in phonological decoding, auditory working memory, and metalinguistic awareness.

In this perspective, digital music tools and interactive environments further enhance inclusive musical pathways. AI-based platforms such as Suno AI (https://suno.com/; last consultation date 08.07.2025) and Udio AI (https://www.udio.com/; last consultation date 02.07.2025) allow linguistic, rhythmic, and emotional content to be transformed into sound, supporting personalized and multisensory learning. Alongside these, accessible tools such as facilitated notation software, ear-training applications, and interactive digital environments expand opportunities for participation in Conservatories and Higher Music Education.

The phylogenetic relationship between musical and verbal language (Brown, 2000) provides a solid theoretical foundation for these approaches. Both systems rely on symbolic sequences organized syntactically, a connection evident in singing and in neuropsychological phenomena such as dysprosody. Rhythm education plays a significant role (Fraisse, 1979), with body-based approaches supporting phonological processing and working memory through the activation of the phonological loop (Baddeley et al., 2011). Empirical evidence also shows that early musical training positively impacts verbal intelligence (Rizzo and Pellegrini, 2021). Integrating music and digital tools into Higher Education thus represents a pedagogically and neuroscientifically grounded strategy for fostering inclusion, participation, and individual potential.

6. Tools that can be used in Conservatories for the personalization of learning in learners with Specific Learning Disorders

Extending the reflection on music as a personalized teaching resource for students with Specific Learning Disorders (SLD), it is necessary to consider also Higher Music Education contexts, particularly Conservatories. While inclusive music education has gained recognition in compulsory schooling, Conservatories still show methodological and regulatory delays in ensuring equal educational opportunities for students with SLD (Ruiz and Guerrero, 2021). The complexity of academic musical skills, such as sight-reading, notation, analysis, composition, and critical listening, makes the adoption of digital tools and flexible teaching strategies increasingly urgent, especially in theoretical and analytical domains were dyslexia, dysgraphia, or dyscalculia can hinder performance. Among notation software, Sibelius (https://aviditalia.it/prodotti/sibelius/; last consultation date 01.07.2025) is widely used in Conservatories but may present accessibility barriers due to its complex interface. Inclusive use can be supported by simplifying toolbars, creating preconfigured templates, using differentiated colors for staves or voices, and implementing custom keyboard shortcuts supported by visual guides. Real-time playback offers immediate auditory feedback, facilitating self-correction and autonomy, particularly for students with dyslexia or dysorthography. For learners with grapho-motor difficulties, graphic tablets, digital pens, or experimental voice-based notation systems can further enhance accessibility. Complementary tools include Noteflight (https://www.noteflight.com/; last consultation date 01.07.2025), a cloud-based and visually simplified notation platform suitable for collaborative activities, and Flat.io (https://flat.io/?srsltid=AfmBOoqYnb9qicIFtYqq-u2ZygZFSpGix19d_4Bo3Iyii6qRHLBhFX86; last consultation date 01.07.2025), which integrates with Google Classroom and supports peer learning. For music analysis and metacognitive development, sound visualization software such as Sonic Visualiser (https://www.sonicvisualiser.org/; last consultation date 05.07.2025) and Melodyne (https://www.celemony.com/; last consultation date 05.07.2025) allows acoustic features to be represented visually, supporting visual-spatial cognitive styles and strengthening working memory and sequential organization.

In ear training and listening education, adaptive tools such as Musictheory.net (https://www.musictheory.net/products/tenuto; last consultation date 08.07.2025) and Complete Music Reading Trainer (https://completemusicreadingtrainer.com/ ; last consultation date 08.07.2025) offer progressive exercises with immediate feedback and multimodal reinforcement. For solfeggio and rhythm reading, visual metronomes and interactive apps such as Rhythm Trainer (https://www.therhythmtrainer.com/; last consultation date 08.07.2025) and Beatlab (https://www.beatlabaudio.com/; last consultation date 05.07.2025), as well as tactile rhythmic devices, support pulse internalization, temporal anticipation, and rhythmic automation.

To address organizational difficulties often associated with SLD, digital planning tools such as Trello (https://trello.com/it; last consultation date 03.07.2025), Notion (https://www.notion.com/; last consultation date 02.07.2025), and Google Keep (https://keep.google.com/; last consultation date 02.07.2025) can support task segmentation, time management, and routine building. In composition, simplified

DAWs such as GarageBand or BandLab allow students to explore musical form through loops and sequencers before translating ideas into traditional notation.

From a pedagogical perspective, these tools must be embedded within an inclusive teaching framework where the teacher mediates between technology, content, and individual needs. Technology alone does not ensure inclusion; its effectiveness depends on intentional and reflective educational use. Therefore, targeted teacher training on SLD and compensatory strategies is essential, along with the development of Personalized Teaching Plans (PDP) in AFAM courses, in line with Law 170/2010. The integration of adapted digital tools thus represents a concrete pathway toward accessible, democratic, and high-quality music education in Conservatories, where cognitive diversity is recognized as a resource rather than a limitation.

7. Conclusions

The analysis conducted in this contribution highlights the strategic role that music can play in the design of inclusive educational environments, particularly within Higher Education and Conservatory contexts, in support of students with Specific Learning Disorders (SLD). Music education emerges as a transformative pedagogical tool that activates cognitive, linguistic, motor, and emotional processes in an integrated way. Scientific literature confirms its effectiveness in enhancing executive functions such as working memory, attention, planning, and inhibitory control, as well as phonological skills involved in reading and writing.

Inclusive technologies play a key role in ensuring equitable access to musical activities. The study builds on over a decade of research conducted by the Teaching Learning Centre for Education and Inclusive Technologies, directed by Elisa Frauenfelder, which has led to the development of digital tools and immersive learning environments using graphic engines and HMD technologies. Designed through co-design approaches, these tools emphasize emotional engagement and accessibility, particularly for learners with special educational needs.

The integration of music and immersive technologies fosters motivation, multisensory learning, and active participation. Conservatories can thus promote inclusive practices through innovative methodologies, accessible technologies, flexible curricula, and targeted teacher training in neuroeducation and inclusive pedagogy, recognizing music as an ethical and educational imperative for truly inclusive education.

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