Collaborative Music Composition Using Cloud Tools

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***Abstract*—This paper illustrates an ongoing study to design and create a collaborative digital learning environment using new technologies, within the active-learning methodological approach. The aim of the research is to propose a new methodology for the development of composition and musical practice for upper secondary school students, based on Cloud computing, within a learning context characterized by the acquisition of skills in an informal manner.**

***Index Terms*—Music Composition; Cloud computing; Music practice; ICT Music education.**

I. Introduction

Digital technology has changed the world of music. Not only music that is "listened" but also, and especially, music that is played. The acoustic instrument has remained (almost) the same, but the approach towards every type of musical product has changed: the personal computer has become an almost complete "home studio" with costs considerably lower than a "real" professional recording studio. Digital technology has also made a big impact on the teaching of music at school, especially in recent years, with the widespread use of mobile devices (smartphones and tablets) that offer a variety of applications for music education, already used by many music teachers for their students [1].

By exploiting new technologies (software cross-devices, 2.0 applications), it is possible to offer students a digital environment that can bolster the informal type of school activities accompanying formal education subjects, to generate an "appetite" for musical practice, with the awareness that music "is essentially culture, knowledge that is reticular and interdisciplinary, that can shed light on other kinds of knowledge from which it continuously receives light in turn [2]".

The construction of an appropriate learning environment allows experiments with methodological solutions that give students the opportunity to enjoy musical experiences in contexts without external constraints, allowing them to temporarily abandon educational/formal practice and delight in the freedom of exploration during their music education.

Starting from a general outline of the educational basics that led to the writing of this paper, Section 2 will show the relationship between the construction of learning environments and 2.0 digital technologies. Section 3 will then show the technological context of music production and its development in the Cloud which, thanks to the constant increase in performance of web communication infrastructures, represents the main novelty for collaborative musical production activities not previously possible, when the characteristics of bandwidth and storage were insufficient to allow a quality/price ratio accessible to schools or individual students.

Section 4 looks at the details of constructing a learning environment: tools, facilities, objectives, technical feats, and examples of tasks. Section 5 identifies the expected results from the on-field study, both in general terms and from the standpoint of individual students learning. New developments and conclusions (Section 6) wrap up the paper.

II. Learning environments between Constructivism and didactics

The learning environment is the key element of the didactics of Constructivism, which bases its principles on the following conditions: "collaboration, personal autonomy, generativity, reflectivity, active involvement, personal relevance and pluralism. [3]"

Constructivism is an approach to teaching that puts the learner at the centre of the learning process as an alternative to an educational approach based on the centrality of the teacher.

In these environments, knowledge is the product of an active construction on the part of the learner, is connected to the concrete situation where the learning is taking place, and arises from social collaboration and interpersonal communication.

In these environments, so-called "significant learning" [4] is also born from social collaboration and interpersonal communication, integrating seven fundamental aspects: active, collaborative, conversational, reflexive, contextualized, intentional, and constructive. It follows that knowledge is a "making of meaning", a creative interpretation by learners in the process of understanding the reality that surrounds them [5], and as the product of an active construction by the learner, coupled with the concrete situation where the learning is taking place. The goal is not the learning of specific content, but the ability to internalize a methodology that makes learners independent within their own cognitive journeys: not knowledge that is already coded, but methods for personal growth, learning how to learn.

In 1990, Lavas and Wenfer [6] proposed the Situated Learning

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theory: that knowledge is not a set of learned theoretical concepts, but the result of a dynamic process, i.e., the active participation of a learner within a context, given by interaction with other members and the surrounding situation.
Constructivism has not developed a one-off teaching model.
For Jonassen, "there are no predefined models for constructivist learning environments, and for many, they could never even exist, since the processes of constructing knowledge are always inserted into specific contexts. Thus, with every probability, the types of support for programmed learning in each context will never be transferred to another. [4]" Jonassen provides some basic suggestions for any learning environment and identifies the construction of knowledge as the main objective, while in the attention to the context and the use of internal communication tools, negotiation and problem-solving are the key aspects.
The teacher guides and supports the group, and a space is defined (physical or virtual) where the work tools are located.
The current technological level inside the World Wide Web, especially with the deep shared use of social tools and Cloud services and the progressive growth in performance of web communication infrastructures, offers the possibility of preparing a digital learning environment in line with the assumptions of Constructivist teaching, abounding in stimuli for working groups and small communities. Teachers assume the role of facilitators of learning processes, and this represents a stimulus that creates conditions for positive collaboration, stimulating research and internal sharing, by focusing on the personalization of teaching strategies within the group/community.

III. The technological context of music production and the innovation of Cloud services

Since 1877, the year when Thomas Edison invented the phonograph, which made it possible to record and reproduce sound waves, the technology to record the human voice, singing, instrumental music, environmental effects, etc., has evolved through the recording and reproduction of sound using electrical and optical recording systems (photocells), vinyl, magnetic tape and cinema film.
In the beginning, all audio recording systems were based on the acquisition of analogue signals in the form of waves, which were physically recorded on supports (phonographic, vinyl or magnetic) with the aim of replicating the waveform, and then reversing the process and converting the tracks recorded on the various media into audio pulses and by using an amplifier, restoring the original waveform.
The large-scale introduction of digital recording has completely changed the technology of acquiring sounds, coupling the evolution of audio capture technology with the evolution of information technology.
Digital recording uses a tool that measures changes in sound pressure and converts and stores these on a support as a sequence of bits, thus creating an abstract model of the sound that varies in time.
The component that measures the sound pressure is the analogue-to-digital converter (ADC) which through an input device (e.g., a microphone) acquires a signal that is then converted by sampling, continuously measuring the level of the analogue sound wave and storing the binary number for each measurement on a support that can be: magnetic, a hard disk, an optical drive, or more recently, a solid state memory.
The sampling frequency indicates the number of times per second that an analogue signal is measured and stored on the support in digital form, and thus measures the quality/accuracy of the digital signal obtained; for example, the standard for telephone communication is 8,000 per second, while for music it is 44,100 memorizations per second. For playback, the sequence of numbers is sent to a digital-to-analogue converter (DAC), which reconstructs the waveform, by interpolation, which is then amplified and sent to the speakers for listening.
Despite an awareness of the physiological decrease in quality of the reproduced signal, digital recording presents numerous advantages, the main one being the versatility with which information can be stored/managed through computer media which are more efficient, compact, and inexpensive systems for analogue acquisition/copying.
The development of digital electronics and computers has without a doubt influenced the preference for digital sampling, leading to a vast public, something which, in the era of analogue acquisition, was the prerogative of a restricted reality: in fact, nowadays, ADC and DAC converters are to be found in every smartphone, computer, tablet, and digital music player, and allow the owners of such devices to record/playback their own voice, an instrument, the sounds of the environment, etc..
The gradual improvement in the performance of web communication infrastructures has allowed the transmission of large amounts of data in a very short space of time, and today operations are possible that were unthinkable until a few years ago, such as the digitization of musical performance and the ability to send it in real time to a remote server capable of processing the input data and structuring them inside multitrack music software.

IV. Construction of a learning environment for collaborative musical composition

The learning environment that is the subject of this research (developed by the INDIRE project "Disciplinary Didactics and ICT"), is dedicated to the practice of music, music composition, and the planning and active participation of members in educational activities of an informal nature.
Participants can record their performances inside virtual spaces set up inside the environment, recording and over-dubbing music tracks, and adding their own recordings to those of other participants asynchronously, to realize/arrange a full track with all instruments as indicated/guided by the teacher.
The presence of a tool based on Cloud computing that can handle incoming data (i.e., the performance of a musician on his own instrument) solely by means of the browser, delegating the power of calculation to the "Cloud" server, is a technological aspect not previously available in the multimedia

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landscape. This is a key factor for the potential access of all students with any device and an internet connection: the type of hardware/software owned is no longer relevant, but it is sufficient to have any device and a stable connection to the web to work fluidly.

The construction of such an environment requires two main methodological approaches: the active and collaborative learning, and its main point of reference is musical practice and composition plus the acquisition of skills in an informal way. If on the one hand the active learning is a methodology that enhances the experimental approach to problem-solving by promoting its educational potential (fielding activities in which students are not mere executors of operations led by the teacher, but work reflecting on the ways the experiment can be carried out, and analysing the results [1]), cooperative learning is a method that involves students in group work to achieve a common goal, placing the emphasis on certain key features such as positive interdependence, individual responsibility, interaction, the appropriate use of skills in collaboration, and assessment of the work carried out [7].

In the process of creating a learning environment that fosters musical practice, the experiences and special features of the informal acquisition of skills have been considered, particularly within the framework of music.

John A. Sloboda [8] maintains that human beings can acquire implicit knowledge with regard to the structural characteristics of music in their own culture within the first ten years of life, by means of activities, rhythm games, songs, dance, etc..

Subsequently, this musical knowledge is fostered and maintained by means of exposure to the media (TV, radio, etc.); thus, all this happens informally. These skills are then possessed by many people without any explicit musical training or formal education.

Even earlier, James L. Collier conducted a study on Louis Armstrong, and on the informal acquisition of active musical skills without any allied formal education [9]. In the analysis of the contexts that led Armstrong to become such a brilliant musician in his musical genre and within the history of twentieth-century music (early exposure to a musical environment, freedom of exploration and expression, lack of distinction between practice and performance, etc.) Collier demonstrated that people can become experts even without specific formal education: “Musical involvement has the character of a visceral emotion, in total antithesis with situations of external constraint; i.e., that such experiences take place in almost all cases in the company of friends and family or alone, rarely with the presence of a teacher.” [10]

Moreover, the construction of a digital learning environment for music cannot ignore the “electro-acoustic paradigm” [11], i.e., the effect that the introduction of digital equipment for the production and reproduction of music has had on individuals, and the change that the advent of digital technology has brought to everyday life, which can then become an all-out part of music education.

Prior to the introduction of recording/playback systems, there were two major means of creating and transmitting music: the oral tradition and writing. Electro-acoustic music has seen the appearance of music played through speakers and (subsequently) made in the studio by means of computers, samplers, and other digital systems.

Therefore, if “current musical pedagogy is linked to the musical attitude that preceded the advent of reproduction technologies, and within that attitude, more than a century old,” [12] then what we need is a sort of “informalization” of music education, accepting that “formal education has been undermined and contaminated by the informal kind” [12].

The approach to teaching music in the environment that is the subject of this paper intends to use a workshop procedure, moving the centre of learning from information to training, promoting a more proactive attitude among students towards knowledge; in addition, it intends to rely on an equal interchange of work and collaboration between students and teachers, combining the skills of both, becoming a virtual lab to redefine teaching times by applying organizational and methodological innovation, facilitating hands-on teaching rather than lecture-style lessons. A space in which to enjoy experiences with others, using materials and methods that produce learning processes and “build” knowledge.

In this way, learning becomes the result of a continuous interaction of community members who, by interacting with each other, “build” knowledge through the elements typical of a workshop.

Within these learning communities, the teacher then becomes a “facilitator” whose task is to create the conditions for positive cooperation, to stimulate research and internal sharing, and to provide credible models for learning.

A. Objectives and spaces

The purpose of the learning environment is to allow the design, composition and production of music following instructions and guidance from the teacher.

The characteristics of the learning environment must allow students to tackle music using multimedia tools that can increase their awareness during their studies.

The a-synchronicity of the method facilitates the study of music: recording and listening back to what you have just produced is one of the main methods of acquiring musical awareness.

It is also possible to consider the digital recording approach as an “apprenticeship” towards the working world of music; a world in which musicians find themselves in the presence of very similar systems every time they offer their services in musical production situations.

The environment will be entirely online, and will use cross-device web interfaces, handling all incoming data through Cloud services.

B. Tools and features.

The tools that make up the learning environment are developed and/or integrated within a web platform, subject to login procedures, where the teachers can manage several groups of

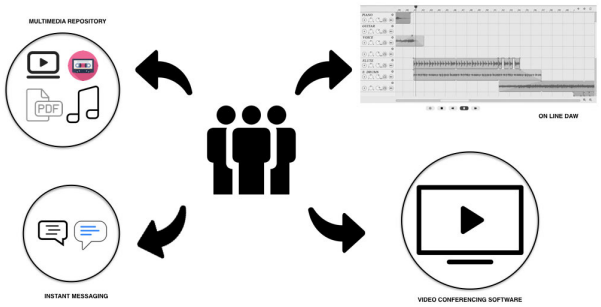

Fig. 1. Content type management: multimedia files, instant messaging, Video conferencing software, on line DAW

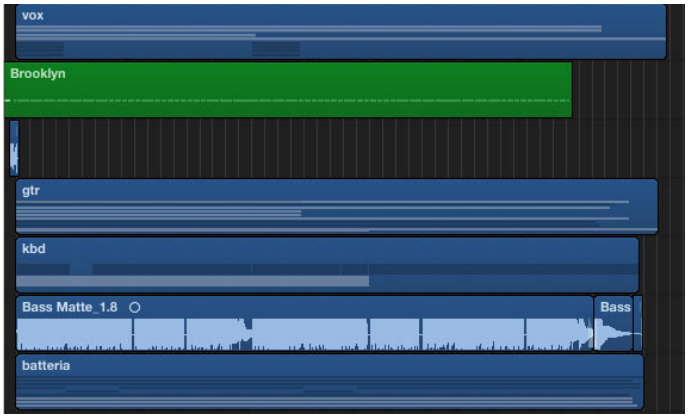

Fig. 2. Generic DAW session view

students (Fig. 1).
Each student can participate in the activities of several groups, and tools have been developed for peer evaluation of the results of each group, triggering a virtuous interaction between students who can also be in different classes/schools.

Online Digital Audio Workstation (DAW).

This is a software that allows the recording of analogue and digital music using computerised tools, by overdubbing multiple recordings/different instruments and allowing a final mix-down and export of an audio file readable by any device (Fig. 2).
The use of a Cloud-based online DAW, that allows access and recording directly from a browser window via a web interface, brings great benefits compared to desktop solutions, i.e., using a PC:

- Independence from the operating system and browser (Windows, Mac, Linux, Android, iOS). In fact, it is sufficient to have an internet connection and an access device;
- Independence from a device to access the Web (PC, Tablet, Smartphone, etc.);
- The software data and technical performance are managed server side, allowing access by almost any device user, regardless of the quality of the hardware owned;
- All participants can access the software at any time to record their performances, finding the work done by all the others previously;

Repository of multimedia materials. An area in which participants can share files of any type to plan a work, supporting the ideas with multimedia contributions (songs, audio-video bites, scores, etc.).

Instant Messaging. Instant messaging system present within all areas of the environment, to comment on the materials shared or as music design forums. The messages are saved and organized chronologically for correct navigation over time.

Video-conferencing software. Organized in circumscribed "rooms" accessible only to the working group in which the participants, moderated by the teacher, can organize the performance, editing and design of the work. Internal tools for screen sharing and the upload of materials for instant sharing are the most efficient for the proposed use.

Devices to access the platform, manage the content, and record musical performances. The environment is accessible from all computing devices, to make it particularly suitable for the reference target: the use of cross-device programming languages (HTML5, JavaScript) makes the virtual space accessible and usable (as well as from any PC) also by common smartphones, widespread among the students of reference. These devices are accompanied by high quality microphones, suitable for converting the analogue signal of an instrument into a digital signal that can be saved and stored inside the online DAW.

C. Technical Realization.

A prototype of the environment has already been created by INDIRE as part of the projects to take a closer look at the relationship between disciplinary didactics and new technologies (Fig. 3).
An analysis was made of the technical aspects of the project, the communication aspects of the software produced, and the delicate issue of managing students privacy.

The following technical choices were then made:

- Programming languages: to maintain cross-device compatibility, the programming languages used for the areas to share materials, for instant messaging and bulletin boards, to create groups and manage teachers content and CMS, are HTML5, JavaScript (Angular), and CSS3, with Ionic Framework.
- Two third-party software packages have been used for the management of synchronous meetings and the DAW. Many commercial products are available on the market that can satisfy these needs, but instead those that provide Web-Services interfaces were chosen.
  These enable a transparent link to the user and a management of personal data that complies with the regulations in force on privacy. Using API and federated identity systems (OAuth) it is perfectly possible (if the third-party software supports and develops these services) to

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Fig. 3. Prototype of the environment

authenticate a user by providing an alphanumeric code only, keeping the link to the actual personal data inside the source information systems.
In this way, users are authenticated directly and transparently using third-party products without any of their data being shared elsewhere.

D. Description of an activity within the learning environment.

To illustrate the features of the application in more detail, and how these can be integrated from the active-learning point of view, we can show one possible activity within the learning environment in which the teacher establishes the start-up mode and supervision with the intent of supporting/moderating the students' work.

1) The instructor divides the class into groups of 4-5 people and assigns each group a corresponding online environment, by fixing as an objective the composition of a pop song in a specific style (Italian / English pop, Hip Hop, Rock, etc.).
2) The teacher provides an essential discography that students must listen to (and expand to their liking) to evaluate the compositional aspects and the arrangements: the objective in this step will be to decide and establish the structure of the song (AABA, intro/verse/bridge/chorus/variation/finale/outro/etc.) and discuss the main aspects of the arrangement (instrumentation, melody lines, harmony, any modulations).
3) This activity will be carried out using instant-messaging tools and by sharing multimedia materials, and the teacher will moderate any discussions. Each student will be able to record and share audio files with their own compositional ideas or can share them synchronously using video-conferencing.
   This delicate and deeper phase ends with an indication by the group of the main parameters of the song:
   a) Metronomic tempo
   b) Bars
   c) Key
   d) Structure
   e) Electronic instrumentation needed (asking the teacher for help)
4) The teacher supports students in the realization of the structure of the piece inside the online DAW, building a template within which students can record their performances, and providing help with inserting electronic samples, rhythm loops or ambience effects.
5) Each student enters the DAW to record his or her performance, overdubbing their recordings until the desired result is achieved. No limits are placed on the number of overdubs nor the access times.
6) The teacher monitors the work and suggests changes to performances considered below par. When the recording work is finished, the teacher helps the groups in the mixing and mastering steps, to explain how a piece of music is produced.
7) Part of the sharing of materials is a specific evaluation of finished products among peers: tracks are shared in a particular form, and other groups of students are asked to evaluate them, anonymously, by responding to a preset questionnaire based on musical criteria, in order to offer their own opinion.
8) At the end, students write a report on the key points of the work carried out.

V. Expected Results

A. Expected results in the learning of individual students

Knowledge

- Learning of new languages and digital music codes using a Digital Audio Workstation (DAW) to record musical performances.
- Access to tools of collaborative learning online to exploit different points of view and approaches in a musical project.
- Knowing the importance of developing creative abilities
- Understanding interaction in the sharing of knowledge within social networking environments.

Skills

- Strengthening and valorization of musical practice.
- Mastering the use of the network by means of independent tools and collaborative environments, to search for useful material, and to share and discuss musical roads in the realization of a collaborative musical project.
- Ability to use tools for music creation through Cloud software and DAWs, in general. Developing a capacity to operate in technologically advanced environments and as part of a work team.

Competence

- Competently using dedicated software and technological applications and understanding the management mechanisms.
- Recording music using systems commonly employed in recording studios, precociously bridging the technological gap between a personal "acoustic" performance and the technological procedures to record this performance.

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- Recording using a metronome, and overdubbing backing tracks/performance by other musicians, listening to the nuances and dynamics and trying out different approaches to better match the performances of their band mates.
- Musical performance skills aimed at recording.
- Working, studying and planning as a group, being responsible for the completion of a project and adapting personal behaviour to the circumstances in resolving problems.

B. Expected results in general terms

- Shared leadership. Making music "together" lets students grow, also and especially technically, and allows them to express a considered sensitive leadership and to develop skills of "mediation" in a group, sharing and making the most of the emotional elements of a musical experience in a working group (a band) to achieve an effective artistic product.
- Feedback and evaluation. Each student is an integral part of a group within an environment of communication-participation-collaboration, and is therefore placed in a direct relationship with all the other students, to realize a product in the most effective, fun and interesting way possible, using musical language. The interventions of revision and control of the activities carried out, and the assessment of the work of the group represent a constant within the environment, which manifests itself through synchronous and asynchronous tools of content sharing, to correct/improve the musical project.
- Simulation, through an educational and training project, of the concrete manner of operating in a musical production when it comes to organization, environment, compiling of reports and work tools.
- Assessment. It is not only the assessment of the "final" product that matters within a group of collaborative learning: elements such as the improvement of self-esteem, communication skills, and problem-solving abilities are of great efficacy in a workshop approach.
- Social skills. The quality of the work and the results are directly proportional to the communication and problem-solving ability of the participants, who are mutually supportive.
- Responsibility. The environment favours the self-realization and personal growth of each participant in the group, inside which is triggered a sense of mutual responsibility that promotes learning.

VI. Conclusions and potential new developments

This paper has illustrated a digital learning environment to develop musical practice and collaborative composition within small groups of students moderated by a teacher, and are considered the didactic outcome of the activities proposed therein.

The learning environment uses Cloud services for its operation and the necessary hardware for access is cross-device, allowing any web-connected device to exploit the potential offered and to deepen the students' knowledge, skills and abilities in connection with musical practice and composition.

As to future developments, the following guidelines have been considered:

- Testing of informal training in the composition, performance and remote sharing of musical tracks/projects with technological tools based on Cloud computing, within a virtual studio community, assembled under the supervision of teachers.
- Testing the efficacy of an informal learning model in a creative key as part of Italian school curricula, as indicated in the Italian "National Guidelines for Lower-Secondary-School Music Education' (p. 59).
- Testing ways of offering assistance and support to all students in the processes of learning within a virtual environment, not only in the planning of a project/song, but also in the management of teamwork communication.

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