Towards Accessible and Sustainable Learning of Real Time Electroacoustic Composition and Performance at Undergraduate Academic Level

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Abstract: Electronic music undergraduate and graduate teaching is mainly characterized by a strong theoretical basis and the practical approach is often proposed during the last part of the academic programme. Also, the resources used for electronic music production are available in the last years of academic studies, but not during the early stage of the career of the musician who graduates in electroacoustic composition. Moreover, the recent pandemic situation and the need for online teaching has exacerbated some of these problems. Lack of specific material for each student and recording studios, the need of specific knowledge in analogical & digital electronics and programming languages potentially lead to inequality between different institutions with similar programmes. The goal of this research is the presentation of a practical workflow for ready-to-use tools in electroacoustic music teaching in Italian and French academic institutions. A sustainable approach in terms of availability of the tools (from an economic point of view and easiness of use) is proposed in this research work. The proposal is divided into an overview on the situation of the studies in the electroacoustic music domain in Italy and in France, a brief description of the tools proposed for a sustainable teaching and a practical example. This consists of two short instrumental pieces with live electronics.

1 INTRODUCTION

Electroacoustic studies gained popularity amongst students of conservatories, faculties of Fine Arts, Music and Musicology. In the last decades of the 20th and 21st centuries the musical studies included in their syllabus repertoires such as jazz, popular music, and electroacoustic music. In these areas there is often a lack of conventional representation as a score, or different ways of representing musical events that we can define 'new textualities'. (De Benedictis, 2009). With the inclusion of these new repertoires in the undergraduate studies, some problems arise:

- Lack or diversity of a graphic representation.
- Need for a practical approach.
- Improving the role of performance.
- Need for sustainable learning tools.

In these new perspectives, mixed electroacoustic music performing act became as important as music notation, theoretical analysis, and composition processes.

This paper focuses on possible educational solutions in mixed electronic music in undergraduate musical studies.

2 ELECTROACOUSTIC MUSIC TEACHING: A PRACTICAL APPROACH

Education in electro-acoustic music is a constantly evolving field of research and musical practice. A full program in electroacoustics studies at undergraduate level has usually a duration of 5 years divided into two periods: a basic period (undergraduate) and a further training.

In order to contextualize the main finding of this research work we briefly summarize the current situation of the studies in electronic music in Italy and in France, based on the experience of the authors and their colleagues. Particular attention is paid to the sustainability of the means used in teaching. By sustainability we mean the ease of access to the means

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themselves and their availability at relatively low budget, or no cost at all in the best of cases.

We observe an extended theoretical approach, compared to a quite limited practical experience. The programme in the two countries shows several similarities in the pedagogical content that includes the following disciplines: Ear training and Music Theory, Music History, Electroacoustic Music History, Acoustics and Psychoacoustics, Electroacoustic, Music Composition, Musical Computer Science, Electroacoustic Music performance, Electroacoustic Music Composition, Ethnomusicology.

At the end of the studies, the successful student should be able to compose a piece using different technologies including the mixed techniques, such as the blending of instrumental and vocal composition and live electronics. The main tools are based on Digital Sound Processing (DSP) techniques that use software, referred as Digital Audio Workstation (DAW). DAW uses special functions or instruments, called VST (Virtual Sound Technology), for sound generating or processing. Amongst well established commercial packages, we acknowledge Cycling ’74 Max/MSP and Ableton Live. Beside commercial software, we cite open-source audio programmable environments such as Open Music by IRCAM or Pure Data. Some of the open-source audio resources have been developed as an independent programming language, such as C-Sound or *Faust* by GRAME.

2.1 Learning Electroacoustic Music in Italy

Since 2004, the Italian Academic Institutions (‘Conservatori di Musica’) have been included by MUR (Ministero dell’Università e della Ricerca) in the context of University studies. The first approach to Electroacoustic Music takes place in the first year of undergraduate studies, referred as *Triennio I* (Licence). The entire training course of the Electroacoustic Composition faculty lasts five years and is divided into a basic three-years (*Triennio*) and a higher two-years period (*Biennio* or Master). Table 1 shows the program of the first year of the undergraduate curriculum in Electroacoustic Music Composition, at the Conservatorio ‘G. Verdi’ in Milan. One of the most popular textbooks used in electronic music courses for the practical training (analog synthesis, sound processing and MIDI synthesis) is *Musica elettronica e sound design* by Alessandro Cipriani e Maurizio Giri, a work in 3 volumes widely used in Italian institutions. This work is a comprehensive guide to electronic music, and it includes a wide range of the topics with a practical approach with examples and exercises. According to Cipriani and Giri, Max/MPS is considered the program that most 'contributed to the development of computer science in real time' (Cipriani, Giri, 2009, VII), but despite being a very popular program, it is not intended to be used for free.

Table 1: disciplines of the first year, Electroacoustic Music Composition, Conservatorio ‘G. Verdi’, Milano.

Discipline typology	**discipline**	**Hours**	**ECTS**
Theory and analysis	Ear training	36	6
musicology	History of music	36	6
	History of electroacoustic music	36	6
technology	Acoustics and psychoacoustics	18	3
	electroacoustics	36	6
Composition	composition	10	2
	Computer assisted comp.	18	3
	Electroacoustic comp.	18	3
	Music informatics	18	3
Performance	Electroacoustic music performance	18	3

Beside DSP software, also special hardware is required for performing electroacoustics compositions. An important reference text for theoretical disciplines is *Studiare la Computer music* by Laura Zattra (2011) focused on the importance of electronic music in all musical genres. The text of Zattra is a precious resource also in terms of musical examples, since the excerpts cited in the book are not easily available and can be found only in specialised music collections and libraries. I will quote among all a well-known Italian text that collects important

articles for the research carried out in the first decades of diffusion of electronic music: *La musica elettronica, testi scelti e commentati da Henri Pousseur* (A.A.V.V., 1976). Practical training takes place in the laboratory. At home, the same tools are not always easily accessible to the students.

2.2 Learning Electroacoustic Music in France

According to the *Association Européenne des Conservatoires* (AEC), 12 French institutions can provide higher education in Electroacoustic Music:

- 2 *Conservatoire National Supérieur de Musique et de Danse* (CNSMD), one in Paris and one in Lyon.
- 10 *Pôles d'enseignement supérieur de la musique* (PESM), some of those are linked to the neighbour CRR (Pre-academic courses).

French composers in the second half of the XX century have a wide experience in electroacoustic music and the associated bibliography seems to be quite heterogeneous, according to the *Association des Enseignants de la Composition en Musique Électroacoustique*. Amongst the most used bibliography we cite *La Musique électroacoustique* by Michel Chion and *L'analyse des musiques électroacoustiques, Modèles et propositions*, by Stéphane Roy. Michel Chion suggests that the approach of the student and scholar to composing with electroacoustic music, is mostly based on experimenting the acoustic objects, rather than using the traditional approach of music composing, such as in *Ecriture Musicale* classes. The approach of the electroacoustic composer is quite different: starting from an acoustic sound, he manipulates the acoustic object until obtaining a new, surprising sound according to the expressive needs of the musical composition. The notion of alterity is a key concept in electroacoustic music (Delalande, 2003), and the undergraduate programme in Electroacoustic Composition in France dedicates several teaching modules to improvisation and practical research. In the following table a synthesis of the programme during the first three years of study in the conservatory of Lyon (CNSMD). Most of the students that start the academic path in electroacoustic music do not have the mathematical vocabulary and information technology skills used in sound processing and synthesis.

To ensure pedagogical homogeneity in electroacoustic programme of studies, even between institutions that do not share the same student level, the teaching staff created a society: *Association des Enseignants de la Composition Électroacoustique* (AECME).

Couprié (2003) points out that the electroacoustic composer should have an extremely wide range of artistic and scientific skills and knowledge, including music, physics, mathematics, programming languages, electronics, material science. From the point of view of sustainability, an academic curriculum deeply exploring all these disciplines can not be set in a three year long undergraduate course. For this reason, a musicological approach to electroacoustic music seems the most successful in undergraduate studies. This approach is completed by a practice-based overview of the techniques specifically used for composing electroacoustic music.

Table 2: The Programme of undergraduate studies in Electroacoustic Music in the Conservatoire National Superieur de Musique et Danse (CNSMD) of Lyon.

LICENCE: SEMESTERS 1-6			**Hours**	**ECTS**
UE1	Composition	cours individuels	3	16
		cours collectifs		
UE2	projet de recherche		-	15
	Programmation en informatique musicale		sessions	2
	technologies musicales		sessions	2
	Piano complementaire/ analyse XX-XXI		2	15
UE3	Aspects pratiques du métier/improvisation		Conf.	05
	Chant choral / discipline spécifique		2	15
UE4	langue vivante		15	15
	discipline complémentaire		2	15
	TOTAL		**105 x 3**	**30 x 3**

3 AIMS AND METHODS

This description of the pedagogical methods in electroacoustic music studies in Italy and France shows some aspects on which the hypothesis for the

research work is based on. Both countries seem to have extremely similar pedagogical approaches. Current pedagogy in undergraduate courses on electroacoustic music shows a good compromise between artistic and scientific theoretical knowledge and technical skills. An historical and musicological approach points out the need for specialized hardware and software during the last decades of the XX century. Often, only well-established institutions are equipped with the machines and the software for reproducing the original setup for mixed electroacoustic performance. France and Italy both have specialised and well-known research centres for this purpose: *IRCAM* in Paris, *GRAME* in Lyon, *Laboratorio d'Informatica Musicale* in Milan and *Centro di Sonologia Computazionale* in Padova, to mention only the well-known.

However, these research environments are adapted to professional composers and researcher, while this paper focus on undergraduate studies. The main criteria for this work are:

- practical approach to electroacoustic composition tools: sound processing, recording and notation tools.
- open-source tools: the proposed method should be available free of charge.
- online (web based) availability: the tools should be available out of the institution.

3.1 The Need for Sustainability and Accessibility in Electroacoustic Music Studies

In section 2 we pointed out the problem of sustainability, in particular the accessibility of pedagogical facilities and tools from practical and economical point of view.

- Only a limited number of institutions can afford hardware and software for historically informed performance in electroacoustic music
- mastering DSP software requires a deep amount of knowledge more similar to IT practice than the musical one.

Moreover, with the pandemic situation the practice of distant learning has a negative impact on practical experiences and workshops: in fact, the access for students to the institution's material is critically reduced.

The concept of sustainability should lead to a critical consideration of the choice of musical examples made by the tutor/professor. The authors should point out that some electroacoustic composition, despite the evolution and availability of technology will always present technical difficulties. As an example, we cite *A Pierre. Dell'azzurro silenzio inquietum* composed by Luigi Nono in 1985 for bass flute, bass clarinet and live electronics. According to (Zattra, 2011), the live performance requires expensive equipment and skilled technicians. (Sallis, 2012) points out that the use of live electronics made by Nono, required high quality studio techniques in 1985, mainly based on digital electronics. Since the beginning of the third millennium, Digital Sound Processing (DSP) has become more and more popular for amplified music. Now, Virtual Sound Technology allows the reproduction of expansive analogic sound machines. As explained in an essay by different authors (Sallis, and others, 2012) *A Pierre* is a work that requires technical means present only in recording studios. "Nono employed the studio technologies of electroacoustic music to experiment with new types of performance practice and to develop new forms of notation to accommodate this practice". (Sallis a.o., 2012, p. 1).

On the other hand, works depending on technology developed in '60 and '70 now should be sustainable by using modern DSP technology. The case of *Solo* shows a piece that could be played in 1966 (the year of its composition) with analogical means and with the assistance of three sound technicians, today can be performed by the performer itself (Sargenti, 2017) using a downloadable application for smartphone.

3.2 Methods

In this section we want to illustrate a practical approach to sustainable composition with live electronics. It is divided into:

- a short description of sustainable DSP tools used in presence of the teaching staff in the institution, but also at home (developed in section 4.1)
- a practical example of application consisting of two short instrumental pieces with live electronics (developed in section 4.2)

In order to ensure sustainability in terms of economic viability and reduction of the digital divide shat affect most of the programmable audio device, the key point of the methods proposed in our paper are:

- open-source resources (no cost)
- no install required (browser-based approach)

- easy to use (no previous programming experience is required)

This enhanced practice of electroacoustic music, suggests "a new figure of musician: the interpreter of electronic musical instruments that combines traditional musical skills with the sonological skills of the signal processing expert." (Vidolin, 2009)

A pedagogical sequence based on these methods should include:

- listening and analysis to excerpts from the repertoire with live electronics. Sargenti (2018) suggests that several sustainable (online or freeware) tools can be used for achieving this taks, such as *Sonic Visualiser* (by Queen Mary University, London) and *e-Analyse* (P. Couprie, IRCAM).
- composition practice: choice of instrumentation, style, and structure of the piece according to the sound processing.
- live electronics design: effects, duration, technical realisation, and materials.
- pedagogical output: realisation of the piece with the participation of the students as vocal/ instrumental and live electronics performers. Section 4 is providing some guidelines for this point.

4 PRACTICAL EXAMPLES

In this section we want to briefly describe the sustainable tools used to produce practical examples. We have identified the cost-free accessibility as a criterion of sustainability. *Faust* provides functions similar to MAX/MSP for free, indicated in section 2.2 as one of the most used programs in the field of education.

4.1 Web based Real Time DSP with Faust

Faust (Functional Audio Stream) is a functional programming language for sound synthesis and audio processing with a strong focus on the design of synthesizers, musical instruments, audio effects, etc. *Faust* targets high-performance signal processing applications and audio plug-ins for a variety of platforms and standards.

The language was developed by GRAME (*Générateur de Ressources et d'Activités Musicales Exploratoires*), created in Lyon (France) in 1982. In this work, *Faust* is used for low latency digital sound processing from a live recorded audio signal, captured by USB microphone. Figure 1 shows the block diagram between an instrumental input and the output of a digitally processed sound by *Faust* with a web browser.

Figure 1: Block diagram.

The *Faust* language can be implemented by using the Faust Playground via web browser. *Faust Playground* is an online tool to assemble programs written in *Faust* in a simple way with a graphical interface. The Figure 2 shows a patch of Faust Playground composed of four tuneable effects: *echo*, *reverb*, *ring modulation*, and *flanger*. Each effect is acting like a transfer function with its own input and output.

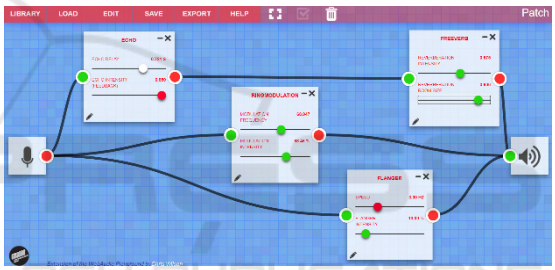

Figure 2: A patch for Faust Playground.

Individual patches can also be used via web browser. One of the patches used in this research work is a *Dual Pitch Shifter* developed by Oliver Larkin (Figure 3). Window size is set to a small value for latency reduction. Input value "50" is set to no-shift in the pitch.

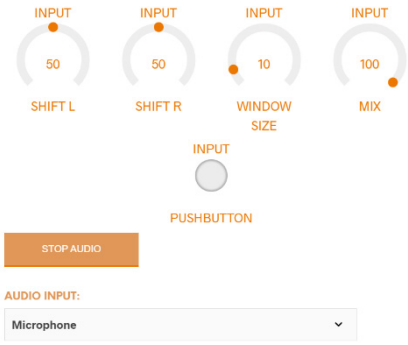

Figure 3: The *Dual Pitch Shifter* web interface.

4.2 Short Compositions using Web based DSP

In order to illustrate our idea, we present two short examples of instrumental compositions with live electronics for our educational purpose, one for flute, piano and live electronics, the other for violin and live electronics. The score of the two pieces can be found in the appendix. An audio recording of the pieces will be presented during the Conference. In the next paragraphs you can find:

- Short description of the piece for flute and piano.
- Short description of the piece for solo violin.

4.2.1 *Lumen*, for Flute, Piano and Live Electronics

Lumen is a short chamber music work for flute, piano and live electronics composed by Andrea Bareggi. The duration of the piece is approximately 2 minutes. The work can be performed by two instrumentists and a technician, or even by two instrumentists if the two musicians manipulate the interface of live electronics. The piece was video recorded in the lecture hall of *ESME Sudria – Lyon*, (approximately 10x15x5 m^3) with a Huawey smartphone. The setup for live DSP is extremely simple: a USB Blue Yeti microphone and a portable loudspeaker connected to a 2004 HP MiniTower computer by a double jack cable. The setup is intentionally simple since the goal of this research work is a democratically approach to the electroacoustic music.

The score (see Appendix) includes specific instructions for the instrumentists and the technicians. The DSP patches are easily available on the internet. They are programmed in FAUST language, developed by GRAME.

4.2.2 *Schegge*, for Solo Violin and Live Electronics

The piece entitled *Schegge,* composed for solo violin and live electronics by Simonetta Sargenti is a short piece lasting about 1 minute and 30 seconds.

It includes some musical gestures characterizing of the basic violin technique processed with effects like reverb, echo, delay etc.

It consists of 8 fragments (‘Splinters’) as shown in table 3. The sound processing procedures are applied to the piece using the *Faust* patches. As an example of the first patch implemented in measures 1-4 of the violin piece, we take the ‘echo and freeverb’ as how it looks in the *Faust Playground* (fig.4). Each fragment making up the formal structure of the piece is separated from the next by rests. This is to allow the performer to be able to manipulate *Faust*. All sections of the piece are composed so that the performer can manipulate DSP effect during the rests in the score. The composition ends with short, improvised section *ad libitum* where the improvisation involves the live electronics using granulation from Faust Playground and the patch *Dual Pitch Shifter* described in fig. 3.

Table 3: Formal structure of the violin piece *Schegge.*

Fragment	**Character and technique**	**Effect**
mm.1-4	Long held note	Reverber and echo
mm.5-9	Short pizzicato notes	Delay
mm.10-13	Expressive short sentence	Short rev.
mm.14-20	Tremolo	Echo
mm.21-25	Double note pizz. And arco staccato	No effects
mm.26-31	Expressive sentence	Rev.
mm.32-34	Long held note	Rev. Echo and delay
mm.35-38	Improvisation	Granulation and dual pitch shifter

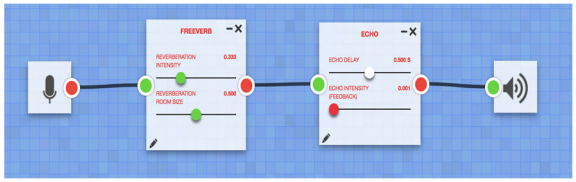

Figure 4: Effects of reverb and echo in mm.1-4 of the piece *Schegge.*

Besides a sustainability of means we are pursuing even a sustainability of the performance. In fact, *Schegge* should be performed by the violinist itself managing the live electronics in real time. The audio example of *Schegge* presented during the Conference was recorded in *LTW3 Studio* in Milano.

Our approach can be successfully applied to the latest pedagogical approach, opposing traditional individual learning to group pedagogy and flipped classroom. With this approach in mind, students can share multiple tasks such as instrumental playing, composition, sound shaping by DSP and spatialisation. In this way, each student can grasp a wide range of techniques and know-how by practicing different roles in the ensemble.

5 CONCLUSIONS

In this research work we reconsidered the electroacoustic music teaching process in relation to modern pedagogical approaches, more practical and student centred (learning by practice). We based our analysis on the current situation in France and Italy (section 2). Despite the validity of the traditional approach from the theoretical and analytical point of view, the authors point out a lack of sustainability in the pedagogical tools. The consequence of this pedagogical approach lead to digital divide and a steep learning curve in Information Technology, with a consequent reduction of the musical content. The choice we made in this research work is reducing these downsides of the traditional approach with more user friendly tools for DSP (section 3).

In order to demonstrate our approach, the authors composed and recorded two practical examples using sustainable DSP tools. These examples can be easily applied to group pedagogy (section 4). Thus a learning by practice approach is gaining popularity in the last decades, the pandemic situation is not helping the evolution of new teaching styles. The sustainable tools presented in this paper can be easily exported out of the music institution, and used by the students at home for their practice.

This approach open the chance for each student for playing the role of composer, instrumental of vocal performer and sound engineer. This early stage work is based on a small amount of experimental results developed by the authors. Further works include:

- Complete range of sustainable tools.
- More examples to make students comfortable with the practical approach.
- Experiments with students.
- Design of the evaluation process for students works.

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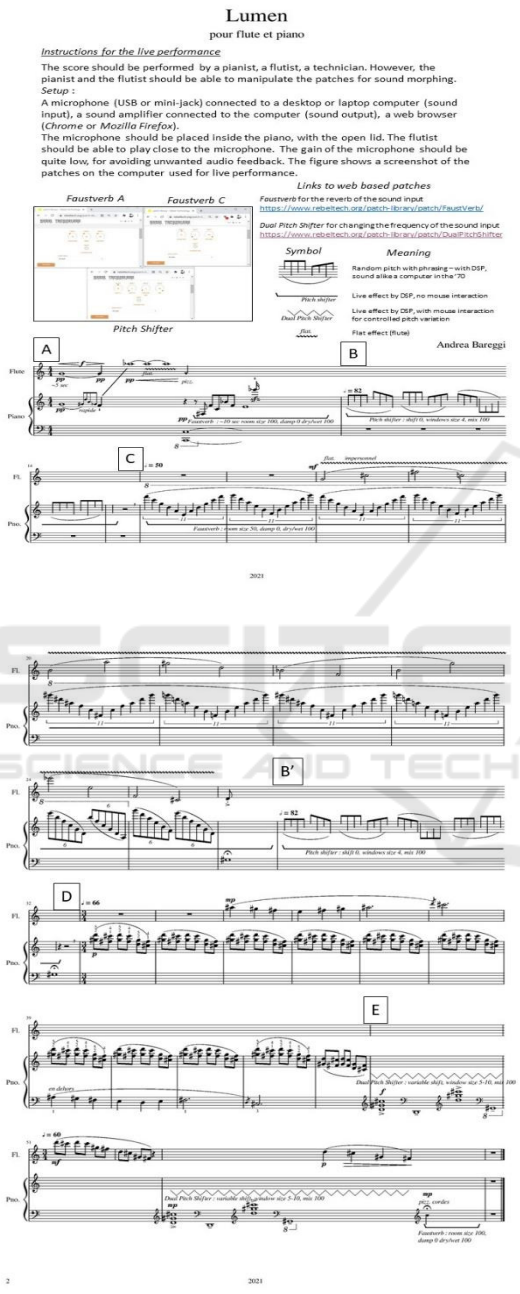
APPENDIX

Score: *Lumen* by Andrea Bareggi for flute, piano and live electronics.



Score: *Schegge* by Simonetta Sargenti for violin and live electronics.