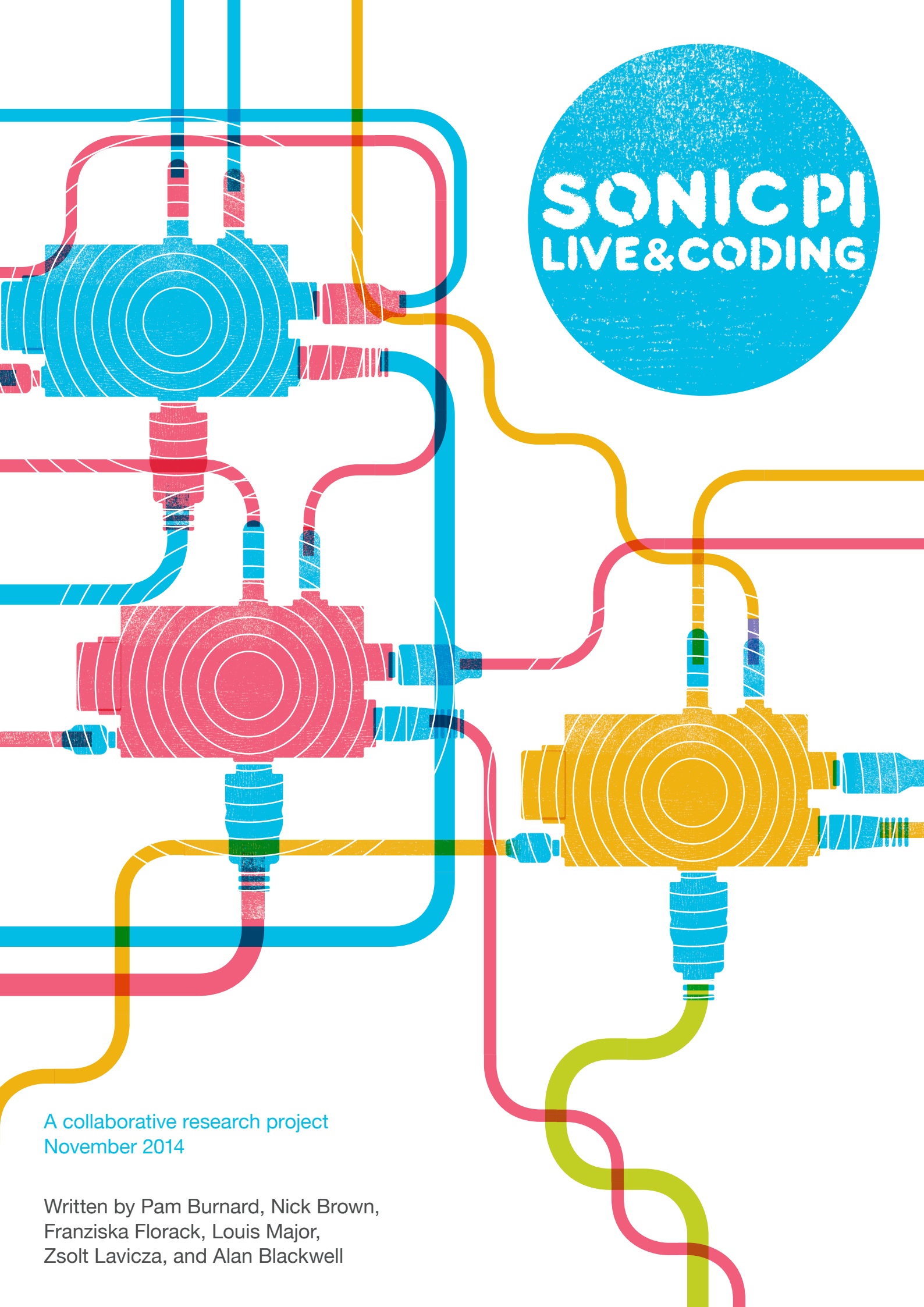

A collaborative research project
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Written by Pam Burnard, Nick Brown,
Franziska Florack, Louis Major,
Zsolt Lavicza, and Alan Blackwell

Contents

EXECUTIVE SUMMARY - page 2

1. Introduction - page 3
- 1.1 Project overview
- 1.2 An introduction to live coding
- 1.3 Interest to the arts, education and technology sectors

2. The research process - page 10
- 2.1 Research proposition
- 2.2 Research objectives
- 2.3 Key steps and processes
- 2.4 Partnerships: roles and responsibilities

3. Findings - page 14
- 3.1 Learning from an arts-led partnership
- 3.2 Some research statistics
- 3.3 The students perspectives: digital music journeying

4. Insights and implications - page 25
- 4.1 Building artists and audiences through engagement with young people and learning
- 4.2 Next steps
- 4.3 Planning for new projects: a glimpse of the future

5. References - page 28

Executive Summary

Digital technologies are redefining established practices and creating new opportunities for innovation across formal and informal music education settings and arts venues. The Sonic Pi: Live & Coding (SPL&C) project demonstrates a new model for arts-led partnerships in which professional artists and arts organisations work with instrumental teachers and local schools to develop digital music opportunities. Sonic Pi v2.0 is a system that allows children to create music of a high technical standard in a range of genres and in a live performance context. It does this not just by simulating the behaviour of "professional" instruments and recording technology, but by giving learners the tools to construct their own digital sounds through working with the actual software code, resulting in a fully customisable musical instrument. The result helps children to gain skills and experience of digital technology as a creative and empowering medium.

The SPL&C project represents an urgent response to: (i) the continued rise of digital media as a defining aspect of 21st century arts, (ii) the ongoing debates and criticisms about the relevance of music education and the quality and diversity of provision by music education hubs and (iii) the new computing curriculum., SPL&C has shown the potential for artists to lead digital music education using innovative tools for live performance that can be applied to create exciting and engaging digital music opportunities. In this report explores the way that technology partners, artists, arts organisations and educators explored, defined and expressed a mutual engagement and partnership, providing windows into each other's practices. Practical strategies focus on how arts organisations can engage with young people - enhancing digital and musical literacies, and working as co-producers and co-creators to inspire new thinking and practices for both formal and informal learning settings.

In this project, experimental interventions were made into both formal (school music education in six week blocks) and informal (a five-day summer school at a performing arts venue) learning environments.

Here are the key findings:

- **Learning to live code music performance introduces a driving force for change in music education**
- **Digital music making engages young people in new and different learning pathways**
- **Arts-led partnerships offer opportunities to create new pedagogic practices which make a positive impact on digital learning communities**

1. Introduction

1.1 Project overview

The Sonic Pi: Live & Coding (SPL&C) project sought to develop a model for arts led partnerships that could transform music education by exploring the creative potential of live coding to provide new pathways for young people into digital music. The research centered process worked across arts, technology and education partners with young people to develop software program Sonic Pi so that, when used with a Raspberry Pi computer, it would become a fully customisable musical instrument using code for compositions, timbre and interaction. Further, a toolkit of resources was developed to support delivery of the SPL&C model, including a lesson plans plus guidance notes, a set of short films, inspirational works by artists and Sonic Pi v2.0.

The SPL&C partnership came together in May 2013 after seeing the potential for Sonic Pi, which had previously been tested in a school in Dagenham (v1.0), using music to engage children in learning computer science. The broad partnership comprises: two music education hubs (Cambridgeshire Music and Hertfordshire Music Service), two Bridge organisations (Norfolk & Norwich Festival Bridge and Royal Opera House Bridge), the project lead and arts partner (Cambridge Junction), the technology partner (the Raspberry Pi Foundation with the University of Cambridge Computer Laboratory) and the research partner (University of Cambridge Faculty of Education).

In January 2014, funding for the project was awarded by the Digital R&D Fund for the Arts (£124,663) and Cambridgeshire Music Partnership (£14,087), and during February/ March 2014, a project manager and the lead artists were recruited. The Sonic Pi software was constantly modified and improved throughout the project based on discussions with and feedback from everyone involved including artists, teachers and young people, resulting in Sonic Pi v2.0.

The project was delivered in three distinct phases:

i) Development: during April, a set of four one-day workshops and training days with people involved in delivering the project (the lead artists, the creator of Sonic Pi, two instrumental teachers, the researcher, the project director and project manager, who were joined by two music teachers, two ICT teachers and two IT support staff for the two schools for the third session). The fourth workshop trained the team as Arts Award Assessors. This was followed by a period of time in May for developing the lesson plans, artistic interventions and building the software based on feedback from the workshops.

ii) Delivery: during June and July 2014, two six week trials in two secondary schools (Freman College, Hertfordshire & Coleridge Community College, Cambridge) with Key Stage 3 students. The trials were staggered so that the learning from the first school could be used to inform delivery in the second school and the delivery team worked closely together between lessons to adapt and changes approaches, materials and the software. At the end of July, the model was tested in an informal, out of schools situation through a five day summer school for fifty-seven 10-14 years olds, with each being given the opportunity to work towards a Bronze Arts Award qualification over the course of the week.

iii) Dissemination: August to November 2014 focuses on writing up the research, reviewing the project, and refining the resources for the toolkit, which is being launched on 4 November 2014 to coincide with a national SPL&C summit, which will invite discussion and input from delegates. Beyond this, attention will focus on next steps and further dissemination of the model and research.

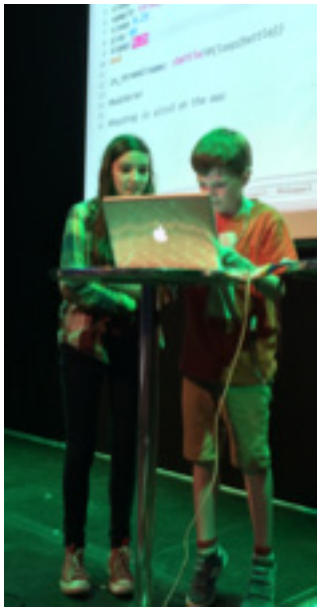
The outcomes from the SPL&C project – the SPL&C toolkit of resources - are available at www.soncipiliveandcoding.com.

1.2 An introduction to live coding

What is live coding?

Live coding is a novel medium that provides ways to combine traditionally separate musical concepts of composition, performance, instruments, and notation through programming. It is a digital genre that SPL&C has shown to offer exciting pathways for the direct engagement of arts professionals in education. On-the-fly computer programming is used to communicate the musical intentions of the live coder to the computer. Programming skills involve the choice of code, its design, abstraction and implementation, the communication of musical intention through computer code.

How is it performed?



A live coder will usually perform on a computer with the code projected onto a screen so that the audience can see it, writing and then augmenting the code to make and change the sounds being played. The screen projection of code is an important and significant feature of both the performer's programming and non-programming actions, demonstrating the liveness of the musical interaction. The coding activity involves curatorial skills, such as the creation of a new piece from existing recordings, an arrangement of an old piece or a newly improvised piece performed at a concert. Some live coders arrive at a performance with pre-prepared code and a plan around how they will develop the music as they augment it, whereas others take a far more improvisational and exploratory approach, starting with a blank screen and building up the sound, allowing it to guide their musical journey.

Challenges in embracing live coding

Live coding languages are highly technical, requiring advanced programming skills. The creation of Sonic Pi introduced an entry level live coding environment suitable for beginners, including children and young people, which can generate sophisticated sounds.

The provision of high quality creative learning opportunities and learning pathways for schools and informal educational contexts is a priority for many arts organisations and artists. Bringing together artists, software designers, computer scientists, teachers and non-teaching staff in the classroom offers an interesting dynamic for introducing and testing new creative technologies such as Sonic Pi in schools.

With the current provision of credible digital music making in schools limited, it is no surprise that young people, especially the disadvantaged, are turning to the more accessible ways of exploring digital music-making. Institutions would be wise to recognise the importance of presenting young people with opportunities to play and engage in digital music within both in-school and outside-school arts-music programs that inspire new thinking and practice, encouraging creative curiosity and the development of new skills using innovative, low cost technology.

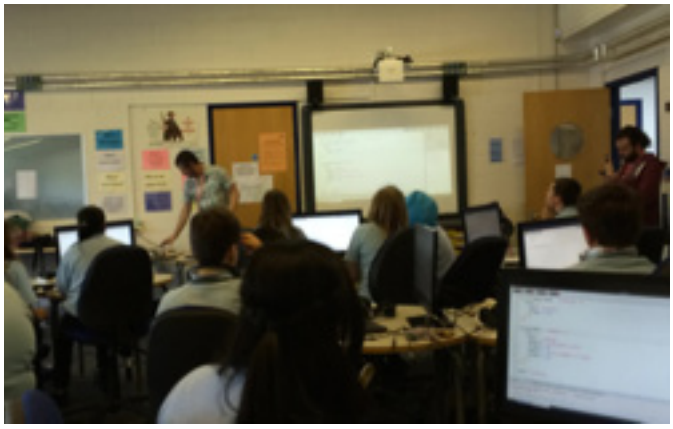
1.3 Interest to the arts, education and technology sectors

Introducing Sonic Pi v2.0, the Raspberry Pi and the link to the new computing curriculum

A registered charity founded in 2009, the Raspberry Pi foundation created a low cost (£25) credit-card sized computer that was produced to encourage children and young people all over the world to learn programming. Sonic Pi is a computer program, developed by Dr Sam Aaron for the Raspberry Pi, to teach children computer science by engaging their interest in music. As part of the SPL&C project, Sonic Pi v.2.0 has transformed the Raspberry Pi into a fully customisable musical instrument, suitable for use within music education settings.

Applications like Sonic Pi v2.0 also allow the educational sector to position computer science and computational thinking as general-purpose skills which can be used across the full breadth of the curriculum. Traditionally, computer science has not been considered as a core curriculum subject in the UK (Drummond, 2009). This has resulted in most high school students not being introduced to topics such as programming (Carter, 2006). Since 2012, there has been a wholesale reform of the English school computing curriculum, and substantial movement in Scotland and Wales (McAuley, 2012). From September 2014 computing will have a new statutory computing curriculum and, for the first time, will become part of every child's education. (Peyton Jones, 2013). This overhaul of computing and digital literacy in UK schools presents a significant opportunity to halt the decline of student interest in the subject (Black et al., 2013), and represents the start of a computing education revolution that will affect over seven million pupils aged five to sixteen (Bacon, 2014).

Developing the place of digital music-making in music education



The rise of digital media is a defining aspect of 21st century music-making, reception and distribution and its use brings changes to arts-culture industries and education sector practices (Hasmondhalgh and Baker, 2011). Technological changes have gone hand in hand with changes in digital music culture and behaviour including music composition especially with the advent of computer/laptop accessibility. New music technologies point to a need for new pedagogies to foster new pathways into music and musical careers suggesting the need for a different kind of music teacher as the technologies open up new spaces for new creativities. Recent changes in music technology have challenged composers and educators to think differently about their music creations (Field, 2007). Computer-based composing creates different treatments of time, texture, and timbre (i.e. more access

and control in mixing different sound sources). All of this gives prevalence to ways of facilitating innovative, exciting and engaging digital music opportunities (i.e. learning pathways) for young people, teachers and artists who are serious about making 21st century music education relevant.

Interest to music educators and music education hubs

'Music Education Hubs' are groups of organisations including arts organisations and schools, led by their predecessor local authority music services, who are tasked with organising music education activities within a defined geographical area . SPL&C will be of interest to them as a model of innovation that delivers on priorities within the national music plan and addresses Ofsted criticism of music hubs by diversifying musical experiences and bringing the professional arts sector, through both experimental digital artists and instrumental teachers, into the classroom. Music education hubs are tasked with providing high quality provision of music-making that brings social, personal and economic benefits to music teachers and leaders, and involving strategies for re-engaging disaffected young people and those facing barriers to accessing music, all within a context of decreasing funding. Hubs not only augment and support music teaching in schools, they also support instrumental teacher professional development by drawing on the expertise of partners involving, for example, collaborations with contemporary music groups, community musicians, and leading edge popular performing artists. This project develop a model which exemplifies quality engagement and creates new pathways into digital music-making for instrumental teachers who worked closely with young people engaging them in digital music opportunities.

Interest to digital media and music sectors

Engagement with out-of-school music-arts and the rise of digital media is a defining aspect of 21st century music-making and its use is bringing changes to music classrooms. The arts sector has a long and established track record of working with schools and young people, and there are an increasing number of examples of collaborative partnerships between schools as well as other arts/music learning sites and universities that attempt to strengthen the link between the music that young people encounter in school and that which is experienced outside school. Where this outside-of-school music is integrated into the school music program, it follows that students' levels of enjoyment and engagement with music is higher. There is little evidence that relying solely on the school system, as it is presently structured, will bring about positive change (O'Neill, S. (2012). Young People and Music Participation Project).

Interest to the wider arts sector

The project will be of interest to the wider arts sector in that it explores the potential for the arts to take the lead in innovative digital projects, using arts approaches/ ways of working that inspire new thinking and practices amongst project partners. Working in partnership with arts organisations such as Cambridge Junction, introduces techniques and partnership-working that for many schools and music hubs is unfamiliar territory. The involvement of artists such as Juneau Projects brings a level of experimentation and creative exploration that ensured a unique, inspiring and high quality experience for all involved.

SPL&C also explores the creative potential of live coding as an artform through various artistic explorations both in (lessons led by Juneau Projects) and beyond (summer school, pop-pi videos) the classroom.

Further, it support the development of artistic interests and skills across formal (in school) and informal (summer school) learning communities to provide new pathways for young people into digital music. Developing the use of Raspberry Pi hardware as a fully customisable musical instrument for using code to compose, improvise and perform simultaneously, encourages a future talent pipeline of artists who have the skills and confidence to use digital technology. Interest to those seeking to develop the programing skills of young people.

Interest to those seeking to develop the programing skills of young people

The significance of this project is partly based on the part it can play in delivering the new primary and secondary subject ‘Computing’. The future mode of teaching ‘computing’ in the primary and secondary schools could be transformed through adventures in coding music with Sonic Pi v2.0. Due to their apparent fluency with digital technologies, it has become commonplace to refer to young people as ‘digital natives’ (Resnick, 2009). Having been immersed in technology all their lives, it has been argued that these students possess impressive and under-utilised technical skills and new learning preferences (Bennett et al., 2008). Regardless of whether ‘digital natives’ possess competencies that render them better able to manipulate technology, the learning of programming is possible in both formal and informal settings. Research on learning programming in schools (Serafini, 2011), ‘after-school’ clubs (Maloney et al., 2008) and the virtual use of web-based resources (Pritchard & Vasiga, 2013) is demonstrative of the diverse ways programming has been taught. Moreover, through their everyday interactions with technology, many contemporary children already engage in a computing milieu where they are unwittingly learning programming skills without

realising it (Petre & Blackwell, 2007). This project is of interest to audiences seeking to develop the computing skills of young people because it advances knowledge of how Raspberry i/Sonic Pi v2.0/live coding can be used as a tool to enhance young people's creative skills of digital music and coding and inspire and motivate them to learn and create new practices in musical composition and performance.

Interest to those seeking to assess live coding skills and quality

Computer programs produced through live coding are subject to assessment issues which arise, in part, because live coding blurs most concepts of established musical discourse, such as composer, performer, and audience; instrument, score, and piece; composition, performance, and improvisation; stage and auditorium; and instrument and tool (Magnuson, 2014). Live coding practice requires users to become fluent with live coding tools so that they are free to concentrate on musical, rather than technical, issues (Brown & Sorenson, 2009). As live coding is an 'intricate dance between human and machine' (Collins, 2011), it may result in learners having to contend with additional complexity (which may not have been encountered had they learned using alternative means). The importance of the visual presentation of code (Sorensen & Brown, 2007), and the fact that true liveness is not only manipulation but actually refers to creation and recreation of code (Magnusson, 2014), are additional factors that may impede the effective assessment of live code. This project has sought to develop an assessment framework/assessment advice.

2. The research process

2.1 Research proposition

SPL&C explored the extent to which arts-led partnerships can use live coding to facilitate innovative and engaging digital music opportunities and progression routes for young people, teachers and artists. The testing and development of Sonic Pi v2.0 for Raspberry Pi was an integral part of the project.

2.2 Research objectives

The research questions were:

1. What are the 'learning pathways' that characterise musical performance practices and programming skills of 'live coding' using Sonic Pi v2.0 (as perceived by learners, teachers and artists) in formal and informal music education?

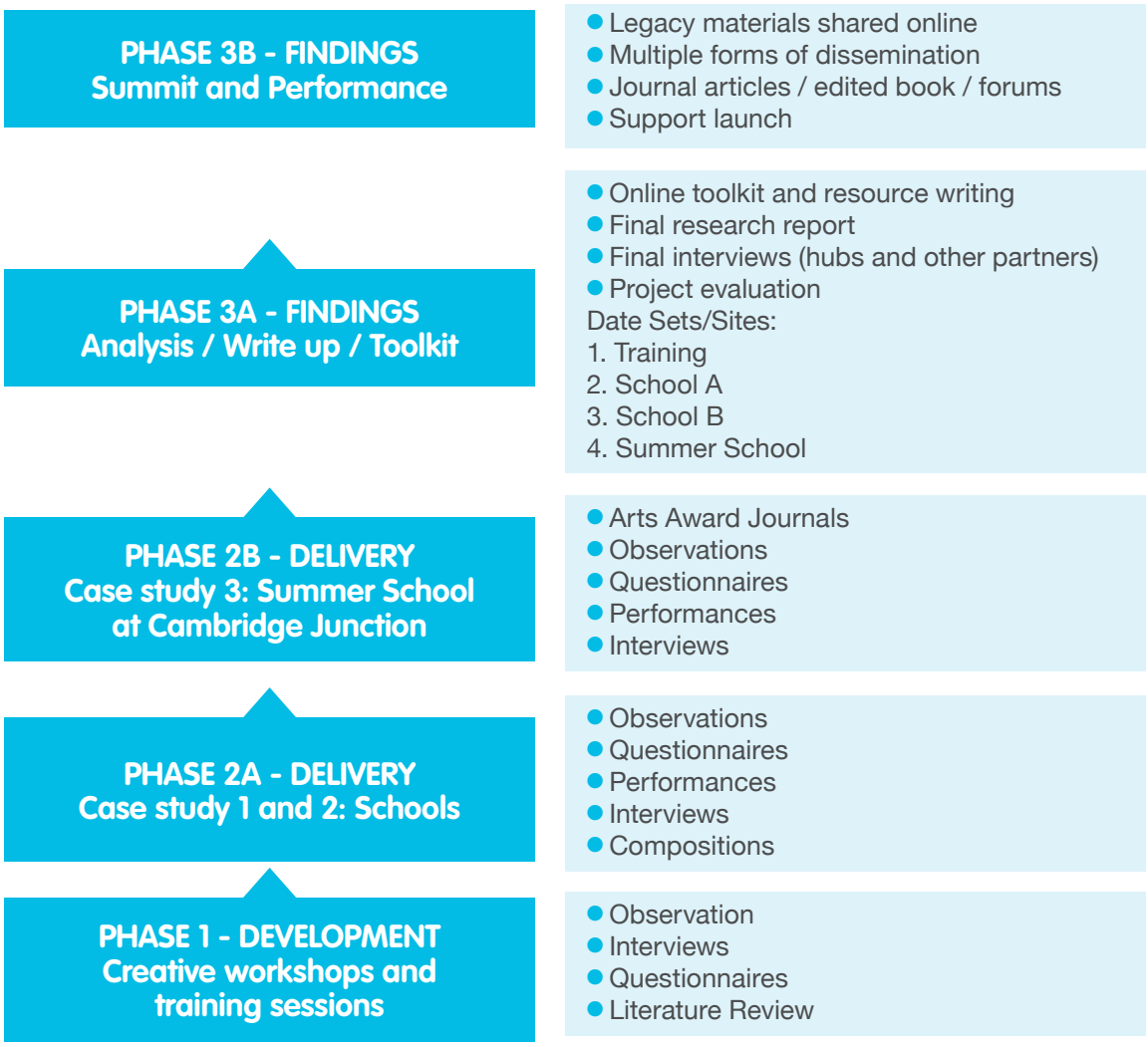
2. What are the digital music opportunities enabled by 'live coding' using Sonic Pi v2.0 (e.g. through composition via whole-class tuition in schools and artist-led masterclasses in arts venues)?

3. How can arts-led partnerships collaboratively work to develop Sonic Pi v2.0 teaching and learning practices in formal and informal educational settings?

Research Proposition Illustrated

2.3 Key steps and processes

For the multi-site case study, there were four distinct interrelated phases, three of which comprised the main data collecting phases.



During the first phase, creative workshops and training sessions were led by arts partner Cambridge Junction via the SPL&C Project Director, Rachel Drury, and Project Manager, Michelle Brace and the technology partner, Sam Aaron (three 1 day sessions). The purpose of these sessions was i) to ensure participants understood the project ii) to develop the delivery team as a team iii) to explain the basics of Sonic Pi iv) to work collaboratively to build the activities for phase two. A fourth day, led by Martin Russell from the Royal Opera House Bridge, provided Arts Award Assessor training for the delivery team. . The second phase involved the two school interventions (Freman College and Coleridge Community College) where the teaching was led by the instrumental teachers in collaboration with the music teacher. The technology partner also attended many of the in school sessions, taking the role of participant observer, assisting when problems arose and taking in ideas for further development of Sonic Pi. The third phase involved a five-day Summer School led by Juneau Projects at Cambridge Junction.

The outcomes of the project to inform business models and policy for the arts were then studied through an intensive workshop involving all artist and technology collaborators, followed by a final review by the steering group. Finally, the arts, technical, teaching and business resources that were tested and refined throughout the project were all shared online, launching at the SPL&C national summit on 4 November 2014.

Data collection (observations, interviews, digital artefacts) took place during the two six-week interventions at Coleridge Community School in Cambridgeshire and Freman Community School in Hertfordshire, followed by the week long Summer School at Cambridge Junction.

In the school settings 28 Year 8 students (at Coleridge School, six 1 hour 40 minute lessons) and 26 Year 9 students (at Freman School, two 1 hour lessons per week for six weeks) were shown how to code music using the Sonic Pi v2.0 software, with each week focusing on different musical and coding techniques. The course, which took place during the regular music lessons at Coleridge and during one hour of music and one hour of ICT at Freman, was led by the instrumental teacher, with assistance from the classroom music teacher. The lead artists, Juneau Projects, led the week three lesson, focusing on the performance side of live coding, returning in the week six to lead a final performance. Juneau Projects introduced design elements to enhance and support the music performance aspect of coding with the use of bespoke controllers to aid learning in how to get to grips with Sonic Pi. Creating a performative emphasis on creative learning, Juneau Projects maximised students' engagement and focus on imagination and creative experience to develop learning as evidenced in the potential to motivate and engage learners, where they become more independent in exploring options for performance.

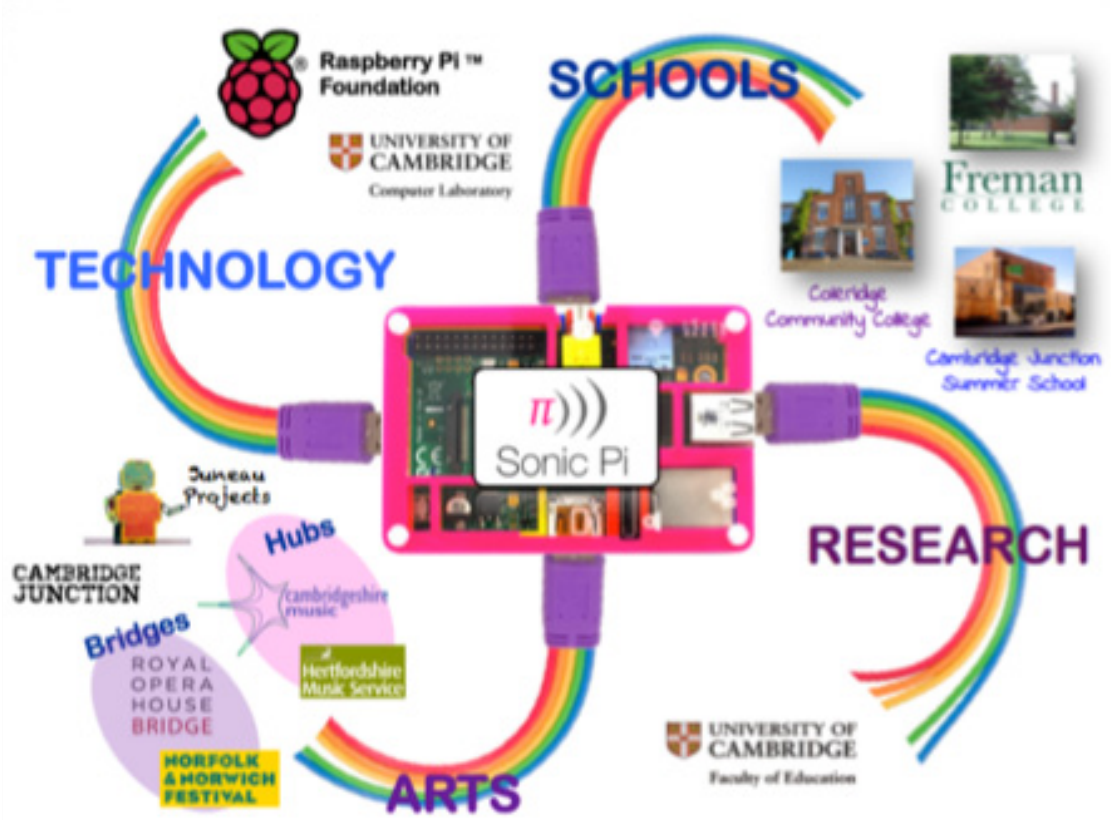
Throughout the two six-week trials, the SPL&C unit-of-work sought to address learning how to code music and compose and arrange tracks, and provided an introduction to live coding performance, culminating in live coding paired, group and whole class performances. Focus group interviews were conducted in both school settings with the students following or near the final stages of the performance event.

Two weeks later, 57 children aged 10 to 16 took part in a five-day (10am – 4pm) live coding Summer School at Cambridge Junction led by Juneau Projects. They were taught how to use the Sonic Pi software on the Raspberry Pi computer and encouraged to develop their own artistic responses to the opportunity presented by live coding, with the week culminating in an afternoon of individual and collaborative performances for

parents and invited public. The week had many highlights of young people live coding in response to a diverse set of creative musical and performance tasks and projects. There was a Sonic Pi X Factor and guest performances each day by professional musicians and live coders. Many young people included in their performance the use of bespoke controllers designed to aid the learning process of getting to grips with Sonic Pi. During the week, daily observations were made, including filmed diaries, and many of the students completed written and filmed diaries in order to be eligible for Bronze Arts Award. The research focused on the topics of experience, learning and engagement.

2.4 Partnerships: roles and responsibilities

There were nine partner organisations, two secondary schools, 110 young people and 20 adults involved in the project as shown in the figure on the next page. The learning community and practices developed as the project proceeded involved learning relationships that were built on mutual engagement, and a shared repertoire of routines, tools and immersive ways of doing things. The SPL&C learning partnership was characterised by: (a) a willingness to utilise each other's expertise and experience as their learning resource; (b) to learn together; and (c) to develop a mutual engagement with each other which included a trust of one another.



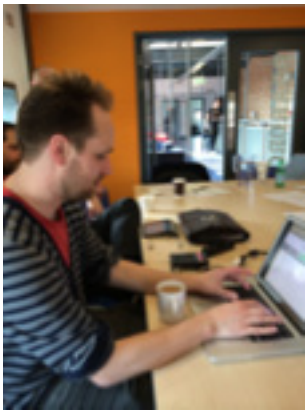
3. Findings

3.1 Learning from an arts-led partnership

The training methods employed across the first phase saw a series of interactions between professionals from diverse disciplines. Partners accessed a multitude of tools and tasks and strategies. Learning to live code music from the creator of Sonic Pi (who led parts of three of the four training sessions) was profoundly inspiring and engaging. Despite being under great pressure and working long and anti-social hours in diverse portfolio careers, the instrumental teachers, Juneau Projects and Sam Aaron provided the trust, encouragement, optimism and teaching tasks that teachers then shared with their classes.

Sam, the creator of Sonic Pi, has this to say:

> Rather than a tool that we can use to engage pupils in Computer Science, which was what the original version of Sonic Pi was ... we want ... to try and imagine it as a musical instrument in its own right, where the interface of the instrument is a programming language ... so one of the reasons why we got you guys here … you can help me figure out which bits of this aren't great and which bits are great…



The feedback process to the delivery team meant they were in a position of being made aware of the variety of tools/strategies – tools in their toolkit – available for executing teaching and learning tasks. Partners were open and availed themselves of a range of strategies for executing the teaching and supporting the learning of coding.

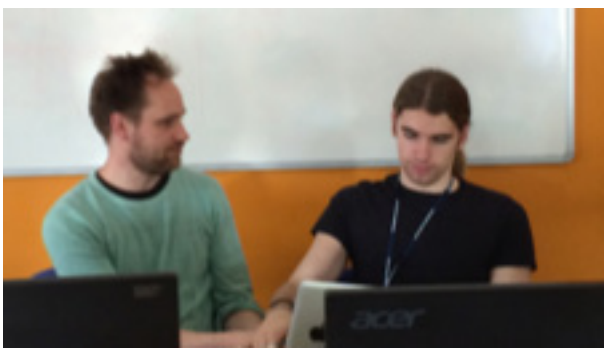
Ross and Ben, the instrumental teachers and professional musicians who led on the teaching of Sonic Pi in schools, have this to say:

Ross talking about 'planning for delivery':

> I think the first time they see it, it should all be unplugged, physically unconnected, and we take them through step by step ... When they open it they'll see the work on a template. … I think they'll pick that up

Ben with this insight into planning:

> I reckon when you do the lesson, it'll probably be best to go in straight, just with a blank page and get them to enter stuff – rather than starting with a template, get them typing in straight away. I think so, even if they're playing just one note.

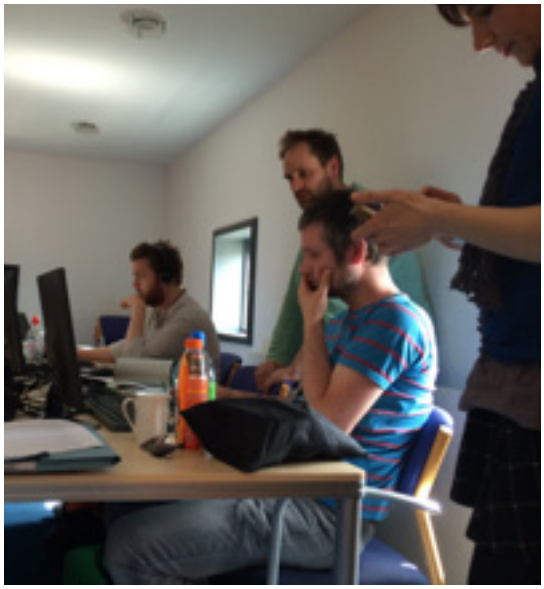


When the partners were first introduced to Sonic Pi they were invited to explore coding by making a piece of music. Three ways of working were identified:

1. using an already known piece of music (e.g. 'Can't help falling in love') and writing the code for this piece;

2. starting with an already known piece of music, but then creating a new arrangement for this piece by writing the code for the new arrangement;

3. writing the code for a completely new piece of music (a new composition).



Wertsch (1997) points out that although students often have access to more than one tool (or strategy) for responding to a task, "they tend to have a very strong tendency to approach the task as if only one of the tools is relevant" (p. 229).

This was seen in the initial response to coding tasks, where each participant seemed to have his/her own preference of a strategy and used only this one.

By using feedback as a training method, participants became aware of the different strategies within the 'toolkit' that they could draw on when training others in future.

Jane, Head of Music, Freman College, has this to say:

> **I've finished my tune … I've done 'Can't help falling in love with you' by Elvis Presley and I'm really satisfied … I think if they take some tune they come across at home, and then experiment in how to do it, and then (trying to write) the syntax – ultimately it's more powerful for them than having somebody say 'type-play-[audio unclear, but sounds like: I-M] -space' – much as it galls us old schoolteachers to let them get on with it, I quite like what we've done so far in watching a demonstration and seeing some code, and do what I've done – write code for something I already know … so, I'd be interested in experimenting with getting them to play around with a tune – I do think the carrot for them is to let them play it at the end …**

In all sessions of the training and development phase, the sense that all partners and support staff felt very much a part of a learning community was extremely strong. Perhaps the excitement of the creator of Sonic Pi leading the training and developing what would become Sonic Pi v2.0 as he went along and the multiplicity of activities offered by Juneau Projects seemed to engage the teachers in planning and reflecting on various activities in their respective phase. There were also indicators of both negotiated and exploratory pedagogies being used in the school intervention phase, giving students the full experience of being part of a cutting edge digital arts project.

Positive joint working approaches developed between partners as they planned together, regularly discussed learning, and worked together with teachers taking a progressive route from passive to active role in sessions. They reflected together with discussion between Juneau Projects, instrumental teachers, technology partner, music and technology teachers (and support staff) following each of the six sessions. The idea of 'having a go' seemed particularly powerful in building teacher confidence.

Role of the non-teaching IT Support staff in the classroom

The IT support staff were critical to the success of the intervention phase in both school settings. They were key in: (a) negotiating school infrastructure; (b) acting as 'hardware wrangler'; (c) providing technical problem-solving; and (d) affording encouragement and freedom. There is a key role for non-teaching staff in the classroom. This dynamic of introducing enabling/subverting new creative technologies into the school environment suggests the need for a different kind of music teaching and learning as the technologies engage teachers and learners differently and open/enable new learning spaces, freedoms and creativities.

This is what a non-teaching IT support staff had to say about having been given the opportunity to step into an arts-led partnership project which engaged him in a creative facilitative role which was transformative. His words underline the importance of effective interventions to help enable career trajectory and career satisfaction for such staff.

Matt, a non-teaching IT support staff, has this to say:

> **Working with the backing of all departments in school made the project really fun. Working with and feeling part of a collaboration like this, as someone who had never been part of a large project like this before, felt amazing.**

What Juneau Projects said about working and learning collaboratively:

> **Working and learning collaboratively with all the project partners helped us to develop, refine and reflect upon the project at all stages of the project's progression. The initial phase was a critical point in learning how to engage with team members informally in experimental workshops. [The] Sonic Pi [Project] helped us to develop as a community and to develop a kind of communal shared understanding of what the project was and where it could go.**

3.2 Some research statistics

The questionnaires

We asked participant students and teachers (both in the two schools and summer school) to fill in an on-line questionnaire which enquired about their background information, asked them to rate statements about their thinking, and offered them a place for feedback. In addition, the staff of the project completed an evaluation questionnaire. The questionnaires were validated by piloting and statistical tests and the data was analysed with a variety of statistical techniques.

Results highlights

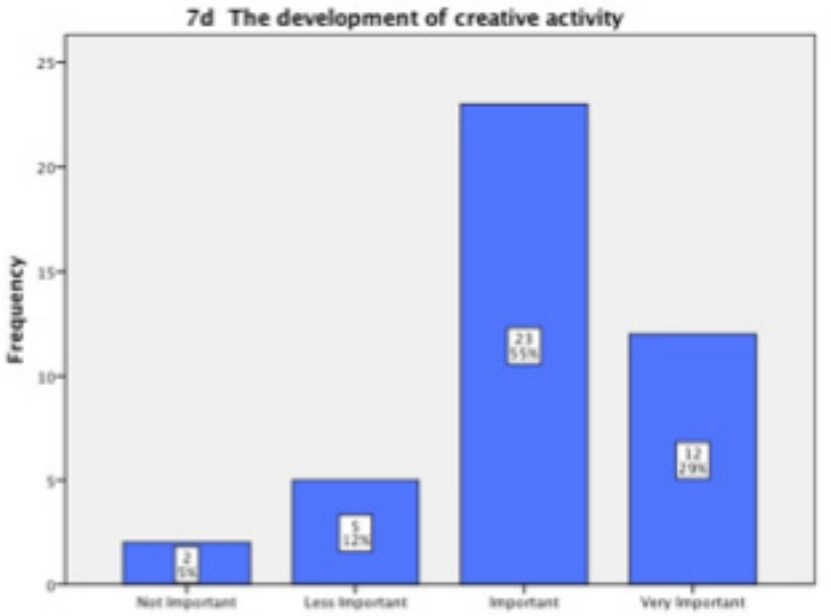
The gender distribution of responders was close to equal in the Sonic Pi Course (48% Male, 52% Female), but in the summer school boys were highly over-represented (16% Female, 84% Male). This distribution highlighted the fact that computer science is still male dominated and when students are allowed to choose courses voluntarily female students are under-represented in these events. In the closed items we asked students to rate the importance of their programming skills and girls responded almost half-point (-0.45, in a 4-point scale) lower than boys, emphasising lesser importance of computer programming in their lives. Nevertheless, girls indicated a somewhat higher (0.57) rating as to what extent music was an important part of their lives. This was despite the fact that boys participated in more formal training than girls. These findings show that it would be important to prepare a more female oriented computing environment to encourage more girls to engage with the subject. Combining music and programming could become a natural ground for developing such environments as girls consider music important and adding coding to the equation could generate their interest in coding as well.

In addition to the gender differences, the questionnaire analyses have led to a number of further findings that inform our understanding of digital learning pathways in music:

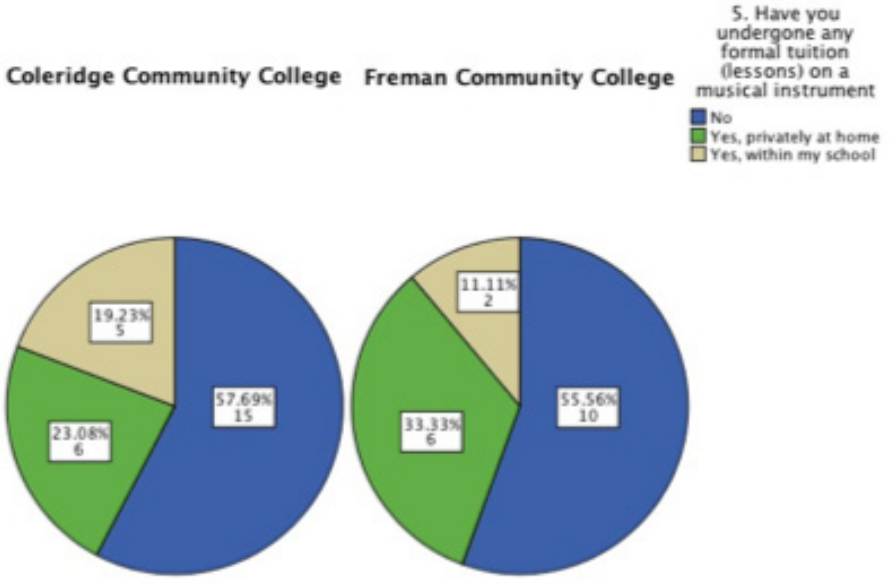
- The most controversial item in the questionnaire concerned whether students considered themselves to be musicians or not, with .1 standard deviation higher than the other questionnaire items. A musician is still regarded as being a highly professional person and associated with formal training, while in the project we tried to convey that being a musician could be less high-profile than it sounds.

Statement	Mean	SD
6a Music is an important part of my life	2.82	0.843
6b I enjoy composing my own music	2.48	0.792
6c I use computers to compose my own music	1.98	0.731
6d I consider myself to be a musician	2.07	0.936

- Among all skills students rated creativity as the most important skill that the project nurtured having the highest mean (3) among all items and 82% of students found the development of creativity as important or very important.



- Getting more formal training and support from schools and family to learn coding and music was an important factor influencing how students see themselves as musicians, programmers and composers. Schools should consider strengthening the training offered in these areas.



- The staff of the project considered that they gained enormously from the project (71% responding gaining more than expected and 29% much more than expected) and all of them were hoped to continue this work on a larger scale.

3.3 The students' perspectives: digital music journeying

Emma and Tom: "It just makes people happy"

Both Emma and Tom have done coding before but for Emma 'The coding is very different because we didn't do music coding.' and for Tom, who is used to Scratch, 'Scratch is different because you put blocks together. It's much more simple. This is very different because you have to type up lots of things. But it's not too hard to understand. You kind of get used to it.'

So what were their initial reactions? Tom reckons, 'It's cool to be able to show people what you can do. And people show you what they can do. It's interesting to see what they've done. It's like a museum where you can go and see really cool projects. It's interesting because you can be inspired by them and then create something of your own. You share your ideas and everyone will then get better at something because you'll know how to do things you didn't used to be able to do.'

```
with_fx :reverb, mix: 0.2 do
  loop do
    sample :drum_heavy_kick
    sleep 0.5
    play 50
    sleep 0.25
  end
```

Tom's idea of a good piece of music is, 'just something you are pleased with.' Emma adds, though, 'you have to believe in yourself to do it. Any type of sound is music.' As far as they were concerned, the best song they produced together, '… flowed together and it actually worked and it made you kind of happy and not "Oh, that sounds horrible I don't want to listen to it." You actually wanted to listen to it. You actually want to listen to the music and not say "Oh, this is dreadful."' Tom wrote in his diary at the end of the first day that what he found most difficult was 'creating a song that flowed' but clearly he felt they had succeeded. They left inspired and motivated with Emma commenting, 'I am proud that we'll be able to do it at home as well.' Her mother says that they looked up electronic music and dubstep online and that they talk about it all the time and continued coding in the evening. Tom printed off an extra page about connecting an LED to the Raspberry Pi and ones too about how to connect the Raspberry Pi to Scratch.

On gender imbalance

Emma has this to say: ‘I don’t know [why there aren’t more girls at the Summer School]. I really enjoy this stuff. But as you can see I am a bit of a tomboy. Some girls don’t do anything really.’ And Tom chips in with, ‘Some girls think that programming isn’t really their thing because they’ve never really been introduced to it. And they don’t know that it’s fun. Those girls [who don’t code] just think ‘I don’t really want to do that’.’

On making mistakes

‘There are lots of different kinds of mistakes.’ observes Tom. ‘There are some mistakes where you think ‘Oh this might work’ and you put an extra instrument in but it doesn’t. And there are some where you accidentally do a typing mistake and therefore you don’t understand it and kind of give up. It often says ‘It’s not working because of this’. You go back to that and then you recheck it and just look. We try not to give up. […] You just try again. You kind of forget [the mistakes] after a while. At the end I didn’t remember it.’

On the kind of perseverance that coding engenders

‘The first song we made was a bit rubbish. It might not have been an amazing song but we learned from that how to use the sleep tool. [In that] song we made everything go at once and that was dreadful. But the third song it was something similar to music and then you just put it on.’ And Emma comments, ‘This has made me code more. I feel proud of learning. I couldn’t really code [before].’ Tom endorses this: ‘[I am proud of] how far we have come because we can now write a good decent song and a cool instrument using this program that we only learned how to use a few days ago. That’s quite impressive and I am proud that we have come that far that we are able to do that. It’s really good fun!’’

On the benefits of the summer school

Tom believes the summer school has improved his music skills: ‘I know what goes together. Like which instruments go together. And you have to listen to it lots of times because you can’t have something going really fast and something at a random speed unless that is what you are going for.’ For Emma, it has been a different inspiration: ‘I did the guitar a few months ago and then I stopped because I didn’t like the guitar teacher and now I’ve seen some of [the artists] and now I want to do it again.’

On the pleasures of live coding

'I love building things. […] It's just one of my hobbies.' says Tom. 'I just like building things. It's fun and it means that I can enjoy something with a finished product. But I find that with things which aren't really hands on you just end up with a piece of paper with writing on it or something. And if you build something you can show someone which is kind of more visual and I like working visually.' He adds, 'I made [the controller] quite similar to the format of a piano because I play the piano. […] And I find it quite easy to use both hands at the same time.' So why else might people enjoy live coding? 'It's a thing that makes them happy. It's the same reason why people perform normal music on stage. Why they sing songs. It just makes people happy.'

Oliver: "This is my life now"

Oliver probably had something of a head start on other students given his home background: his mother is a musician and his father a coder who has created a language called Racket. 'So that is why I am interested in programming.' He is also fortunate in being well equipped: 'I am so lucky to have a laptop. My dad needs all the versions of Mac so I got his old one.' Not that programming necessarily came easy to him: 'Racket was hard. It was so different. But then I just kept asking my dad. And a lot of times he had to teach me.' But it's not just his dad: he has his own musical and programming background: he started playing violin when he was six 'but then separately eventually I started to do a little bit of coding, starting in Scratch and then a little bit of Racket.' He is currently involved in taking private music composing sessions.

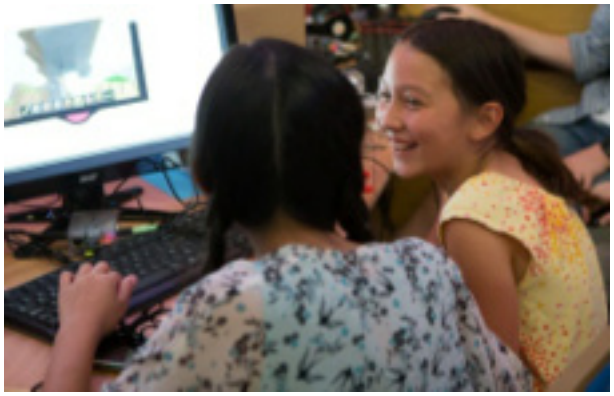
Perhaps unsurprisingly, given the gap between him and his peers, but also possibly because of a sense of his own worth in comparison with others, he finds that 'working with people is the hardest thing!' Is this just a stereotypical geek position? He does come back to this theme frequently: 'Most difficult [aspect of the project], working with people…'; 'With our giant group it's hard to get everyone on one topic'; 'I had a partner and he wanted to do different things from me. But then we switched and I had a new partner. And he just wanted to play Minecraft. I got to code a lot though.'; and 'It's kind of hard to work with other people…' though he does add '…but I like sharing'. (There is a photo of Oliver working on his own and his two team mates working on their own as well.) However, he is not entirely oblivious to others and enjoys spreading his expertise: 'I really like sharing my code with others and helping others to get better, too. They make things that are different from me and I like seeing what they make after I help them'. And he is quick to recognise talent in others: 'It was cool to see Shelley program in supercollider'.

There is no doubt that he is extremely motivated and completely immersed in the project. His diary is filled with comments such as, 'I liked exploring what I will do tomorrow' and 'Today I did awesome live coding'. On day 2 he comments that, 'I liked the live coding battles and learning cool things to do'. On day 3 he writes in his diary, 'Each day I get more advanced by asking questions' and he goes home and creates more code, as, according to his parents, he has done every night. On day 4 he notes that 'I set up a free work space so people can try the new version of Sonic Pi'.

How he works

Oliver is noticeably a highly independent learner who feeds avidly off the project and develops things in his own way and on his own paths. He has also completely internalised the attitude, indispensable to a coder, that things don't always work out right first time: 'I keep going and I want more of what I am doing. And it's really because of trial and error. I do something and then it breaks and then I try again and then I learn something. And that just keeps happening over and over. If it goes quiet or if you break it you can always recover. The first mistake I want to avoid is crashing the machine.' He is also a true coder in his disdain for the use of GUIs: 'I thought about building a controller but to me the controller just seems to limit things. I don't really want there to be a limit to what you can do. Why have a button that prints and plays something when you can just type it and change the number on your keyboard?' But despite this lofty viewpoint, he is genuinely generous and impressed by the professionalism and impact of the project and those running it: 'The kids love to learn new things really quickly. The coaches haven't been stuck on one thing too much. We have been learning really fast. And also getting results really fast… I haven't seen anyone bored at all'.

So was the project a success for this high-flying coder? Before the final performance, his mum confides that he carries his Raspberry Pi everywhere with him and says, 'This is my life now'.



Suki and Sophia: "We just clicked straight away"

There was a predictable gender imbalance at the Summer School so it is maybe a surprise that Sophia and Suki were there at all. On the one hand they do not see themselves as coders and have little experience of it, and on the other, they don't consider themselves to be musicians either. Suki is quite clear on this: 'I don't really like doing music. I used to play piano but I stopped. It's not that I don't like doing it, it's just that I wouldn't see myself as a musician. I prefer sports. I think I like the programming bit more than the music bit.' So why aren't there more girls here? Suki speculates that, 'They might rather be doing shopping,' and Sophia concurs: 'They might like fashion and not this computer stuff.' So in what way are these two girls different? 'I like trying new things,' says Suki, whose dad is a programmer.

Outnumbered by boys and starting from a low skill-base, it would be quite natural for them to feel a little overawed and intimidated, yet they develop excellent strategies for coping with the demands of the Summer School. Importantly, they immediately gel and work tightly as a team. When asked if they like working together, they simultaneously and enthusiastically say 'yes!'. The reason? 'We seem to agree on the same things.' And Sophia expands on this: 'My brother sometimes says that his partner doesn't cooperate; that he doesn't like the same things and so I think that we are good partners because we actually like the same things. I think [agreeing on things] makes it funnier because you have no big conversations and you don't have to compromise.' Suki notes in her diary that there is no division of labour in their team, they are 'working together on everything'. This is apparent when, for example, watching them building a box; they work really collaboratively and ask each other questions: "Is this good?" " Is this the right size?"

Nevertheless, there are anxieties that inhibit them. They are, with good cause, worried about performing on stage. Suki is worried about how she would cope with technical problems in public: "When we listened to Shelley she said that plenty of times the computers crashed,' and Sophia agrees: 'Something could fault. Something could crash. You could mess up and maybe it doesn't play and you are on stage and you are standing there. […] That's probably a bit scary.' And then there are the boys: 'When we were doing the coding-war thing someone, when it didn't work or something, everyone said 'boo!'

and the people on stage, I felt bad for them,' says Sophia. And it's not just seeing others getting a hard time. Suki adds, 'And one time we were up there and sometimes people can be discouraging. A boy started yelling at us and we were like 'Ok, whatever' but it can be scary going on stage. That's why we are not doing live coding on stage.'

So instead of a performance, they decide to build a controller. Did they make the controller because they still found coding a little bit scary? 'That might be part of it as well,' admits Suki and Sophia quite reasonably points out that 'We only had a little bit of time [to learn to code].' They find live coding difficult and get easily discouraged when things don't go well. Sometimes the computer crashes - and Sophia writes in her diary, 'What I found most difficult was getting the song to actually play, because ours would sometimes not play.'

However, despite their lack of confidence and their fears of having their inadequacies exposed to unsympathetic scrutiny, they clearly find their own way through the five days expertly, get a lot from it and, above all, enjoy it. What are the things they learned and enjoyed? Suki can over-ride her anxieties and comment that, 'It doesn't seem like a school. It's more like a club that is fun and that you can choose to [do it]. Everyone is really nice here and you don't have to worry about anything. And the other people. You see what they can do and how different they are and how different you can be. Basically what I am trying to say is that it doesn't matter what other people think. You just do what you think is right. Thor was very inspiring because it was not the computer he loved, it was the music he loved.' And meeting Shelley has inspired Suki to feel that, 'If you don't get what you want at first you can improve it and have something better.' They were pleased with their controller.

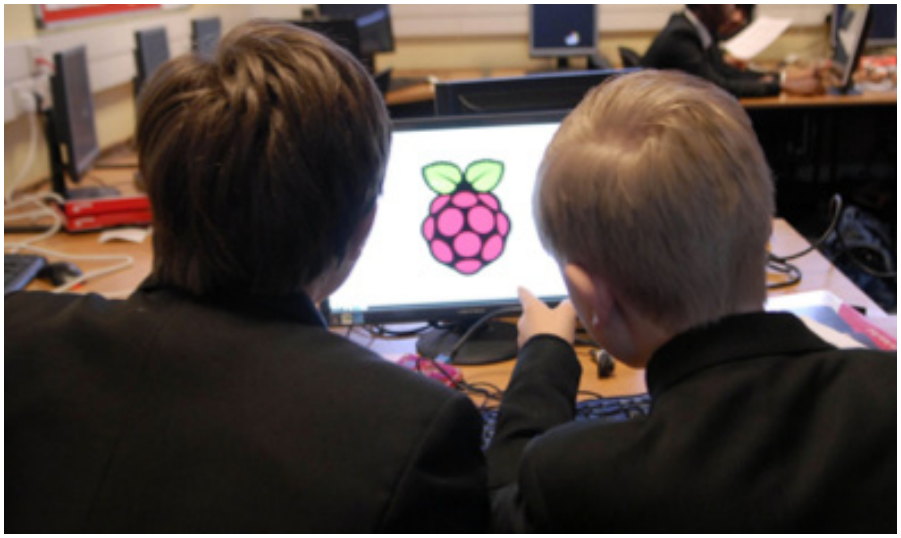
Suki again, 'I didn't have any idea what we were going to do but once we got started [the controller] really began to look great. I am really pleased with how it turned out. And she adds, 'I'd like to do more complicated code. Not just do Raspberry Pi coding but also other programs. That would be fun to find out. There's different ways…'. However, what shines through most clearly is the friendship that has developed between the two girls. Sophia says, 'We just clicked straight away.' Suki agrees: 'We didn't know each other before we came here and this is really fun.' And Sophia reflects, 'We've found new friends.'

4. Insights and implications

4.1 Developing artists and audiences through engagement with young people and learning

Cambridge Junction has a long track record of delivering high quality creative learning programmes and experiences, both in schools and at the venue. They played a lead role in this project, as the overall project manager and through the recruitment of the lead artists, introducing arts-led ways of working that led to inspiring and positive experience for everyone involved as well as excellent and innovative outcomes. Further, they demonstrated how a performing arts venue and the unique opportunities they provide to engage with the professional arts sector can validate the experiences of learners as performers.

SPL&C encourages young people, as well as their friends and families, to see themselves as a creatively engaged audience and artists, participating in live arts rather than simply receiving it via digital media consumption products. Thriving community culture depends on the presence of local creative contexts, which is very much in contrast to the global corporate model of media consumption usually associated with digital content. This project is based on the user-testing in schools of Sonic Pi v2.0 and brings together meaningfully the abundance of expertise, skills, digital artists, cutting edge technology, arts organisations, schools and universities. Arts organisations and artists can provide a unique contribution to user testing processes and the trialing digital education tools to complement and/or enhance what goes on in the classroom. This in turn helps to generate future artists, participants and audiences.



4.2 Next steps

It seems apparent that arts-cultural and education sectors need radical change in ways which emphasise arts-led digital media partnership imperatives. Indeed, it would be somewhat surprising if the overwhelming push towards marketisation in the neo-liberal policy regimes of the last thirty years in education and the dynamics of arts organisations together with work in the cultural realm, do not bring considerable innovation in multi-agency partnership work. We need more effective strategies that empower and enable collaboration across subject disciplines (e.g. particularly between music and computing teachers, and between instrumental teachers and non-teaching staff), paying particular attention to the closely related issue of arts-led partnerships:

1. Young people emphasised the pleasures, rewards and satisfactions of live coding. The potential for digital music-making to reform arts and the education sector requires inter-organisational multi-agency collaborations to act as a catalyst for arts-led educational change.

2. Crossing the boundary between subject discipline teacher teams leads to innovative team teaching. The delight in the discovery of new possibilities and the co-creation and implementation of a new activity-based live-coding pedagogy will require paying particular attention to the closely related issue of what constitutes the relationship between innovative processes and product in creative learning and how to assess the learning pathways. Some of the many excitements about Sonic Pi v2.0 inspired diverse forms of creative learning which was evidenced by involvement in high-quality creative work in: (a) coding (from simple to complex pathways); (b) digital music-making (ideas, inventiveness and development); and (c) performance activity (and its unique quality of 'liveness').

3. Negotiating, co-creating, mutuality, reciprocity and scaffolding are qualities of rich collaborations which enable and support the co-construction of effective arts-led partnerships by communities of interdisciplinary experts. Developing ways in which the arts and education sector learning environments are transformed by the integration of

coding into teaching and learning practices will depend on the vision and enterprise of senior management teams and policy makers. The model of business and arts-led activity systems developed through this project's collaborations between professional performing artists, arts organisations and schools calls for digital performance-oriented entrepreneurial events of this kind, along with boundary crossing which triggers and embraces risk-taking as a source of creative learning and coding literacy.

4. Itinerant teachers need not be isolated, working in silos, but should rather be people who take on extra responsibility beyond traditional roles as instrumental teacher employees – roles that are redefined by the diverse ways they are charged with, and expected to work across, multiple projects that implement new directional music learning and new performance enactments. These would involve overlapping teams in the area of inter-organisational music learning and multi-voicedness activity. Time for discussion, reflection and planning was decisively important for the evolution of collaborative work teams that co-construct innovative teaching and learning activity.

4.3 Planning for new projects: a glimpse of the future

The next stages of this project involve the broader deployment and support of the toolkit validated in this study. However, we also see opportunities to further advance this creative digital agenda, in which young people are empowered to develop artistic performance practices of their own.

SPL&C has proved to be a fantastic initiative that has brought together a strong group of partners and we are keen to find ways to build on this success and our collective ambition for the future.

Options for the further artistic exploration of Sonic Pi is being explored by Cambridge Junction with the Raspberry Pi Foundation and Sonic Pi creator, Sam Aaron.

The partners are looking at how they can embed and expand the project within their own local partnership by increasing the number of schools engaging with SPL&C within Cambridgeshire and Hertfordshire, as well as across the wider East of England area covered by the two Bridge partners, Norfolk & Norwich Festival and the Royal Opera House. They will continue to share their learning with other local hubs as they develop.

To achieve the expansion identified, the model is being refined using this research to consider how best they can be delivered in a sustainable way. Additional funding will be sought to support the achievements of these ambitions.

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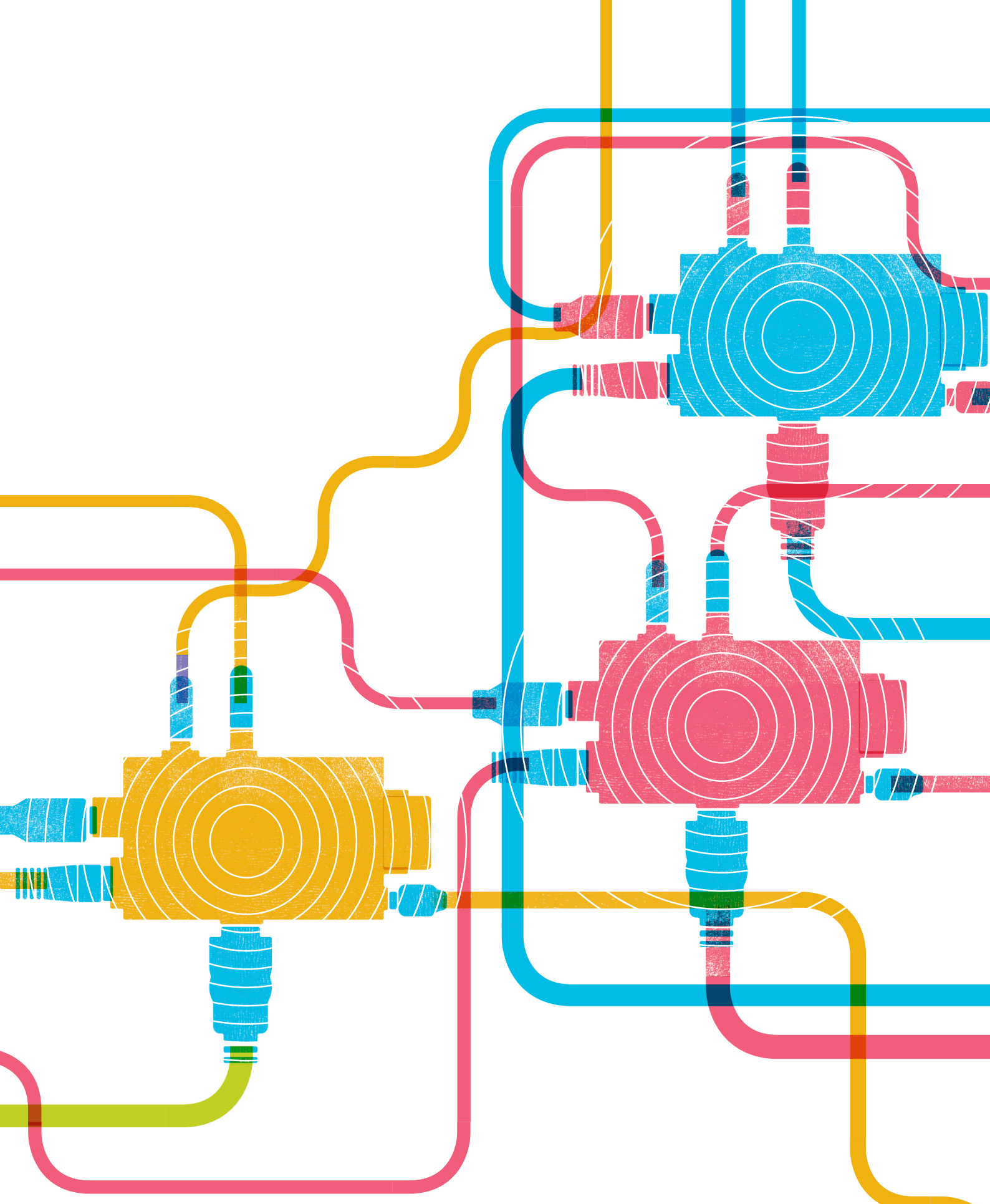

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