A Collaborative Digital Audio Workstation for Young Learners

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Keywords: Remote Education, Digital Audio Workstations (DAWs), Web, Online Technologies, Sound and Music Computing.

Abstract: This paper presents the early results of the project titled "A Band in the Cloud", conducted in cooperation between INDIRE, the agency of the Italian Ministry of Education for educational research and innovation, and LIM, the laboratory of sound and music computing of the University of Milan. The goal of the project is to foster the development of musical and extra-musical skills in young learners through a free web-based digital audio workstation. After presenting the state of the art and discussing the pedagogical aims of the initiative, we will describe the technical details of the platform and give details about the release plan.

1 INTRODUCTION

A digital audio workstation (DAW) is an electronic device or application software aiming at recording, editing, and producing audio files. In the digital domain, DAWs are usually software applications based on the metaphor of a multitrack tape recorder. In general, they present a standard layout that includes transport controls (play, rewind, record, etc.), track controls, a mixer, and a waveform display. DAWs mainly represent music-production tools in use in professional environments, but they can also have educational purposes, being adopted at various school levels and with different goals.

The purpose of this paper is to demonstrate that DAWs and web technologies can be profitably combined to create opportunities for the development of musical, technical, and soft skills. These educational results can be encouraged by remote collaboration between users, where the concept of collaboration embraces both supervised work, namely a teacher-learner relationship, and peer-to-peer cooperation occurring between learners. This article aims to introduce a model for a digitally mediated online collaboration that focuses on music composition through the use of an online DAW. To this end, a free software platform has been developed in the context of a publicly funded Italian project involving an educational research institution, a university lab with expertise in the field of sound and music computing, and external experts for software development and user-acceptance tests.

As better explained in the following, the project is still at an early stage, so this paper will outline the pedagogical context, discuss the state of the art, and provide details about the first implementation steps, whereas the results of the test phase from both a technological and an educational point of view will be addressed in future publications.

The rest of the paper is organized as follows: Section 2 will describe the state of the art concerning online applications for music education, focusing in particular on Digital Audio Workstations, Section 3 will frame this initiative in the context of a publicly funded Italian project, Section 4 will provide technical details about the developed solution, Section 5 will discuss the expected outcomes from an educational point of view, Section 6 will propose a roadmap for future development, and, finally, Section 7 will draw the conclusions.

2 STATE OF THE ART

In the digital domain, a huge number of tools for music training and education is available, including "traditional" computer software, mobile apps, and web applications. For the goals of this paper, we will narrow the field to the latter category and, certainly far

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Baratè, A., Ludovico, L. and Presti, G.
A Collaborative Digital Audio Workstation for Young Learners.
DOI: 10.5220/0011135100003182
In *Proceedings of the 14th International Conference on Computer Supported Education (CSEDU 2022) - Volume 1*, pages 458-464
ISBN: 978-989-758-562-3; ISSN: 2184-5026

from being exhaustive, we will mention some examples.

Based on their functions and educational objectives, web platforms can be subdivided into various categories:

- **Online Music Studios** usually have the characteristics of a sequencer, offering music loops and sounds for song creation. Examples include *BandLab*,[1] *Groovy Music*,[2] *Soundation*,[3] and *Soundtrap*;[4]
- **Music-performance Platforms** offer practical tools to help students learn how to play an instrument or sight-read music at distance. Examples include *Doozzoo*,[5] *PracticeFirst*,[6] *Sight Reading Factory*,[7] *Smartmusic*,[8] and *Yousician*;[9]
- **General Music-education Platforms**, with respect to the previous category, aim at fostering more general music abilities, focusing on listening skills, theory, composition, computational thinking in music, also through gamification. Examples include *BrainPOP Arts and Music*,[10] *Chrome Music Lab*,[11] *Classics for Kids*,[12] *Focus on Sound*,[13] and *PBS KIDS Music Games*;[14]
- **Music Notation and Creation Platforms** offer online tools often augmented with score sharing and collaborative functions. Examples include *Flat*,[15] *Noteflight*,[16] and *O-Generator*;[17]
- **Music-theory and Ear-training Platforms** mainly address the study of formalized music knowledge through music-theory lessons with interactive exercises and tools. Examples include *Auralia*,[18] *MusicTheory.net*,[19] and *Musition*.[20]

[1] https://edu.bandlab.com/
[2] https://www.musicfirst.com/applications/groovy-music/
[3] https://soundation.com/
[4] https://www.soundtrap.com/edu/
[5] https://doozzoo.com/
[6] https://www.musicfirst.com/applications/practicefirst/
[7] https://www.sightreadingfactory.com/
[8] https://www.smartmusic.com/
[9] https://yousician.com/
[10] https://www.brainpop.com/artsandmusic/
[11] https://musiclab.chromeexperiments.com/
[12] https://www.classicsforkids.com/
[13] https://www.focusonsound.com/
[14] https://pbskids.org/games/music/
[15] https://flat.io/
[16] https://www.noteflight.com/
[17] http://www.o-generator.com/
[18] https://auralia.cloud/
[19] https://www.musictheory.net/
[20] https://www.musition.cloud/

Even if the present review is far from being exhaustive, it can return a broad idea of the educational offer for music education currently available on the web.

The category that best fits the goals of the present proposal is that of online music studios. The use of DAWs in education has been addressed in several research works. A trivial field of application is the use of DAWs to develop specific musical and/or technical skills, e.g., in recording and layering parts (Brown, 2014), in collaborative songwriting (Clauhs, 2020), and in audio signal processing (Tarr, 2021). It is also important to remark that some experts warn against the indiscriminate use of DAWs in music education. For example, Dorfman deconstructs the myths that incorporating music production and related software is simple and requires little thought (Dorfman, 2022). Similarly, Bell argues that music educators should be able to critically assess how DAWs influence the decisions of music-makers and highlights the fallacy that these applications are wrongly perceived as "easy to use" in music education (Bell, 2015).

Another interesting field of investigation concerns the adoption of DAWs to develop extra-musical skills. For example, Walzer studies the use of relevant technology, including DAWs, for digital storytelling in music and audio education, thus inspiring modern reflective practices (Walzer, 2016). Duncan investigates the cognitive processes that emerge when students interact with *GarageBand* and *Soundtrap*, two of the most popular entry-level DAWs, both in classrooms and in online learning (Duncan, 2021). Cipta discusses a case study where DAWs are employed in a self-learning scenario in order to foster creativity (Cipta, 2021).

What are the reasons to implement a new web solution when well-established platforms are already available? In the authors' opinion, there are mainly three reasons. The first reason is connected to commercial and legal aspects: in general, these platforms are not free and/or require premium access to fully benefit from all the services, which is not compatible with extensive use in public schools; moreover, user data are stored and managed by private companies, and, even though protected, they would not be accessible for educational research purposes. The second reason is connected to one of the fundamental aims of the initiative, i.e. fostering peer-to-peer cooperation between students. In fact, even if the web seems the natural means for team working, many online platforms turned out to be the web version of offline applications, mainly intended for personal use and equipped with *a-posteriori* sharing functions. Finally, one more reason to design a brand new product, even if inspired by previous solutions, is the possibility to study ad hoc interfaces and functions tailored to the target audience represented, in this case, by young learners.

For the sake of clarity, it is worth mentioning the availability of free DAWs (e.g., *Ardour*[21]) and shareware DAWs (e.g., *REAPER*[22]) that currently present a good level of maturity and usability; nevertheless, these solutions cannot be considered our competitors, since they are not online platforms and they have not been explicitly conceived for interaction within educational activities.

3 THE PROJECT

The design and implementation of the online DAW described below has to be framed in the context of a wider project financed by the Italian Ministry of Education (Ministero dell'Istruzione, dell'Università e della Ricerca) and focusing on multidisciplinary laboratory teaching. Such an articulated project, codenamed 10.8.4.A2-FSEPON-INDIRE2017-1 (CUP: B59B17000020006), was entrusted to INDIRE.

Within this framework, the music area of the project was developed in cooperation between INDIRE, the *National Institute For Documentation, Innovation And Educational Research* of the Italian Ministry of Education, and LIM, the *Laboratory of Music Informatics* of the University of Milan. The resulting proposal, explicitly addressing musical goals, was called "A Band in the Cloud". The public call was published by INDIRE on July 14, 2020, and the beginning of the operative phase, determined by an official communication sent from INDIRE to the University of Milan, dates back to May 7, 2021.

3.1 Project Partners

Founded in Florence in 1925, INDIRE[23] is the earliest institution of the Ministry of Education and represents the reference point for educational research in Italy. Among its activities, it is worth mentioning the development of new teaching models, the use of new technologies in training programs, and the involvement in some of the most important experiences of e-learning at the European level. Within the project "A Band in the Cloud", INDIRE represented the educational and pedagogical point of reference. Moreover, INDIRE provided the specifications for software development.

LIM is one of the first research labs of the Department of Computer Science of the University of Milan. Founded in 1985, LIM[24] has hosted renowned composers and experts such as Franco Donatoni, Angelo Paccagnini, Antonio Josè Rodriguez Selles, and Dante Tanzi. In almost 40 years of activity, LIM carried out international projects and established important collaborations. Among others, it is worth mentioning: Teatro alla Scala of Milan, Bolshoi Theatre of Moscow, RAI Radiotelevisione Italiana, RSI Radiotelevisione Svizzera, Orchestra Verdi di Milano, IEEE Computer Society, Ricordi Historical Archive, and the Italian Ministry for Cultural Heritage and Activities. LIM contributed to the project with its know-how and expertise in the field of sound and music computing, being mainly in charge of software design and implementation.

The evaluation of the user experience and the testing phase, which is currently in progress, have been performed in cooperation between the two institutions.

3.2 Project Goals and Research Questions

One of the key goals of the general project was the design and implementation of prototype educational software to be experimented with in learning environments and characterized by the acquisition of skills in an informal way. Within the project "A Band in the Cloud", such an objective has been interpreted as the creation of a digital learning environment for primary and lower secondary school students based on cloud computing and web technologies.

The purpose of the learning environment is to let students develop specific skills – including the composition of musical pieces, instrumental practice, musical analysis of formal and structural aspects – in a collaborative way. In order to support peer-to-peer cooperation and out-of-the-school learning activities, the user interface has been released as a browser app.

This product will be first experimented in a pilot study, and, after an evaluation and refinement phase, released for free use in Italian primary and low-level secondary schools. From this point of view, the platform is expected to have a deep impact also in difficult educational scenarios, such as small and rural schools, where technology can make up for the shortage of "traditional" teaching aids and specialized educators (Barter, 2013; Wang et al., 2019; Kormos and Julio, 2020).

The research questions of "A Band in the Cloud"

[21] https://ardour.org/

[22] https://www.reaper.fm/

[23] https://www.indire.it/

[24] https://lim.di.unimi.it/

focus on the capacity by the proposed platform to make young learners develop three categories of skills: i) basic musical skills (e.g., rhythm, melody, harmony, timbre, piece structure, etc.), ii) computer-oriented skills (i.e. the ability to use web tools and technologies and the development of computational thinking), and iii) soft skills (e.g., communication, problem-solving, teamwork, leadership, creativity, etc.).

4 TECHNICAL DETAILS

In this section, we will provide some technical details about the platform we are proposing. In Section 4.1 we will illustrate the strategy used to implement client-server interaction and the synchronization between the local and master copies of the project, in Section 4.2 we will list the main functions offered to users, and in Section 4.3 we will show the graphical user interface.

4.1 Client-server Interaction and Synchronization

The web DAW is based on client-server interaction and presents a specific synchronization model between the *local copies* of a music project and the central one, called the *master copy*.

The key role of the server is to host the master copy granting access after an authentication process. Music projects are shared between groups of users and can be accessed concurrently according to the scheme described below. Each project is described in the server as a JSON (*JavaScript Object Notation*) document which describes some general features (e.g., tempo, meter, title, author) and the music content (e.g., tracks, events, list of multimedia materials). The *master copy* can be read and written by clients by invoking ad-hoc web services. The server also hosts a collection of samples, i.e. short audio files organized in four families (tuned loops, percussion loops, hits, effects) and characterized by a description, a base tempo, and a reference music genre. Users can employ these samples in their music projects as well as upload their own audio files. Each project is hosted in a specific server folder that contains both the JSON document and, potentially, the custom audio files uploaded by users. Users work on their local copy of the project through the graphical interface of the client, as described in Section 4.3.

As it regards the synchronization of the local copies of the musical project with the master copy, a critical decision was required. An option was a hard synchronization, where any action on each client would have immediately impacted on the master copy and such an update would have propagated to all the clients connected to the project. Rather, we opted for a soft synchronization model, where the information transfer from the local to the master copy (*upload*) requires an explicit confirmation action by the user and the alignment of all the clients with the server (*download*) occurs either periodically, at regular time intervals, or on demand, upon explicit request by the user. This architectural solution implies misalignment between local and master copies, but it presents several advantages:

- The mechanism is simple to implement and does not require push notifications or similar approaches;
- The server workload is, in general, low;
- The approach is flexible, in that – if necessary – it lets a user request the master copy at any time, upon explicit action. Moreover, by setting a very high refresh rate, users can have the illusion of real-time interaction;
- Also in case of low refresh rate, misalignment is only temporary, and the synchronization process is transparent to users;
- Even if collaborative, such a strategy is a non-blocking one, since users can have concurrent access to the master copy.

In order to avoid conflicts during the misalignment phase, each user is enabled to work on a subset of tracks only. The implementation of a locking system further improves the efficiency of the client/server interaction. In fact, called U the current local user, the U's client uploads only the tracks under the control of U, and it downloads (and consequently overrides) all the tracks but U's ones.

4.2 Main Functions

As mentioned before, the developed platform can be seen as the simplification of a standard DAW, adapted to an audience of young learners and oriented to a collaborative workflow. The main functions the system supports are:

- **Track Operations** – Add, remove, and change properties such as name, color, pan, volume, etc. Please note that tracks can be either audio tracks, intended for samples, or instrumental tracks, intended for MIDI-like music events;
- **Event Operations** – Add an event to a track, remove an event from a track, move an event along

a track or across tracks, duplicate an event, resize an event (i.e. cut an event before its natural end);

- **Sample Library Operations** – List available samples, add self-produced samples to the project library, search by name or family;
- **Transport Operations** – Play/pause, rewind, monitor and alter the playback point;
- **Project Operations** – Rename the project, synchronize project copies (upload and/or download), change tempo, change the time signature.

The mentioned functions are those available to any user. There are also features that depend on the specific user's profile. For example, a teacher has complete visibility on the project, with the possibility to change its general properties and operate on all users' tracks, whereas a standard user is enabled to act on his/her part of the project only. Moreover, the prototype described in this paper is still lacking some key functions, such as user-profile customization and cooperative tools (e.g., chat and file sharing).

4.3 Graphical User Interface

In order to ensure full compatibility with HTML5 web browsers, several standard languages and formats approved by the World Wide Web Consortium (W3C) have been employed for the implementation of the client. In particular, *HTML* (*HyperText Markup Language*) version 5, a language to describe static hypertext documents, provided the logical structure of the web page. *CSS* (*Cascading Style Sheets*) version 3 was adopted to define the formatting and graphic appearance of the client; in detail, we used *SCSS* (*Sassy CSS* superset), that is a syntactical variant for the CSS Sass preprocessor equipped with some relevant extensions (variables, functions, etc.). *JavaScript* was adopted as the reference client-side scripting language. *Web Audio API* and *Web MIDI API* constituted the low-level JavaScript-based libraries for handling audio and MIDI events, respectively; moreover, *Tone.js* was also employed as the high-level JavaScript-based library for handling audio events. *React*, another JavaScript library, was useful for creating user interfaces updated on the base of state changes; thanks to this technology, modifications in data structures are automatically reflected in the graphic interface and vice versa. *JSON*, a structured plain-text format, was selected as the means to exchange data between the server and the client in response to web-service calls. Finally, *PHP* (*PHP: Hypertext Preprocessor*) was the interpreted scripting language running server-side to process client requests.

The resulting graphical user interface is shown in Figure 1. The main area is taken by the visual representation of tracks and their sound events (i.e. the *sequencer* part). The left column provides the tracklist, the right one contains the sample library, and the upper part presents performance controls. Colors can be used to improve the project's organization and structure, e.g., to highlight the work by different users or group instrumental families. Unlike typical DAWs, in order to keep the interface simpler, a *mixer* part is not present as an independent area, whereas mixing actions (such as changing volume and pan) are already available in the left part. In other words, this part can be considered as a *vertical mixer*.

Currently, the interface is available in Italian only, since it is the result of a national-funded project; but the platform is ready to be localized in other languages, too.

5 EXPECTED EDUCATIONAL OUTCOMES

Considering the advances for educational research, the learning environment is expected to have a high potential thanks to the analysis of i) user data, ii) performance data, and iii) experimental data.

Concerning the former aspect, even if users are anonymized (i.e. identified only by a nickname in the platform), available data can be analyzed to extract relevant information. Needless to say, user statistics such as participants' age, grade, school type, and country can help define the typical use cases of such a learning tool. But even more, relevant information can be obtained from the analysis of users' behavior: e.g., where, when, how frequently, and how long learners use the platform, how many learners cooperate on a single project (huge class assignments vs. small-group projects), how many intersections occur in their cooperation (in-parallel vs. in-sequence operations), and so on. Please note that the mentioned aspects disregard the musical aspects and the disciplinary learning aims of the platform.

The analysis of users' performances, intended as the musical outcome of learning activities, is another area to be evaluated. Even if the practical outcome is the collaborative creation of a music piece, such a result is necessarily based on a number of skills: the ability to plan a music piece both "vertically" (number, type, and family of instruments) and "horizontally" (structure and sections), the ability to select and organize suitable music materials (samples, loops, etc.), the technical skills to adjust tempo, volume, panning, and so on. Soft skills are required

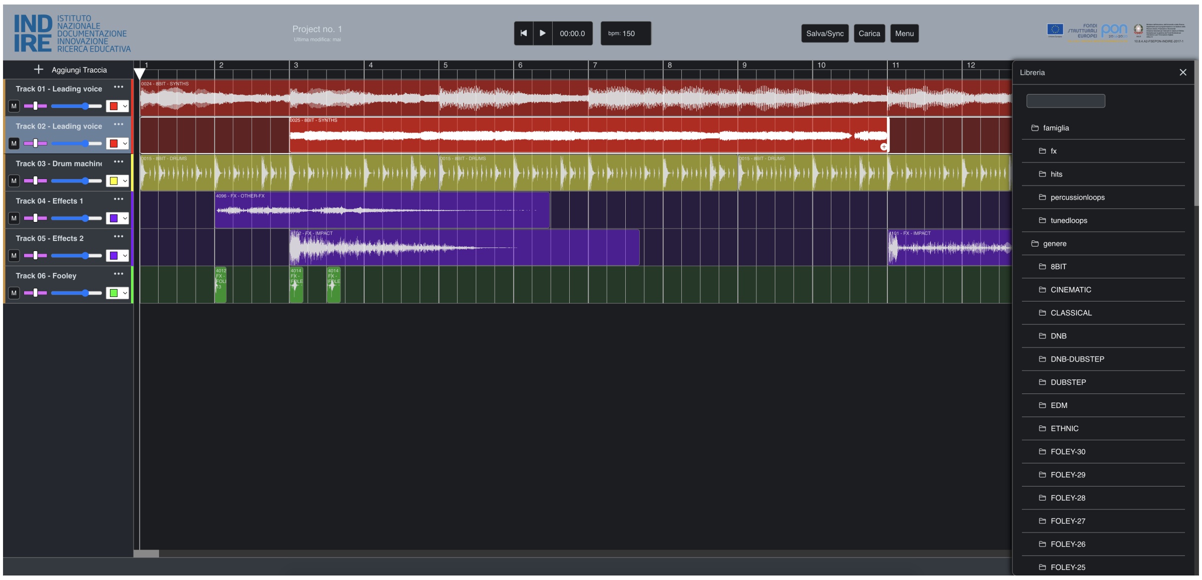

Figure 1: The client's graphical user interface.

as well, including communication, peer-to-peer cooperation, self-regulation, problem-solving, computational thinking, etc. (Bassett, 2013; Ludovico and Mangione, 2014; Baratè et al., 2015) Unfortunately, the assessment of music abilities is a complex problem, due to the difficulties in establishing a reliable system of parameters to measure them (Law and Zentner, 2012). Planning an educational path of increasing difficulty may be challenging for teachers, too. What are the critical aspects for students? The number of tracks to be managed by a single user, the number of students who work in parallel, the need to include specific instrumental families, or something else? Users' data could help in shedding new light also in this research area, which is extremely important from both an educational and a technical point of view.

The third field of investigation concerns the acquisition and analysis of experimental data from the teacher's perspective. All the data collected through platform activities are updated on the fly and made available for educators. Each teacher can adopt heterogeneous strategies and plan different working sessions to be experimented with students in order to form experimental and control groups with the final goal of finding the most effective teaching strategy. Needless to say, such a strategy can be adapted to specific learning goals and can be differentiated on the basis of students' musical background, school level, possible impairments, etc.

6 FUTURE WORK

At the moment of writing, an early but fully working prototype has been implemented. The solution already presents all the functions described in Section 4.2 and the graphical interface shown in Section 4.3.

Concerning the test and deployment phases, the release plan includes the following milestones:

- Alpha test (March to April 2022). In this step, the prototype will be presented to a small number of selected users, mainly scholars and experts in the field of music education;
- First public presentation (May 2022). During Fiera Didacta, the most important school-innovation fair in Italy, the prototype will be publicly shown to the participants. Fiera Didacta aims to encourage debate on the world of education between institutions, associations, and entrepreneurs. The event addresses all levels of education and training: nursery school, kindergarten, primary, lower and upper secondary school, professional institutes, universities, scientific research and professional training institutes, and companies working with schools;
- Beta test (June to September 2022). After collecting the results of the alpha test and the remarks and suggestions made during Fiera Didacta, the prototype will be revised and brought into a small number of schools in order to conduct a pilot study;

- Final release and deployment (from October 2022 on). The platform, in its final version, will be made freely available to all Italian schools thanks to the support of INDIRE.

7 CONCLUSIONS

This paper has presented the early results of the project titled "A Band in the Cloud", conducted in cooperation between INDIRE and LIM – University of Milan, whose aim is to foster the development of musical and extra-musical skills in users. Based on web technologies and a cooperative approach, the main outcome of the project is the release of a DAW equipped with basic but relevant functions and explicitly conceived for an audience of young learners.

Even if, at the moment of writing, the goals of the project, the pedagogical strategies to adopt, and the technical features of the platform are clear and well established, the efficacy of the approach in a real learning environment has still to be verified. Answering the research questions listed in Section 3.2 will be the focus of the experimental phase that we are going to open. The roadmap towards the final release of the platform is articulated and can bring substantial modifications. The web DAW will be hopefully ready for use in October 2022, allowing both classroom and out-of-school music composition and performance activities.

ACKNOWLEDGEMENTS

This project is the main outcome of the 10.8.4.A2-FSEPON-INDIRE2017-1 project (CUP: B59B17000020006), funded by the Italian Ministry of Education in the context of the National Operational Program (in Italian: Programma Operativo Nazionale, PON) titled "For school – Learning Competencies and Environments" (in Italian: Competenze e ambienti per l'apprendimento). Such an action plan aims to create a high-quality education and training system. Financed by the European Structural Funds, it has a seven-year duration, from 2014 to 2020.

REFERENCES

Baratè, A., Ludovico, L. A., Mangione, G. R., and Rosa, A. (2015). Playing music, playing with music - a proposal for music coding in primary school. In McPherson, M. and Nunes, M. B., editors, *Proceedings of the International Conference E-Learning 2015, Las Palmas De Gran Canaria, Spain July 21 - 24, 2015*, pages 3–10. IADIS Press.

Barter, B. (2013). Rural schools and technology: connecting for innovation. *Australian and International Journal of Rural Education*, 23(3):41–55.

Bassett, P. (2013). *Benefits Beyond Music: Transferable Skills for Adult Life. Musically active adults on the value of their music education and experiences during childhood and teenage years to adult life beyond music.* PhD thesis, University of Sheffield.

Bell, A. P. (2015). Can we afford these affordances? garageband and the doubleedged sword of the digital audio workstation. *Action, Criticism & Theory for Music Education*, 14(1):43–65.

Brown, A. R. (2014). *Music technology and education: Amplifying musicality*. Routledge.

Cipta, F. (2021). Digital audio workstation in music self-learning. In *3rd International Conference on Arts and Design Education (ICADE 2020)*, pages 208–212. Atlantis Press.

Clauhs, M. (2020). Songwriting with digital audio workstations in an online community. *Journal of Popular Music Education*, 4(2):237–252.

Dorfman, J. (2022). *Theory and practice of technology-based music instruction*. Oxford University Press.

Duncan, R. (2021). Cognitive processing in digital audio workstation composing. *General Music Today*, page 10483713211034441.

Kormos, E. and Julio, L. (2020). Technology in rural schools: Access, acquisition, perceptions, and barriers. In *EdMedia+ Innovate Learning*, pages 1010–1016. Association for the Advancement of Computing in Education (AACE).

Law, L. N. C. and Zentner, M. (2012). Assessing musical abilities objectively: Construction and validation of the profile of music perception skills. *PLOS ONE*, 7(12):1–15.

Ludovico, L. A. and Mangione, G. R. (2014). Self-regulation competence in music education. In McPherson, M. and Nunes, M. B., editors, *Proceedings of the International Conference e-Learning 2014 (EL 2014)*, pages 46–54, Lisbon. IADIS Press.

Tarr, E. (2021). Teaching audio signal processing using a digital audio workstation as the calculator. In *Audio Engineering Society Conference: 2021 AES International Audio Education Conference*. Audio Engineering Society.

Walzer, D. (2016). Digital storytelling in music and audio education: Inspiring modern reflective practice with relevant technology. *TOPICS for Music Education Praxis*, 3:46–76.

Wang, J., Tigelaar, D. E., and Admiraal, W. (2019). Connecting rural schools to quality education: Rural teachers' use of digital educational resources. *Computers in Human Behavior*, 101:68–76.