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Navigating at the Interface of Digitalisation, Sustainability, and Music Education

Introduction

In the rapidly evolving landscape of education, digital technologies have become central actors. Particularly in terms of sustainability¹, this fundamental transformation is not without its complexities. While digitalisation offers tools and resources that can enhance and redefine music education, it also raises critical questions about inclusivity, environmental impact, and the preservation of meaningful, hands-on musical experiences. As society grapples with the broader implications of digitalisation, including its effects on social equity and ecological sustainability, it is necessary to examine how these forces intersect within the field of music education. The tension between the promises of technological progress and the goals for sustainable education calls for nuanced and critical approaches.

In recent European policy frameworks – particularly in those implementing the European Education Area (EEA) as part of the “green and digital transitions” (European Commission, 2020, p. 1) – sustainability and digitalisation are identified as key drivers of educational transformation. Calling for green and digital education (European Commission, 2020), these frameworks provide important orientations for rethinking teaching and learning but remain largely detached from subject-specific perspectives. Within music education, a significant gap becomes evident: European frameworks do not consider how digital technologies and sustainability goals might be meaningfully connected through

¹ In line with the Sustainable Development Goals (SDGs) (United Nations, 2015), sustainability is here understood in a multidimensional sense that encompasses ecological, economic, and social dimensions, including aspects such as inclusion and equity.

music education, nor do they recognise the aesthetic and cultural dimension of music as potential resources for sustainable learning (Stade & Buchborn, 2025).

Building on this observation, the present article aims to explore perspectives on how digitalisation and sustainability can be meaningfully interwoven within music education to address educational, social, and ecological challenges. In order to address this question, the article first reviews current research at the interface of digitalisation and sustainability in education, followed by an analysis of key European policy papers. On this basis, three areas of practice are presented to illustrate how digitalisation and sustainability can be integrated into music education: Inclusion-oriented music education and digitalisation (2.1), music technology in music teacher training (2.2), and *Maker Music Education* (2.3). These examples can be read as action strategies for music teacher education and classroom practice. Together, these focal points provide complementary perspectives on how music education can respond to the challenges and opportunities of the green and digital transitions.

Literature Review on Green/Digital Music Education

As educators incorporate more digital tools into their practice, they must not only reflect on “the promise and pitfalls of techno-solutionism” (Sætra, 2023) but also on the long-term ecological implications of these practices and explore ways to mitigate environmental harm (Treß, 2024, 2025a). Concerns regarding sustainability have become increasingly salient, as the proliferation of digital devices contributes to resource consumption that runs counter to the *Sustainable Development Goals* (Selwyn, 2024).

At the same time, discussions on digital literacy in music education are gaining prominence. Educators are called upon to equip students with the critical competences required to navigate an increasingly digitalised musical landscape (Buchborn & Treß, 2023). This includes understanding the ethical implications of algorithmic recommendations in streaming services, copyright and intellectual property issues in digital composition, and the broader sociopolitical dimensions of algorithmic-driven software in the classroom (Treß, 2025b). In this context, it has been suggested that fostering digital literacy can enable students to engage critically with technology rather than consume digital tools passively (Macgilchrist, 2024).

Nevertheless, the increasing digitalisation of music education also introduces structural and aesthetic challenges. Certain digital instruments and commercial software tend to privilege specific musical genres and standardised uses, which can narrow students' creative and aesthetic experiences (Simon, 2020; Bell, 2018). Moreover, the dominance of commercial providers – with update policies that govern usability and access – creates dependency and limits pedagogical autonomy (Bell, 2015a, 2015b, 2022; Selwyn, 2021; Vetter, 2018). These dynamics underscore the need for critical reflection on which

technologies are integrated into music education and for what pedagogical purposes (Buchborn & Treß, 2023; Treß, 2024).

Building on current discussions of digitalisation and inclusion, Godau (2022) identifies both the potential and risks of digital technologies for inclusive music education. On the one hand, touchscreen devices and sensor-based tools can expand bodily and musical participation by enabling forms of interaction that challenge ableist assumptions about musical ability and instrumental technique. Digital technologies thus offer new opportunities for accessibility and self-expression beyond conventional physical norms. On the other hand, Godau (2022) cautions against a technological short-circuiting of inclusion, in which digital tools are treated as ready-made solutions rather than as elements within broader pedagogical and relational transformations. From this view, digitalisation may either foster more inclusive forms of agency – if critically contextualised – or reinforce existing asymmetries, if reduced to functional substitution.

While such reflections foreground the ethical and pedagogical implications of digitalisation, they also expose a persistent tension between technological innovation and educational practice. Even where digital technologies are acknowledged for their inclusive or creative potential, their systematic integration into institutional contexts – particularly music teacher education – remains limited. Research repeatedly highlights this technology integration gap, emphasising the need for teachers to develop both technological acceptance and competence (Bauer, 2010; 2012; Gall, 2016; Koehler & Mishra, 2009; Redecker & Punie, 2017; Scherer et al., 2019). Frameworks such as TPACK² and DigCompEdu underline that effective integration depends on the interplay of technological, pedagogical, and content knowledge, while Scherer et al. (2019) demonstrate that competence and acceptance are mutually reinforcing: teachers' attitudes influence their engagement with technology, just as competence shapes their perception of its usefulness and ease of use.

Looking into sustainability, this topic has also become a central theme in music education in recent years (e.g. Barret & Westerlund, 2023; Eusterbrock et al., 2024; Imada, 2022; Malmberg & Gall, 2025). Bates (2024) claims: "It would be untenable for music educators to stay on the sidelines, providing background music for the events happening on the field" (p. 54) asking for "sustainable futures" (p. 55). He distinguishes between personal, cultural, and ecological dimensions of sustainability, similar to Shevock's concept of "Eco-Literate Music Pedagogy" (Shevock, 2018). Sustainability issues, and in particular work with the Sustainable Development Goals, have been widely received and discussed in music education (Imada, 2022; Malmberg & Gall, 2025; Schmid, 2024). In this article, however, we focus specifically on the interface between the sustainability and digitalisation discourses. To date the role of digitalisation in sustainable music education remains underexplored,

² The TPACK framework has been widely well-received and, in some cases, adapted in music education (e.g. Bauer, 2010; 2012; Gall, 2016; Cipta et al., 2024; Macrides & Angeli, 2018).

or as Bates puts it: "The uncritical adoption and proliferation of digital technologies in music education [...] is just one trend among many that warrants critical review" (Bates, 2024, p. 59). Therefore, music teachers should "recognize human-made limits, say 'no' to un-sustainable tools, and adopt convivial tools" (Bates & Shevock, 2020, p. 267) that – in contrast to many industrial tools – empower users to actively engage and co-create by offering individual control and space for creativity. Further, educators should ask: Who defines a technology integration gap or deficit? What cultural or policy narratives construct technological integration as progress?

Subsequent to these questions, several approaches begin to converge into what has been described as the "contours of a postdigital music education"³ (Treß et al., in press). This emerging theoretical framework integrates competence-oriented and critical-didactic perspectives, acknowledging the inseparability of digital, material, ecological, and social dimensions of musical learning. Within this postdigital understanding, technology is seen not as an external tool to be mastered or resisted, but as an embedded condition of contemporary musical and educational practice – one that requires continuous reflection on sustainability, inclusion, and artistic agency in both school and higher education contexts. The postdigital perspective enables a move beyond binary views of the digital and the non-digital (Knox, 2019; Jandrić et al., 2018).

Sustainable and/or Digital European Framework Documents⁴

Beyond the academic literature, educational policy documents such as national curricula, competence standards, and, at the European level, various framework guidelines provide a normatively oriented basis for the organisation of (music) education and for teacher education at the interface of digitalisation and sustainability. The convergence of digitalisation and sustainability at a policy level is visible in initiatives like the *European Green Deal* (European Commission, 2019), which presents digital technologies as enablers of sustainability goals. The *Digital Education Action Plan* acknowledges environmental concerns but presents digitalisation primarily as a tool for progress rather than a potential ecological burden (European Commission, 2021). The *2030 Digital Decade* report highlights environmental challenges such as increased energy consumption and e-waste, yet the overall narrative remains optimistic about the role of technology in achieving sustainability goals (European Commission, 2024a).

While digitalisation and sustainability are considered together in a coherent strategy at the policy level, the topics are developed separately at the level of competence frameworks and recommendations for action in educational practice. A detailed analysis

³ See also, Schaubruch & Feneberg in this volume.

⁴ This section draws on a critical document analysis of Stade & Buchborn (2025). The paper provides detailed information on data selection and the methods applied for analysis and interpretation.

of competence frameworks reveals a significant disconnect (Stade & Buchborn, 2025).⁵ The frameworks for digital competences *DigComp* and *DigComp 2.2* (Ferrari, 2013; Vuorikari et al., 2022) introduce sustainability considerations, such as energy efficiency and responsible digital consumption, but these remain secondary to the overarching goal of technological proficiency. While addressing accessibility and inclusion, *DigCompEdu* (Redecker & Punie, 2017) and *SELFIE for TEACHERS* (European Commission, 2024b), the competence framework and self-reflection tool for educators, largely omit environmental considerations, reinforcing the perception that digital skills and ecological responsibility exist in separate domains. Parallel logics can be observed in the framework for sustainability *GreenComp* (Bianchi et al., 2022), that acknowledges digitalisation's environmental impact but does not integrate digital skills as core sustainability competences. This separation is problematic, as it results in contradictions and conflicting objectives and fails to equip educators and learners with a holistic and critical understanding of the interdependencies between digitalisation and sustainability (Stade & Buchborn, 2025).

Three Sustainable and Digital Perspectives on Music Education

Having provided a brief overview of the relevant research literature and identified the critical shortcomings and missing interconnections between the EU competence frameworks on sustainability and digitalisation, we now introduce three perspectives that, in our view, offer potential strategies for developing postdigital approaches to music education in both schools and higher education.

Inclusion-Oriented Music Education and Digitalisation

Digitalisation and inclusion are key innovation challenges for schools, education and for teacher education. At global policy level, the *United Nations Convention on the Rights of Persons with Disabilities* (United Nations, 2006) provides the framework. Its general principles are, among others: "Non-discrimination; full and effective participation and inclusion in society; respect for difference and acceptance of persons with disabilities as part of human diversity and humanity; equality of opportunity; accessibility" (p. 5). The convention emphasises "the importance of mainstreaming disability issues as an integral part of relevant strategies of sustainable development" (p. 1). Digitalisation in an inclusion-oriented music education must therefore take these overarching issues into full account.

⁵ This research was part of the TEAM-project, the Teacher Education Academy for Music: <https://teacher-academy-music.eu/>. Funded by the European Union. Views and opinions expressed, however, are those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Schulz (2021) proposes viewing digitalisation and inclusion as mutually constitutive processes and introduces the concept of “diclusion”. This framework positions digital media as assistive, supportive, and individualising tools, emphasising their potential to foster participation and accessibility. However, a recent study in this field (Gerland & Niediek, 2022, 2023) raises critical questions about the impact of digitalisation on inclusive music education, considering whether digital technologies can enhance the sustainability of inclusive music education practices or if they risk rendering these efforts meaningless. Additionally, the research explores the potential of postdigital (see above) mindsets to reshape power dynamics within music education, questioning whether these new perspectives can effectively address existing asymmetries or inadvertently exacerbate imbalances. Finally, the study examines the integration of inclusion and digitalisation topics in teacher education programs, pondering whether this combined approach uniquely supports the professional development of music education students or if it potentially overwhelms them with an excessive cognitive load. These interconnected inquiries highlight the complex relationship between digitalisation, inclusion, and music education, encouraging a nuanced examination of both the opportunities and challenges presented by technological advancements in this field. Three central questions can be identified.

The first is the question to what extent digitalisation can make music education more sustainable in inclusive contexts: Digital musical instruments (DMI) can be customised and adapted to individual physical conditions to a much greater extent than conventional analogue musical instruments (Gall, 2017; Gall & Backmann Bister, 2024). For example, interface control instruments with eye control systems that transform even the smallest movement as opening and closing eyelids into sound seem to ensure accessibility. They also provide more opportunities for active music making, especially for students with severe and complex disabilities. This advancement enhances social sustainability by allowing previously excluded learners to engage in active music-making, a core aspect of music education. However, it could also be questioned whether unrestricted accessibility might diminish the perceived value of music-making, as it could no longer be considered something special and worthwhile.

Secondly, we ask whether postdigital mindsets can change asymmetrical power relations in music education: In traditional music settings, playing an instrument involves a direct person-instrument relationship, e.g. student – violin. Digitalised contexts add the option of decoupling musical action from specific knowledge and practice, e.g. by using samples or preconfigured apps (Godau, 2018; Stakelum, 2015). This might cause a shift of the imputability of musical competences: The musical outcome is produced in a kind of socio-technical alliance (Ismaiel-Wendt, 2016) rather than by individual effort. If teachers critically engage with these changes of core elements of music education this may lead to really transformative considerations concerning accessible musical learning for all students. In fact, this shift from individual abilities to the abilities of person-device-arrangements

queries the issue of individual instrumental skills which is a very significant aspect in music education. If those arrangements are not thoughtfully implemented, they risk becoming mere substitutes that provide quick but superficial results, potentially depriving students with disabilities of meaningful musical experiences and reinforcing existing inequalities. This in turn would even increase imbalances in the field of inclusive music education.

The third question addresses whether and how inclusive teaching can deal with diversity. In order to promote students' learning progress, digitalisation can be considered as an option for new concepts of music and musicking. This can lead to new forms of and new competences in music. As a consequence, a new focus on the biographical conditions for one's own beliefs of diversity, music, and music education is necessary, because the new forms of music(king) outlined can differ significantly from those that music teachers are used to from their own biographies.

Appropriate reflective approaches need to be carefully integrated into teacher education in order to avoid an add-on feeling of multiple and additive challenges. The joint consideration of inclusion and digitalisation topics can only enhance professionalisation and sustainability in music education if it neither leads to a loss of orientation nor to reduced self-efficacy as a teacher caused by an overload.

Music Technology in Music Teacher Education

The integration of technology in both music education and music teacher education appears to be slower than the general technological developments of recent decades (Weidner & Stange, 2022). On the one hand, this is problematic because children's musical reality is infused with contemporary music technology (Ahlers, 2018); on the other hand, music education, thereby, offers a possibility to consider critical and non-consumerist approaches to music technology, especially in music teacher education. Prospective music teachers should be encouraged and enabled to engage in critical reflection. They need to develop the capacity to decide when the use of digital media and artificial intelligence is pedagogically meaningful – and when it is more appropriate to refrain from using them. However, this also requires that they have had their own hands-on experiences with the tools and their possibilities, which highlights the difficult balance that music teacher education programs need to strike.

To transform this situation, greater attention must be paid to the professional development of music teachers. Structurally preparing pre-service music teachers to implement contemporary technology in their future teaching is a logical starting point for building a sustainable, technology-integrated future for music education. In such a setting, technology can become invisible, not following the idea of technological solutionism (Sætra, 2023) but being understood in the sense of postdigitality (see above).

How can structural music teacher education in digital technology be achieved? A learning trajectory within the Bachelor of Music in Education program at ArtEZ

Conservatory Enschede (Spieker, 2021) includes a weekly one-hour digital skills class in years 1 and 2, followed by a weekly two-hour class in year 3, focusing on developing innovative and reflexive approaches for integrating (music) technology into music education.

In this context, several recurring challenges and opportunities related to the integration of music technology have been identified. A persistent issue concerns the widely unfounded negative attitude towards media and technology-based music practices of some teaching staff. Multimedia and technology courses are often assigned to younger, more technologically confident educators, which may limit broader faculty engagement and interdisciplinary collaboration. Experienced instrumental teachers, in particular, may expect immediate results when engaging with electronic or digital instruments, sometimes leading to frustration when the learning process proves more complex than anticipated. Furthermore, limited institutional resources and technical support frequently require teachers to rely on their own devices, demanding both financial and temporal flexibility (Treß, in press). Differences in technological knowledge among students, and in some cases an imbalance between students' and teachers' expertise, can also hinder the effective integration of digital tools in music education (Weidner & Stange, 2022).

At the same time, several practices have been identified that can facilitate meaningful engagement with technology. Well-equipped classrooms and university maker spaces (see below), for example, provide collaborative environments that encourage experimentation and exploration. Professional development initiatives play an essential role as well. Some higher education institutions already offer dedicated in-service programmes on digitalisation, while others provide shorter, more flexible formats such as one-day workshops on technology-enhanced teaching and learning. Informal formats like the Tech Cafés at ArtEZ Conservatory Enschede – where staff can explore (music) technology in a relaxed, collegial setting – have also proven effective in lowering participation barriers.

Spieker (2021) presents three “recommendations for designing education that prepares students to enhance their practice with technology: (1) adapt to **your students**; (2) be concrete to [*sic*] **your students**; and (3) embrace collaboration” (p. 263). In connection with the discussion on sustainability and digitalisation, it is important to keep a critical view by asking whether teachers are being trained in the most relevant areas and by thinking about data security, privacy, and the ethical and ecological impacts of using technology in education. This also includes reflecting on the broader pedagogical and societal consequences of digitalisation, such as how technology influences conceptions of musical creativity, authorship, and the professional role of the teacher. This shows how systematically integrating critical tech perspectives in music teacher education can help to relate and link the goals related to digitalisation with those of the sustainability discourse. In the next step we will present a concrete approach that shows how critical tech perspectives can be put into music classroom and teacher education practice.

Maker Music Education

The concept of *Maker Music Education* or MME (Treß, 2024) can be regarded as an alternative to the consumer-oriented approach that is prevalent in the field. Inspired by the maker movement, this approach emphasises the importance of improvisation and creative and aesthetic shaping of the world (Bettinger et al., 2020, p. 2). Its overarching goal is to enable learners to become creators and makers, rather than passive consumers (Glendening & Glendening, 2018, p. 12). Within a postdigital framework (see above), MME challenges the conventional use of innovation-driven music technology by encouraging students to repurpose obsolete and discarded electronic devices, thereby integrating sustainability into music education. Research findings demonstrate that maker approaches facilitate participatory and hands-on learning, fostering interdisciplinary connections between art, science and technology (Hayes, 2019). Despite their extensive implementation in STEM subjects, the adaptation of these approaches to music education remains in its infancy, with ongoing empirical studies investigating their potential in the classroom environment (Burnard & Colucci-Gray, 2020).

A research project at the University of Education Freiburg is investigating the musical and aesthetic potential of repurposing discarded music technologies (Treß, 2025a). MME is particularly highlighted as a means of supporting creativity, interdisciplinary learning, and sustainability while encouraging a critically constructive – and even subversive – engagement with technology. By repurposing outdated devices, upcycling materials, and integrating historical perspectives on sound recording and musical instruments, this approach offers students not only hands-on creative experiences but also critical media literacy and a deeper understanding of technological developments in music (Hayes, 2019). MME holds the potential to transform the perceived obsolescence of older technologies into an educational resource. Students explore how working with outdated sound carriers, decommissioned electronic instruments, and recycled components could serve as a foundation for creative experimentation and critical reflection on technological change. The concept aligns with broader sustainability efforts, demonstrating how discarded materials can be reimagined as tools for musical expression rather than waste.

However, several challenges and structural barriers complicate the implementation of such approaches in school contexts. A central obstacle lies in the limited technical infrastructure of many institutions. Further, teachers need to develop the expertise to select, adapt, and repurpose existing or unconventional materials. Therefore, teacher education must address both practical competences and theoretical knowledge about the cultural and technological histories of music technologies. On this basis, teachers can help to ensure that maker-oriented practice fulfils its potential. However, the time-intensive nature of hands-on maker projects often conflicts with the rigid structures of standard curricula and assessment frameworks. These challenges highlight the need for systemic support,

curriculum flexibility, and professional development that enables teachers to integrate such approaches meaningfully.

Yet it is precisely within these structural constraints that a different dynamic begins to emerge. The growing adoption of MME approaches increasingly takes shape as a grass-roots movement – one driven less by policy or institutional mandates than by teachers and learners experimenting with new forms of creative engagement in everyday educational contexts. Such initiatives require a long-term perspective, as the barriers outlined above cannot be removed overnight. Nevertheless, their sustainability appears promising precisely because they draw organically on core archetypes of music education, such as composing, improvising, dance and movement. These familiar practices lend continuity and legitimacy to innovation, embedding technologies in established educational traditions. Consequently, technology as a tool recedes into the background, while the collective, performative act of music-making under postdigital conditions becomes the central anchor of these processes. Here, the emphasis shifts from acquiring technical proficiency toward cultivating collaborative creativity, material awareness, and embodied musicianship, aligning the maker ethos with enduring educational values in music.

Setting Courses

With reference to the EU policy papers discussed at the outset, we see a great potential for addressing some of the most pressing challenges of our time by bringing sustainable and digital concepts together – particularly in music education. However, this interrelation is often overlooked. Our analysis showed that separating these two areas within specific competence frameworks leads to fundamental contradictions between the logics of sustainability and digitalisation. In this chapter, we identified three domains and approaches that showed how digitalisation and sustainability could be addressed in music education contexts in an integrated and meaningful way. Our examples illustrate that connecting these agendas requires a broader perspective that links educational and technological innovation with social and ecological responsibility. We hope that they will encourage teachers to consider the digitalisation from a sustainability perspective. The social dimension of sustainability in music education becomes particularly visible when examining digital tools and their role in accessibility and inclusion. While digital technologies can enhance access to musical learning, they can also risk undermining the value of active, embodied music-making if used without critical reflection.

Teacher education remains central to support this transformation. Sustainable and digital competences should be developed together, enabling future educators to make informed, context-sensitive decisions about the use of technology in music learning. Professional development in this area should address both technical proficiency and

pedagogical reflection, ensuring that teachers can engage critically with the social, ecological, and ethical dimensions of digital transformation. In light of accelerating climate change, environmental degradation, and global social crises, it becomes a political and educational necessity to raise questions of sustainability within digitalisation – and vice versa. The concept of *Maker Music Education* provides an example of how digital and sustainable practices can be linked in creative and critical ways. By enabling students to work hands-on with digital media as well as with analogue and electro-acoustic devices while reflecting on the technological systems that structure music production and consumption.

Transferring the philosophy behind these approaches to other fields of music education can strengthen digital literacy and sustainability awareness simultaneously. Music education, as a collective, experiential, and creative field, offers a distinctive context for integrating sustainable thinking into educational practice. Therefore, music curricula should explicitly include the social, ethical, ecological, and political dimensions of digital technologies.

This article can only be one step toward identifying the questions that need to be asked and the answers that can and must be developed within the field of music education. A postdigital framework can support this process by moving beyond binary understandings of the digital and the non-digital, promoting instead a perspective that situates music education within the intertwined realities of technological change and global responsibility: Setting courses for the urgent demands of a changing world.

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