The Interchangeable Roles of Music and Technology in Computer-Supported Education

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Abstract. Scientific literature has frequently focused on the contribution offered by technology to support music education at various levels. A less investigated subject is the possibility of using multimedia and musical languages to encourage the acquisition of digital competences. In this vision, the roles of *mediator* and *disciplinary goal* – which in the context of computer-supported education are traditionally assigned to technology and music, respectively – are reversed. These concepts will be exemplified through applications which explore the relationship between music and technology from a new point of view, merging the two fields and making traditional roles more nuanced, thus encouraging the development of higher-order thinking skills. This paper summarizes the keynote lecture held by the author at the 4th International Conference on New Music Concepts – ICNMC 2017.

Keywords. Digital competences, Higher-order thinking, Education, Music, Technology

1 Introduction

New technologies are revolutionizing teaching and learning activities in school curricula. A comprehensive introduction to the subject can be found in [10], a work that discusses a range of innovative practices in order to highlight the changing nature of schooling and the transformation of music education. According to many experts the availability of new digital tools is causing a real paradigm shift at any level, from basic education in primary school to advanced instrumental training and musicological investigation, as discussed in [13,15,24]. This technological revolution implies not only the availability of digital contents, electronic devices, and ad-hoc multimedia didactic tools, but also the adoption of new pedagogical approaches adapted to the specific goals of music education. The present work will provide an overview of both recent technologies and the corresponding pedagogical theories addressing music education and embracing aspects such as computer-assisted composition, instrumental practice, and theoretical investigation.

But there is an interesting aspect that has been less investigated in the literature: the roles of music and technology in an educational context can be flipped. In the previous case, computer-based approaches were used to improve music skills and competences; nevertheless, music can also be a means to nurture digital competences, e.g., content creation, problem solving techniques, computational thinking, etc. [14]. In this sense, music may act as a media language for the development of disciplinary knowledge in fields such as information representation, data structuring, computer programming, and so on.

Needless to say, the two roles are not mutually exclusive: both music and technology can be seen as mediators aiming to foster the acquisition of competences, and a suitable combination of them can reach effective and persistent results that go beyond single disciplines. This vision requires a close, non-trivial cooperation among actors coming from different backgrounds: pedagogues, musicians, music educators, designers, software developers, etc.

In music education, it should be quite obvious that music skills are the main target to achieve, and anything else – including technological tools and computer-based approaches – is a medium to reach the goal. Nevertheless, the citizenship of the 21st century requires the development of digital competences [23], and in this sense the music language can play a fundamental role, as we will demonstrate in the following. The real challenge is to introduce a radical change of perspective capable to break the *master-slave* relationship computer science is a victim of, often seen as a discipline at the service of other sciences and human activities. As well as digital products constitute *enabling technologies* that were able to drive radical changes in music production, broadcasting, preservation, etc., we will demonstrate that music itself – through its creative and analytical processes – can represent an *enabling language* to acquire digital competences.

2 Supporting Music Education through Technology

When talking about music education, the range of potential activities and goals is wide. Educational initiatives can address students of different ages, from pre-school to academy, and their aim can go from basic music knowledge to a very high degree of specialization in instrumental practice, music composition or theoretical investigation. Covering all possible aspects of music education is clearly beyond the scope of this paper.

Computer-based technologies can support music education from many points of view, ranging from teaching strategies to new approaches to composition and performance, from assistive technology and music therapy to the development of K-12 listening skills [24].

One of the directions that computer-supported pedagogy of music is currently taking is the full exploitation of the potential of the web. The pervasiveness of network technologies and the availability of high-speed connections is causing a rise of distributed music resources. Many studies have discussed the integration of on-line material into music teaching, documenting phases of integration that include supplemental links to resources, web-based teaching sequences, and various media to support course con-

tent [8].
Focusing on music-oriented web applications rather than generic on-line materials, in order to achieve effective educational results some features would be desirable. The "ideal" web interface should not only present high availability, achieve cross-platform compatibility, and give access to high-quality and certified resources, but it should also support an active and customizable experience of music contents, present multimodal interactivity, and foster peer-to-peer as well as student-teacher interactions.
Keeping this in mind, some research questions arise: Q1 – Is it possible to implement a web application capable to meet all the mentioned requirements, thus responding not only to specific disciplinary aims but also to pedagogical needs? Q2 – Is it possible to design an educational environment adaptable to different teaching/learning situations?
As a possible answer to both questions, it is worth mentioning the EMIPIU project.[1] EMIPIU, standing for Enriched Music Interactive Platform for Internet User, is fully compliant with World Wide Web Consortium (W3C) standards and independent from the hardware and software characteristics of the local system in use. Consequently, any device equipped with an HTML5 browser and connected to the web can access its contents.
The goal of this initiative was to demonstrate in a web environment the potential of the IEEE 1599 standard, an XML-based format conceived to describe music in all its aspects [3]. The web framework includes details of the project, official documentation about IEEE 1599, and a community area to exchange opinions, share materials and request clarifications on technical issues; but – for the purposes of this paper – the most interesting section is undoubtedly the *Music Box* area, which contains a media player with advanced navigation and synchronization features for music encoded in IEEE 1599 format. The interface of the web player available in the *Music Box* area is shown in Fig. 1.
Before describing such an application, a short overview of the underlying format is called for. IEEE 1599 allows to embed within a single XML document all the information that can describe a music piece from different perspectives: music notation, score layout, audio performances, catalog metadata, and even structural relationships among music objects. For each of these aspects, IEEE 1599 presents a dedicated *layer*; one of the key characteristics of IEEE 1599 is to allow a multi-layer description of music content. Inside a single layer, there may be multiple descriptions (called *instances*) of the same type. For example, an IEEE 1599 document can describe a given music piece with multiple score versions as well as multiple audio performances attached: music symbols are saved in the logic layer, scores are described as instances inside the notational layer, and sound tracks are linked as instances inside the audio layer. A special data structure, called the *spine* and contained in the logic layer, creates the relationships among descriptions of the same music events inside different layers and instances, thus implementing a mechanism of *intra-layer* and *inter-layer synchronization* [11].
As a consequence, an IEEE 1599 player supports full synchronization among a wide

[1] http://emipiu.di.unimi.it/

variety of materials, including scores, audio, and video. Moreover, for each music piece it is possible to experience different versions for any media type, e.g. different score editions or audio tracks, switching and comparing them in real time. The re-implementation of the original synchronization engine in a web environment posed a number of technical issues, above all concerning the necessity to broadcast multiple high-quality media streams to the client [4]. The implementation provided in EMIPIU is the evolution of that early prototype.

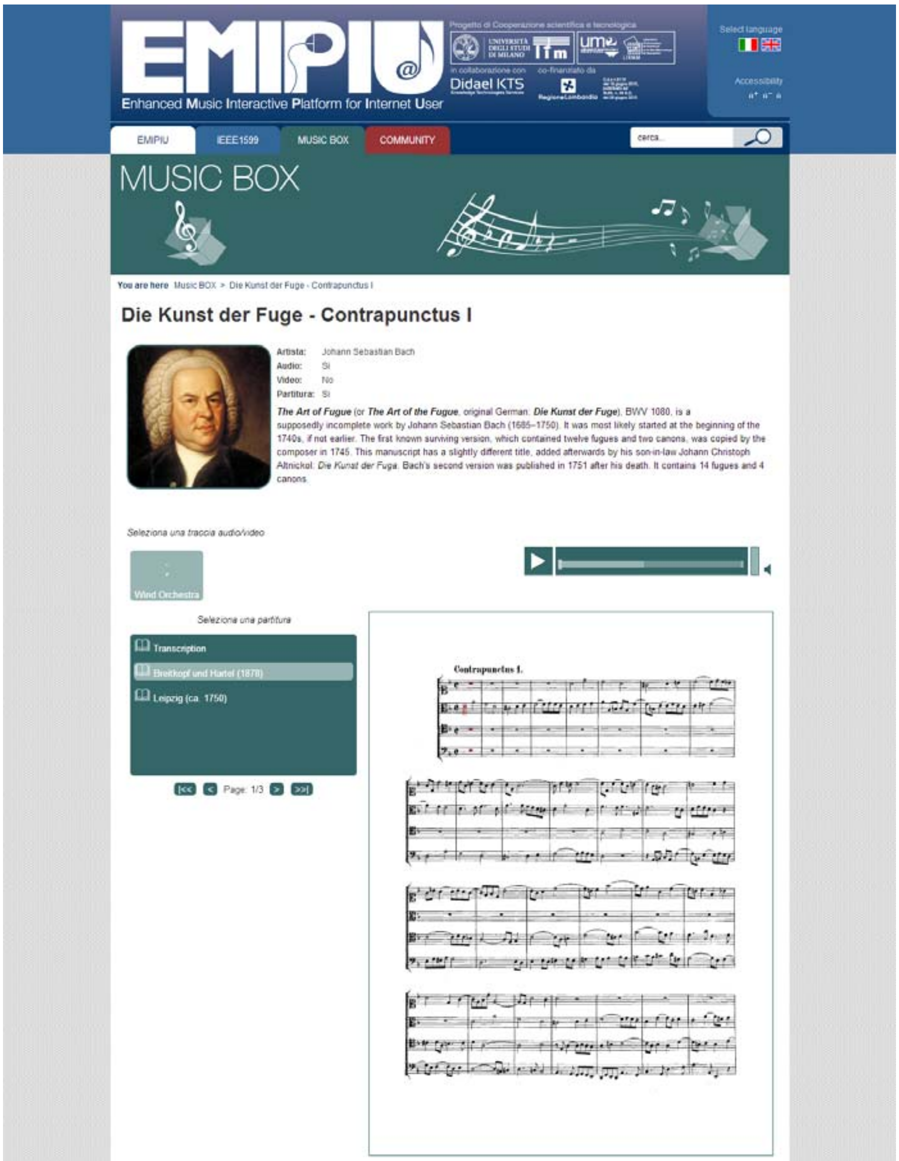

Fig. 1. The *Music Box* area of the EMIPIU portal.

Going back to the initial research questions, EMIPIU is a good example of computer-based application for music education (and much more…), where a suitable use of *ad hoc* technologies results in an enhanced experience of music. Most technical requirements of Q1 are met thanks to a suitable combination of W3C-compliant formats and languages, specifically HTML5, JavaScript, and XML/IEEE 1599.

Now let us focus on the pedagogical issues contained in Q1 and Q2. The EMIPIU approach facilitates and encourages music learning from many points of view. Since the fruition of music contents occurs in a synchronized environment, this application implements – first of all – an advanced score follower, whose granularity (e.g., note by note, measure by measure, etc.) can be configured during the preparation of materials. Consequently, a trivial case of application is the learning of standard musical notation, at different degrees of knowledge and complexity. The EMIPIU digital archive contains examples of easy notation (e.g., the *Gymnopedie n.1* by Erik Satie, *Two voice inventions* by J.S. Bach, etc.) as well as full-orchestra scores (e.g., the *Triumphal march* from *Aida* by G. Verdi, *Pavane pour une infante dèfunte* by M. Ravel, etc.). Concerning musical notation, the flexibility of IEEE 1599 allows forms other than Common Western Notation (CWN), such as neumes (see the *Introitus* from *In Nativitate Domini Ad Primam Missam*), lute tablatures (the *Prélude* from *Suite n.3* by S.L. Weiss), and special symbols for specific musical instruments (e.g., the jew's harp, or *khomus*). Also context-dependent notations are supported, such as so-called *Labanotation*, a notation system for recording and analyzing human movement in dance (see the *Pas de six: Variation III* from *The Sleeping Beauty* by P. I. Čajkovskij). The potential availability of multiple scores allows not only to learn notation through score following, but also to switch the notation in real time, comparing the special and the traditional one. Even when all score instances are written in CWN, this feature can be useful to compare a full score to a reduction (see *Il mio ben quando verrà* by G. Paisiello), or to better understand a hand-written autograph score (see the *Contrapunctus I* from *The Art of Fugue* by J.S. Bach).

An aspect orthogonal to notation is the one related to multiple audio instances. In this case, it is possible to compare a great number of performers (see *A Chloris* by R. Hahn),as well as to experience different ensembles, registers and performance styles, like in the *Ave Maria* by C. Gounod, *Gottes Macht und Vorsehung* by L. van Beethoven, and *Maple Leaf Rag* by S. Joplin, this one containing both a "traditional" execution and an 8-bit musification.

Finally, the educational environment can be adapted also to non-musical goals, as demonstrated by the case study of animal sounds. This is an experiment of CLIL (Content and Language Integrated Learning) for preschool and primary school students, where multiple audio tracks should foster the acquisition of foreign languages, and graphical contents should provide learning reinforcement and support interaction. This interface can be used also to realize educational games, as explained in [19].

The mentioned examples show the great variability of application contexts, ranging from the beginner who is learning how to read music notation to the skilled player who wants to compare great performances. The adaptability of such an application to different learning situations largely depends on the materials that are produced, up-

loaded to the platform, and used with educational purposes.
Finally, it is worth underlining that more advanced applications can be devised. For example, a multi-layer representation of music contents can be integrated with the Internet of Things and experienced through immersive and interactive devices, as proposed in [6]. As another example, the same technology can be employed to turn a "traditional" music textbook into an advanced multimedia adaptive tool, as discussed in [17].

3 Nurturing Thinking Skills and Digital Competences through Music

The previous section has discussed the advantages that the adoption of technology can bring to music education as a didactic mediator. This concept has been exemplified through a web platform flexible enough to cover different pedagogical aims.
Although experts are warning us against the adoption of technology for technology itself [2,12,21], which would distort not only the pedagogical approach but also the final goal of teaching and learning activities, the benefits of a wise and conscious use of technology are quite evident, and they have been documented in a number of scientific papers and on-field experiences.
An aspect less investigated in literature is the role that multimedia languages in general, and specifically music languages can play in the development of so-called *higher-order thinking skills* (HOTS). This concept has been defined in *learning taxonomies* and refers to those types of learning that require more cognitive processing than others, but have more generalized benefits. For instance, in Bloom's taxonomy [9], HOTS involve analysis, evaluation and synthesis. Even if it is commonly accepted that students should master the lower level skills before they can engage in higher-order thinking, according to cognitive researchers HOTS are important even in primary school [22].
A subject which is currently a hot topic and is strictly connected to higher-order thinking is the development of digital competences, which include the following areas: i) information and data literacy, ii) communication and collaboration, iii) digital content creation, iv) safety, and v) problem solving. A formal definition of these concepts and further details about their key components can be found in [14].
Going back to music education, the main research questions now become: Q1 – Can the musical language foster the development of higher-order thinking, and in a better way than other approaches? Q2 – Can it provide scaffolding for the categories of the cognitive domain listed in learning taxonomies, e.g., "Analyze", "Evaluate", "Create", "Apply", "Understand", and "Remember" categories in Bloom's taxonomy [1]? And, finally, Q3 – Can the musical language help learners to acquire (some of) the digital competences listed above?
A possible answer lies in the teaching proposal called *music coding*, introduced in [18], refined and exemplified during the 2nd International Conference on New Music Concepts – ICNMC 2016 [7], and finally implemented and publicly released as a software product [5]. Music coding can be defined as the adaptation of the basic con-

cepts and techniques of computer programming to the field of music analysis and composition, where both data structures and operators are rethought in order to be applied to the music domain. Music coding employs basic music activities and simplified languages to teach computational thinking to students. The idea is to design coding activities based on music processes that are able to unveil algorithmic aspects of music. Such processes may stimulate creativity and collaborative learning, and their audio feedback is immediately perceivable. In our opinion, music is effective since it can represent a valid learning tool as well as an addictive reinforcement technique to approach coding, even for very young and musically-untrained students.
In this context, we propose to learners an educational game especially conceived to exploit the musical media in order to convey some aspects typical of computational thinking. The interface of the latest version, based on the Google Blockly platform, is shown in Fig. 2.

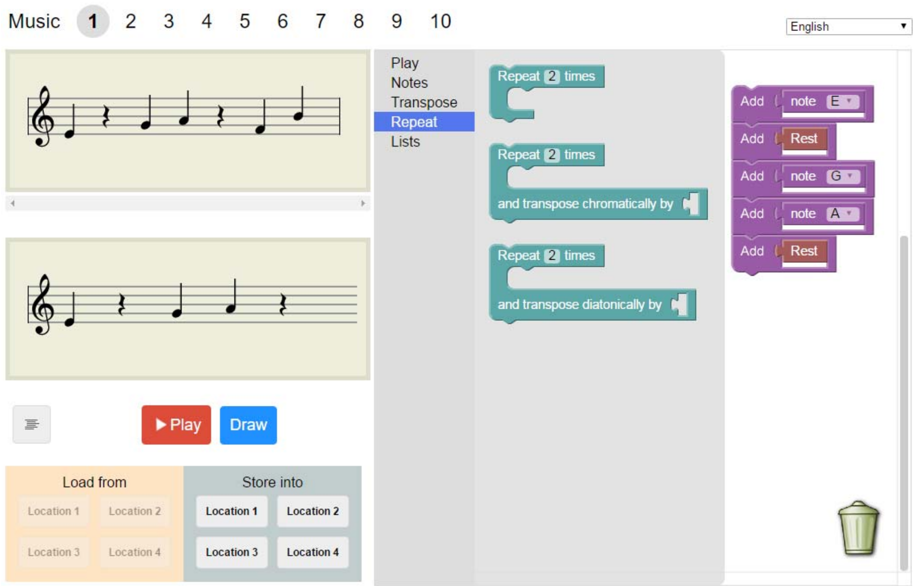

Fig. 2. An application for music coding.

Music coding activities are based on challenging single learners or small groups of students to solve programming exercises of increasing difficulty. Specifically, the application proposes the analysis and re-synthesis of a score by using a reduced set of musical operators. The problem to be solved in an algorithmic way is how to reconstruct the given music tune, and success is achieved when the user's score (displayed below in the interface) is equal to the original one (displayed above). It is worth underlining that there is not a unique and mandatory way to solve a problem, rather there is a range of possible solutions, more or less compact, effective, and algorithmic. On one side, this encourages learners to apply self-evaluation processes and challenges their computational thinking skills, on the other side it allows students and teachers to open a constructive debate on the achieved results.

The experience is based on a visual programming language, represented by the boxes on the right, whose execution generates a melody. This language provides the basic programming tools, such as simple and structured variables, iterations, and so on. When the code is launched, the application produces both a traditionally-notated musical score and an audio rendering. For further details, please refer to [5].

Going back to the aforementioned research questions, now it is possible to answer them with special reference to music coding.

A1 – The musical language can be profitably adopted to develop higher-order thinking skills such as analysis, evaluation and synthesis, since this is exactly the kind of approach we are asking to learners during the proposed activities. Music can provide an engaging and amusing test bed for learners.

A2 – The categories listed in Bloom's taxonomy include not only analysis, evaluation and comprehension, but also creation and memorization. Concerning the former issue, music, which is not only a language but also a form of artistic expression, is an effective domain to foster creativity. For instance, another possible use of the mentioned interface is to leave users free to create their own musical contents by exploring the meaning of operators, and then to carry out *a-posteriori* analyses of results. As it regards memorization, please note that the stimulation of multiple senses (sight and hearing) during the educational activity and the availability of multiple channels to test results is a valid reinforcement technique to consolidate learning. Besides, there are many scientific studies that demonstrate the privileged relationship between music and human memory, even in very young learners [20] or patients affected by dementia [16].

A3 – Music coding can encourage the acquisition of specific digital competences, such as communication, collaboration, digital content creation, and problem solving. The last two issues have been already discussed. As it regards communication and collaboration, these competences can be developed and refined during the educational activity, for instance through peer or expert seeking, problem posing and solving, and the final discussion of results.

4 Conclusion

In this paper we have switched the roles of *didactic mediator* and *educational goal* usually assigned to technology and music respectively in the context of computer-supported education. We have provided two examples of publicly available applications that demonstrate the potential of both the traditional and the novel approach.

Should we employ technology during teaching activities mainly to improve the lesson experience, making it more interactive, effective and engaging? Or can music be seen as a language to actively foster the development of higher-order thinking skills and to nurture digital competences? The research question is open, and the purpose of this work is to encourage a debate among experts.

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