Conductive Music: Teaching Innovative Interface Design and Composition Techniques with Open-Source Hardware

Emily Robertson
Sonic Arts Research Centre
Queen's University Belfast, UK
erobertson01@qub.ac.uk

Enrico Bertelli
Independent Researcher
London, UK
info@enricobertelli.co.uk

ABSTRACT
Through examining the presentation of a multi-media instrument fabrication program to students, this paper seeks to uncover practical elements of best practice and possible improvements in science and music education. The Conductive Music program incorporates public engagement principles, open-source hardware, DIY ethos, contemporary composition techniques, and educational activities for creative and analytical thinking. These activities impart positive skills through multi-media content delivery for all learning types. The program reviewed in this paper is designed to test practices for engaging disadvantaged young people from urban areas in the construction and performance of new electronic instruments. The goal is to open up the world of electronic music performance to a new generation of young digital artists and to replace negative social behaviours with creative outlets for expression through technology and performance. This paper highlights the key elements designed to deliver the program's agenda and examines the ways in which these aims were realised or tested in the classroom.

Keywords
Conductive Music, open source, musical interfaces, public engagement, didactic techniques, youth, urban schools

1. INTRODUCTION
Conductive Music is an innovative international project linking music, technology and science. We designed this project to enable at-risk young people (Key Stage 4, ages 12-18) to gather employability skills (soldering, coding, instrumental design, sound design and composition) and gain interest in science and music. We achieve these goals by teaching them how to create electronic instruments out of everyday objects. To date, in London, we have reached more than 150 students who have built instrument interfaces using tinfoil, water, and kitchenware such as ice cube trays. *Conductive Music* proposes to introduce students to the community of *do it yourself* (DIY) musicians and to link them to the world of open source software — resources which will allow them to continue exploring music technology in their own homes and in the long term.

Generous funding from the Arts Council of England, the PRS Foundation, the Newham Music Trust, Community Links, the European Cultural Foundation and the support of the London Music Hackspace and JoyLabz (USA, the inventors of the Makey Makey) allowed us to host the Conductive Music project in the borough of Newham. We have engaged in discussions with our partners, the Newham Music Trust and various Heads of Department in the areas of science, music and arts, to collate the optimal combination of skills and ensure we reached the correct target group.

2. REACHING OUR TARGET GROUPS
We propose music as the engagement medium and the end product, reached through the academic learning framework of science, electronics and music itself. Music and science presented together in the educational curriculum 'provide more opportunities for students to theorise and evaluate competing theories.' (Monk & Poston, 1999) *Conductive Music* has liaised with the Pupil Referral Unit, to engage with young people in difficulty in education, as well as those in the Free School Meals program, who are more likely to have limited access to creative resources. We have decided to bring *Conductive Music* to them, instead of setting up in a single venue, to ease potential barriers of transportation and neighbourhood or gang-related boundaries. Our target is young people in challenging circumstances, who have daily obstacles to their educational and personal success. They are failing in mainstream education, at high risk or actually involved in crime, living in poverty, or refugees and asylum seekers. Sixty per cent of these secondary school students have English as an additional language (EAL) and do not speak English at home. Furthermore, fifteen per cent of our young participants were categorised as having Special Educational Needs (SEN). We also especially targeted young people who were enrolled in Pupil Referral Units for behavioural issues such as petty crimes, gang involvement, aggression, and other negative social behaviours.

We have also explored possibilities for diverse engagement by creating different workshop schemes tailored to specific groups, beyond our original target. For example, we approached over 200 Russian children (in groups ages 4-6, 6-9, 9-13) at the Mariinsky theatre in short sessions of 45' each, using the *Makey Makey* only with fruit and basic digital sounds. Whilst presenting at the *London Mini Maker Art Faire* and *Re:New* (Copenhagen), we encompassed in-depth sound design and programming, since our audience was conference attendees with prior technical knowledge.

Conductive Music engages with young students by showing the creative possibilities that lie in the technology and objects that surround us everyday, from tin foil to fruit. We also seek to establish a transferrable blueprint for the new music education that moves away from traditional music technology curricula. In particular, we want the students to get inside the hardware and software of new music technologies and understand musical mechanisms through science.

3. WORKSHOP STRUCTURE AND MODULES

Conductive Music is composed of five skills-focused modules, delivered through a variety of teaching methods. Students are introduced to the *Instrument Design*, by familiarizing with the new technology and creating their interfaces, to move on to the software-based *Sound Design*. At the beginning of the second day, they are exposed to different techniques in *Composition and Scoring*, which culminate in the *Rehearsal and Performance* section, where they get to showcase their artistic creation in front of the class, plus other staff and student guests.

3.1 The first day

The two-day project starts with training in core technology design and fabrication skills. We designed it around the *Makey Makey* board, an Arduino-based open source hardware, which generates keystrokes upon completion of a circuit. The *Makey Makey* offers multiple didactic possibilities, with a variety of levels of engagement: once plugged in on a USB port, the circuit can be completed with skin contact, extended via alligator clips or expanded via a basic strip-board with pin headers and extra cables for more advanced uses. After the familiarisation with the board, students are introduced to the coding module, during which they learn how to modify the keystroke output through the Arduino Graphic User Interface (GUI). The soldering module's target is to create an expansion shield from strip-boards, pin headers and cables, thereby giving the instrument more interactive capabilities. During the connection and sourcing of conductive material, part of the fabrication module, we challenge the students to make cardboard, a string, or some paper, into a conductive circuit element by using liquids or metallic pieces.

Once the students have completed their instruments, we teach the principles of sound design, within an *Ableton Live 9* environment. We decided to use this proprietary software because of its cross-platform compatibility, even on low-end computers, and its design as a live performance software, as opposed to a production software. A student can, within a minute, make the first sound with Ableton through her MakeyMakey; we found this immediate result to be key to the continued engagement of the pupils. At the same time, it offers a continuous scope for improvement of knowledge and skills, to the more advanced users, thanks to its integration with the object-based programming environment of *Max4Live*.

3.2 ICT and Schools

As all the ICT installations in our partner schools are managed by external companies, with teachers that have no or limited administrator privileges, we had to weigh risks associated with open source software such as last-minute upgrades or plug-ins, that we would not have access to implement. Where it was possible to implement open-source technologies with stability and troubleshooting access, we integrated them into the program.

Based on lessons learned from *Conductive Music*, we have decided to integrate a number of different proprietary pieces of software in future projects, which are more likely to be pre-installed on ICT suites. For example, Logic Pro X is already part of the secondary school curriculum and many students are already familiar with it, allowing us to skip the initial setup phase and dive further into sound design during the workshop. Furthermore, students are much more likely to carry out continuing work in the school's ICT suite, where they have powerful and familiar computers which they can access during their break and lunch times, than to work at home where they may not have a personal computer or the necessary space.

3.3 The Second Day

By the end of the first day, students have already acquired the basic skills of coding, soldering, instrument design and sound design, and are ready to start thinking about scoring and performance. After an introductory lecture on notation and composition, students are led in short realisations of graphic scores with their newly built instruments. We encourage them to create scores, not only to bridge the gap between composer and performer, but also to be able to interact with other musicians and reproduce their work.

As tutors, we suggest a number of strategies for composition, avoiding the restrictions of 'dot composition' and embracing graphic notations. With a mixture of classic scores such as Michael Parsons' *Pentachordal Melody* (1998) and Earle Brown's *December 1952* (1954) and Cathy Berberian's *Stripsody* (1966)[1] and a few of our own compositions, we encourage students to find their own solutions. Whether they opt for open scores with elements of improvisation or more detailed systems of numbers and colour-coding, the students emerge with compositions that are not 'covers' or adaptations, but instead two or three minutes of their own self-expression in a multi-media performance. We also include brainstorming activities through the *Rory's Storycubes*, a collection of dices with actions, words, which, at every toss, create a section of a story. Students are introduced to techniques that encourage them to express their own creativity. In the compositions presented, we include a range of personal styles, backgrounds, and genders. Two of the host schools were female-only, and female students formed at least 20% of all *Conductive Music* cohorts in mixed schools. A lack of educational material on women composers in mainstream education contributes to misconceptions regarding the place of women in music, and 'only furthers this presumption for another generation of listeners and musicians, who may, in turn, educate the following generations with the same neglect of women composers that they were exposed to themselves.' (Johnson, 2005) We strive to display gender equally within the composition module, including not only historic works but also works-in-progress by the male and female instructors present and videos of male and female students performing their own compositions from previous sessions. Thereby, we both create an opportunity for students to experience music in a gender-equal space and teach the history of contemporary music with an inclusive view. (Jezic, 1987)

The new, original instruments call for novel modes of presentation and communication, both in performance and composition, following in a rich heritage of musical innovation driven by exploratory performance techniques and scoring. In 1964, composer Earle Brown gave a series of lectures in Darmstadt, in which he described the necessary simultaneous development of experimental composition methods and graphic notations, alongside a deeper examination of the processes of

[1] Berberian's piece allows us to introduce the topic of women composers. Whilst this is already a prominent area of study in the contemporary music world, it has been even more important for us since we deliver some sessions in female-only schools.

performance (Brown, 1964). Three years earlier, Bruno Bartolozzi and Brooks Shepard wrote about the "natural evolution of musical languages" occurring alongside "new techniques of composing" (1961).

These observations recorded the rise of graphic notations in the 1960s, a development, which continues to influence experiments with notation today. Alternative graphic notations provide a wider frame for composing with new technologies and extended techniques.

As the notation workshops introduce the basic principles of graphic notation techniques, the students are encouraged to develop systems communicate effectively, reflect their own creative concepts and are specifically targeted for their instruments. After working through realisations of scores like *Pentachordal Melody*, the students start to brainstorm their own compositional ideas. They are prompted to identify ways in which their score design communicates (or leaves indeterminate) performance technique, pitch, rhythm, and ensemble interaction. By using simple illustrating techniques, the students explore methods of effective and innovative visual communication of musical ideas and performance instructions to other participants. These included the use of colour in music notation, indicating musical gesture through lines, and symbolising performative actions through simple icons. For example, one student performer ("Dr. Shoom"), used coloured shapes keyed to specific pads on his drum-machine type instrument. The shapes were written out in carefully spaced rows, with numbers to indicate repetitions and timing.

As the compositional and performance ideas begin to solidify, the groups move on to working in structured rehearsals. A crucial part of musicianship is the ability to work as a team in preparing and honing a performance. Working toward a performance in a group also impacts their compositional ideas. Some students decide to work together and collaborate on the entire performance, while others divide tasks, such that one student composes a score while another works on the sound design, or one deals with the rhythm section, while the other concentrates on harmony and melody.

In all cases, they adapt their instrument interfaces to complement each other within a group. On the other hand, students planning to perform solo, build instruments and compositional sequences that they feel stand alone, whether through complex textures or timbres. These performances are more complicated because one person has to deal with many musical elements at the same time. Nevertheless, the use of arpeggiators, note generators and some backing tracks help creating a more organic musical composition.

During this phase, we encourage them to engage in an exploration of extended performance techniques at the levels of both physical embodiment and software. Two facets become central to the students' projects: the physical interactions between objects and bodies in performance, and the selection of the most adaptable sound design environment for each specific instrument interface. For example, many students build interfaces that physically mimic the patterns of traditional orchestral instruments like drums, harps or pianos. If they wish to expand the analogy through movement, they may fabricate metallic drumsticks to trigger the sensors in a drumming motion. Alternatively, a student may subvert expectations by assigning an unexpected sound to another, less recognisable, instrument shape, such as a violin sample assigned to a cup full of water triggered by a straw. The digital instruments created, 'allow for arbitrary new relationships to be created between objects, actions and sounds' (Jensenius, 2013). We answer Jensenius' pedagogical enquiry, by including the body in our music-making process (the *Makey Makey* circuit), performing with real-time devices whose sounds are programmed in real time, accompanying every module with its relevant theoretical background.

4. TEACHING METHODS

Throughout our modules, we employed multiple teaching methods, and used feedback from school staff and students to refine our teaching methods, reinforcing our responsive program. *Conductive Music* created a positive learning environment in which students developed a better understanding of their own creativity and practiced key personal development skills. We used *Accelerated Learning* techniques to encourage direct involvement and teamwork, and the participants saw their own creative projects through from beginning to end in an overarching exercise in self-realisation.

They had the chance to bring their own experiences and identity into the classroom, and found stimulation during independent learning and team-oriented activities. Each module was subdivided into the key stages of *Accelerated Learning*: *Preparation*, based on vertical teaching, for core knowledge; *Connection*, their first hands-on experience with the new materials, hardware and software; *Creative Presentation*, when newly-absorbed knowledge is put into practice in a creative way, by transforming lifeless electronic components into personalised tools for musical expression; *Activation*, personalising the new concepts and skills by applying them to their specific needs (different sounds, instrumental design, notation systems, performance practices) and *Evaluation,* when all participants in the project assess their own process and feedback to the group about their experience.

All of our students were given the opportunity to pitch and demo their findings and creations, developing public speaking and self-confidence skills, by sharing their work with others.

They were able to perform collaboratively, thus boosting team working and team leading, as well as communication skills, regulating personal behaviour and reinforcing a social value framework. When progressed through the program, students will have clearer views of their own personal artistic potential or career plan, with the goal effect of improved self-confidence and self-esteem.

Conductive Music prioritized formative rather than summative assessment, mixing cooperative and independent learning strategies. For example, a little detail of setup and sound design (what a specific button does, how to change the volume, etc.) was given as a "hint" to one student, who was then encouraged to teach it within his/her working group. This helped not only to stimulate teamwork, where everyone is sharing ideas and waiting for the next clue, but also to overcome the social divides that we anticipated at a planning stage. The host schools are in areas of great diversity and social challenges. We are working with students from different ethnicities, religions, and neighbourhood divisions. Creating an environment of shared discovery encourages the students to talk about their instruments and programming with each other.

They also enjoy learning tips, having 'insider knowledge', and instructing other members of their peer group. Although we are aware that the 'spaces for peer discussion of work will not work in the same ways for all pupils, because of the wider patterns of peer relations [...]' (Pryor and Lubisi, 2001), we also faced the fact that most of our participants came from different classes and different years within the school. The peer discussion space became a way for the group to relate. Social and racial discrimination could be disrupted by the new surroundings and broken down by peer-to-peer knowledge-sharing processes.

5. FEEDBACK

In structured feedback sessions, students are prompted to reflect on the ways in which cooperating with peers on a performance has influenced their creative process or the outcome of their instrument. This project uses a mixed ethnographic method of short semi-structured interviews, group discussions, and open-ended questionnaire forms to gather feedback from the participating students (Rapley, 2004).

The interviews and group sessions were conducted on an opt-in basis and were less frequent, but all students returned feedback forms with written answers to questions such as: "how did today's workshop relate to your interests?" and "what did you learn today?". We encouraged peer-and self-evaluation, to boost critical reflective skills, often neglected even in higher education settings (Daniels, 2001).

At the time of writing this paper, the project had not yet been completed for the 2013-2014 academic year; thus we do not have an in-depth analysis of the student feedback from the program. In this section, we present an overview of the feedback received thus far. Overall, students emphasised their experience building the instruments and sound design.

Throughout the workshops and on the feedback forms, they expressed enthusiasm about learning the principles of electronics, "wiring and understanding the circuit" (Eastlea Community School, Year 10). Several students have remarked on the empowerment they feel when experiencing control over computers and seeing their ideas come to life in the circuitry of the instruments. Students also commented on the connection to their own musical practice or interest: "I love music and everything about it so I thought it was really cool that we can make our own instruments" (Plashet School for Girls, Year 9). Those from secondary schools with a focus on increasing STEM involvement wrote about the crossover they observed between music and science: "interesting to try out different things and see how science and music relate a lot so it is very interesting to see how they connect" (Plashet School for Girls, Year 9).

When asked about what they had learned, the answers ranged from activity lists, to general statements about personal growth. "I learned to make a instrument out of everyday things, to solder, to make friends" (Chobham Academy, Year 9).

6. THE FUTURE OF CONDUCTIVE MUSIC

The primary positive indicators of continuing involvement within the project have been further requests from school staff, relaying unprompted queries from students, and students writing to us after the project. "The project was very fun and shocking which is good because it grabbed my attention. It also combined 2 lovely subjects. I would do more of this if I get the chance" (Plashet School for Girls, Year 9). They have repeatedly asked either to be enrolled for the first time, having missed the first round of workshops and heard about it from friends, or to join more advanced versions of the program, in the form of courses or a weekly club. For example, at the end of the workshop at Drew Primary School, the Year 4 students requested a "club on every week Fridays just like this!". In all cases, students requested further opportunities within their school environment and showed disappointment or lack of interest in opportunities that involved travel outside of their home neighbourhood and school. This confirms our strategy in touring the workshop in schools and delivering during term-time. We have also provided the students with substantial tools for continuation in their own time. Every workshop involved at least one London Music Hackspace member, to assist with soldering and programming modules and personally present the students with various engagement opportunities. We also awarded 80 MakeyMakey units to students who won the performance competition in their workshop. Each student was provided with a list of links to resources to help them continue working (legal music downloads, samples libraries, music freeware software, communities for uploading and sharing their own music).

This positive interest has encouraged us to design a more ambitious project for the upcoming academic year, including a series of courses divided into an introductory session for primary school students, a beginner session (based on *Conductive Music*) and an advanced session, both for secondary schools, based on augmented clothing, e-textiles, and other wearables. These courses aim to equip students with knowledge and a sense of empowerment for building their own creations out of electronic components and the things that surround them every day.

The students' sense of wonder and excitement about electronic interfaces and sound design is the heart of the Conductive Music project. We have organised a programme that combines multi-modal teaching/learning methods, simple experiments with open-source hardware, basic sound design with a DAW, composition and performance guidance, and varying levels of structured feedback. This is calibrated to give students a variety of opportunities to engage with the process of building an electronic musical interface with the MakeyMakey board. While expanding their musical experience and giving confidence with computers, the workshop also aims to equip students with some basic coding, design, and creative thinking skills for the future.

7. REFERENCES

[1] Bartolozzi, Bruno and Brooks Shepard. "Proposals for Changes in Musical Notation." *Journal of Music Theory,* 5, 1961. pp. 297-301.

[2] Daniels, R. "Self-assessment in performance". *British Journal of Music Education*, 18, 2001. pp. 215-226.

[3] Jensenius, R. J. "An action-sound approach to teaching interactive music" *Organised Sound*. 18/2 August 2013, pp. 178-189.

[4] Jezic, Diane and Daniel Binder. "A Survey of College Music Textbooks: Benign Neglect of Women Composers?" *The Musical Woman: An International Perspective.* Volume 2. Ed. Judith Lang Zaimont. Connecticut:Greenwood Press, 1987.

[5] Johnson, Matthew S. "The Recognition of Female Composers." *Agora Journal of Education,* 1, 2005. pp. 28.

[6] Monk, Martin and Mark Poston. "A Comparison of Music and Science Education." *Cambridge Journal of Education*, 29/1, 1999. pp. 93-101.

[7] Prior, J. and Lubisi, C. "Reconceptualising educational assessment in South Africa -resting times for teachers". *International Journal for Educational Development*, 22/6, 2001. pp. 673-686.

[8] Rapley, T. "Interviews", in C. Seale, et al. (eds.) *Qualitative research practice*, London: Sage. 2000.