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Digital technologies and the mediation of undergraduate students' collaborative music compositional practices

Music education is supported by an increasing range of digital technologies that afford a remarkable divergence of opportunities for learning within the classroom. Musical creativities are not, however, limited to classroom situations; all musicians are engage in work that traverses multiple social and physical settings (Burnard 2014). Guided by sociocultural theory of human action, this paper presents a case-study analysis of two computer-based composers creating one soundtrack together. Analyzing how collaborative work was undertaken in all of the naturally occurring settings, this paper shows how the students' inter-relationships with technology constituted their understandings, creative output and their ecology of practice. The research contributes new knowledge about how digitally resourced creating is shaped by remote, remembered, hypothetical and imagined digital technologies. It also shows how technology-mediated co-creating is a *complex interactional accomplishment*; implicating the value of long-term multi-setting digital co-creating to higher mental development through discourse within music education.

Keywords: music, computer-mediated music, sociocultural theory, interthinking, creative process

In recent years there has been a significant growth in research exploring how digital technologies mediate creative processes within primary and secondary music education. This work has offered understandings of the role of digital technology in music, and computer-mediated music composition (Cain 2004; Savage 2005; Burnard 2007; McNichol 2012; Dillon 2012) and musical creativities have been construed as something that happens in relationship with technology (Burnard 2007). Studies examining how technologies mediate learning and creating in music composition have led to greater diversity of digital technologies being used in the music classroom.

Classroom computer-based composition traditionally utilized a relatively few technologies, notably MIDI [Musical Instrument Digital Interface]-based composition for controlling default instruments, audio loops and sequence-based composition (Burnard 2007). Young composers found these technologies to be unsatisfying (Airy and Parr 2001; Savage 2005) and research indicated how the typically circumscribed use of this technology was limiting students' breadth of education about composition techniques (Cain 2004; Savage 2005; Burnard 2007; McNichol 2012). Recognising that such restricted use of digital technology affected the students' conceptual understandings of music and musical possibilities numerous studies suggest a broader use of technologies in music education (Cain 2004; Savage 2005; Burnard 2007), leading to new tools developed for music composition, utilizing hardware and software interfaces to broaden the range of creative practices, sound concepts and techniques available. Examples include the Sound Manipulator interface for children to work directly with sound (McNichol 2012) and jam2jam Xo platform (Dillon 2012), an online software environment that fosters generative processes, enabling users to interact with a semi-automatic system: 'A young child can experience making complex works in real time with such technologies, whereas in the past access to this music would be limited by instrumental skill to a passive listening experience.' (Dillon 2012 p178). Aaron's resources for teaching coding,

using Raspberry Pi (As of June 15th, 2014 <http://www.raspberrypi.org/tag/sam-aaron/>) introduces his own interface Sonic Pi; an open source programming environment for children, and Butcher and Savage have developed their DubDubDub project for performance and improvisation using live information captured from the internet (Butcher and Savage 2007). This enables other kinds of digitally facilitated musical creativities where children ‘...remixed the sonic content of the internet, arranged sounds and prioritised them in real time to form new musical works’ (ibid p83). There are many examples of work focused on introducing beginners to new technologies for exploring music, and related studies, typically observing time-limited and location-specific tasks that are set up *for* the composers, but not *by* them (Airy and Parr 2001; Nikolaidou 2012; McNichol 2012; Seddon and O’Neill 2014). It is, however, also important to consider situations where students develop their own tasks, particularly as these connect with prior knowledge with music concepts and technologies. For example while composers develop knowledge about the digital technology and composition tools available to them they begin to work more quickly, but experiment less with the technology (Hickey 2003; Dillon 2004; Hewitt 2002; Seddon and O’Neill, 2014) while experienced composers appear to deepen knowledge of particular techniques and tools, students with very little musical training remain more open to experimenting with software, adopting more variable compositional strategies (Hickey 2003; Dillon 2004; Hewitt 2002; Seddon and O’Neill 2014).

The empirical focus on the composition processes implicated in the use of digital technologies in music has not been extended to an examination of undergraduate situations. Within the university, students are engaged in longer-term, multi-setting activities and little is known about inter-relationships with digital technology in the context of long-term collaborative computer-based music composition. A few studies have considered music composition practices that have developed over several weeks; for instance, Kirkman’s research adopted a longitudinal perspective, but the task was still directed by a member of staff and undertaken within a curriculum framework (Kirkman 2007). So far there has been no real exploration of the learning and digitally mediated music composition practices of undergraduate composers – where they are responsible for choosing their technologies, and where their composition practices are constituted by the technologies that they choose. There is an incredible diversity of music technology in Higher Education (Boehm 2007): resourced by a diversity of performance technologies and social networks, composition, interactive and microcomputing tools (sound beam, Raspberry Pi, Reaktable, Max MSP), coding languages and studio, or computer-based music composition and production tools (DAWs, performance technologies and software). Undergraduates have access to a sophisticated range of technologies, and they are also not necessarily constrained by their physical contexts; while working on longer-term creative projects, that traverse multiple physical and social settings, students must make choices about which tools to use, and this must affect the work and learning that is happening.

This paper presents research that analysed the composition trajectory of two undergraduate composers to understand the influence and relationships between the multiple social and cultural settings and their emerging practices. By analysing key episodes in a long-term trajectory of co-creating, this research contributes significant new knowledge about how digital resources mediate and constitutes music composition over time. The temporal, multi-situation perspective offers a number of new insights about collaborative processes where digital technologies are used to

create work showing; that the digital resources mediate composition even when they are not physically present, and how this fosters creative ‘possibility thinking’ (Craft 2011).

Sociocultural theory of the mind, collaboration and creativity

This research considers music composition as a computer-mediated process also formed through inter-relationships with a composers’ historical, social, cultural, physical and conceptual environments. It views the compositional process through a sociocultural lens, informed by Vygotsky’s work on the mediated development of the mind which focused on studying the historical and temporal genesis of events in and around human action: ‘To study something historically means to study it in the process of change; that is the dialectical method’s basic demand. To encompass in research the process of a given thing’s development in all its phases and changes – from birth to death – fundamentally means to discover its nature, its essence, for “it is only in movement that a body shows what it is.”’ (Vygotsky 1978 p64-65).

Student composers develop knowledge about their discipline through inter-relationships with the tools available in their cultural and social settings and also through their collaborative work. However, whilst the dynamics of various collaborative practices have been explored, notably in respect of group assessment in music (Bryan 2004; Orr 2010), the emerging inter-relationships between social interaction, technologies used and collaborative music practices have not yet been studied. Collaborators enter ‘into an interpersonal exchange in which it is understood that there should be sustained investment in constructing shared meaning.’ (Crook 2000 p166). Engaging in meaning-making this way can stimulate cognitive development as knowledge becomes a resource, as ‘... to learn something is to be able convert information stored in the expanding external symbolic storages of our social memory into something that is new, interesting and consequential for a practice or an issue.’ (Saljo 2010 p62). Undergraduate computer-based composers may have a degree of background common knowledge about their domain, but through their process of working together they are dynamically constituting local common knowledge where new shared meanings and contexts are created informing shared understanding about what they know: about each other and also the work as it ‘emerges from the dynamics of the group’s own extended activity.’ (Littleton and Mercer 2013 p60). Language plays a central role in this dynamic process of developing common knowledge (Vygotsky 1978; Wertsch 1979; Lantolf 2000; Wells 2006; Littleton and Mercer 2013). For example, Mercer and Littleton’s (2007) research, analysing the interactions of young children working and talking together to solve problems and discuss ideas, generated characterisations of talk that can be used to evidence the qualities of talk that foster common knowledge and developmentally valuable discourse:

- Cumulative talk: where contributions build on each other in an uncritical way, building common knowledge, trust and solidarity;
- Disputational talk: where disagreement is constituted from short exchanges, or an absence of engagement;
- Exploratory talk: where joint reasoning is happening and collaborators are critically engaged in both disagreement and agreement. This is regarded the most educationally valuable form of discourse.

This focus on learning through collaboration and quality of collaborative discourse is an aspect of music practice that is currently uninvestigated within higher education.

Sociocultural theory of creativity

Sociocultural grounded research on creativity¹ has shows how live improvised performance groups build meaning while forming a shared history and longer-term common knowledge of the piece (Sawyer and DeZutter 2009). Through the analysis of live improvised theatre across multiple rehearsals within longer-term improvised narrative Sawyer and DeZutter offer the concept of *collaborative emergence*, where:

- the activity has an unpredictable outcome, rather than a scripted, known endpoint;
 - there is moment-to-moment contingency: each person's action depends on the one just before;
 - the interactional effect of any given action can be changed by the subsequent actions of other participants; and
 - the process is collaborative, with each participant contributing equally.
- (Sawyer and DeZutter 2009 p82).

Long-term collaborative music composition may also exhibit collaborative emergence, especially as collaborators are engaged in a developing common knowledge to navigate the digital technologies available, but Kirkman's study of computer-mediated music composition stands alone in adopting a temporal approach, to observe 'the social and cultural contexts that shape emergent classroom computer-mediated composing processes.' (Kirkman 2010). Kirkman's analysis considers multiple lessons, and rehearsals, revealing the evolutions in music practices, knowledge and cultures, showing how a reduction of tutor-led criteria influenced changes in the students' compositional strategies over time; 'Throughout the study, as the restrictions placed on location, resources and task were reduced [the students'] ability to compose musical responses to the brief increased.' (Kirkman 2010 p120). Kirkman explored emergent relationships by embracing a longitudinal perspective, showing how a student's '...way of working developed alongside the range of technologies he employed.' (ibid). It implicates a collaborative emergence with and through technology, which worked in relationship with the students' shared history, and the emergent interrelationships between collaborators, their social and cultural surroundings, and creative accomplishments. A temporal perspective evidences '...characteristics of a more enduring conversation, offering a contextually situated interpretation of learning and creative collaboration. (Dobson 2012 p309).

Moving out of the classroom to the long-term improvised devising that can happen in higher education music and performing arts, the research presented here examined how relationships with digital technologies affected a 'moment-to-moment' distributed creativity and collaborative emergence. It explored how social and cultural tools (conceptual, physical and psychological), mediated and constituted meaning-making and the co-creating in longer-term collaborative, computer-mediated music composition. It asked how the process of collaborative music

¹ This paper presents research that talks about creativity, though it acknowledges a pluralist view of musical creativities as presented by Burnard (2012) since this signals a spectrum of inter-connected practices.

composition is mediated by social and cultural contextual resources in small group creative practice, over time. Two more focused questions were asked:

- 1) How do undergraduates (re)negotiate common knowledge, shared meaning and a collective understanding of collaborative creating over time? □
- 2) How are co-constructive processes of collaborative creating mediated by concrete tools and resources?

This paper focuses on the role of digital technologies in respect of each of these questions.

Methodology

This research necessitated a temporal emphasis to consider an emergence of distributed creating within the students' social, cultural and physical settings. The methodology employed was a long-term case study that adopted an ethnographic perspective (Mehan 1979; Hammersley and Atkinson 1995), maintaining a micro-analytic focus on the moment-by-moment collaborative action within a macro-analytic examination of students' emerging ecology of practice. It prioritised recording the situated activities and dialogue of a student group to evidence '...the nature and significance of the interactions, relationships and cultures which constitute and sustain such activity, as well as the mediational role of cultural artifacts, including tools, sign systems and technologies.' (Miell, Littleton and Rojas-Drummond 2008 p175). Semi-structured interviews were conducted to provide supplementary data about their collaborative music making histories, individual composition processes and their relationships with music making tools and technologies.

Context

This research observed 2 composers enrolled on a final year undergraduate cross-discipline collaboration module as part of their Creative Music Technology BA (Hons), composing a soundtrack for a short contemporary dance film. The module was available to students on courses in Music Technology, Theatre, Dance and English Literature. Students were invited to pitch project ideas, form groups, then devise an original piece of work that is presented to the public. They complete learning contracts, which inform an assessment of their finished piece.

Participants

As this study was designed to work extensively with undergraduates, it followed the British Educational Research Association guidelines for undertaking research on human interaction within an education setting (2004). The study was approved by The Open University's Human Participants and Materials Ethics Committee. All 44 of the students on the module were invited to participate, attending a presentation about the research, where 'participant information' and 'consent' documents were provided. These documents explained what their participation would involve, that it was completely voluntary, would not positively or detrimentally influence their formal academic work, and also that all recorded materials would be stored securely and only viewed by the research team in its original form. Students were informed that they could withdraw from the study at any time, with no further demands on

them or consequence to their studies. Their identity remains anonymous as pseudonyms are used in all presentation of recorded transcriptions.

The group selected needed to meet 3 criteria:

- to be comprised only of students that had already provided their informed consent;
- to contain one or more composers intending to create new work for the project;
- be prepared to self-document group meetings using their own equipment when the research was not present.

Several groups met these criteria, however, one group was selected for this research; comprising of two creative music technology students, and two theatre students. Participants were aged between 19 and 24.

Data collection

This study focused on analyzing the emergence of creative work; analyzing interrelationships between collaborators in their discourse, actions, and the relationships between composition processes and their physical, social and cultural settings. It was therefore important to record: the unfolding moment-by-moment of events; discourse and distributed creativity within an emerging ‘ecology’ of practice (Crook 2000; Grossen 2008); Between October 15th and January 23rd the group’s meetings were audio recorded by the researcher, however, when co-creative activities in occurred more spontaneously in locations and times that were not available to the researcher, the students used their own mobile technologies to audio and video meetings themselves. This provided data for conducting a micro- and macro analysis of process.

24 hours of audio and video were recorded from collaborative work undertaken in over 8 locations:

- 2 computer labs resourced with Apple Mac computers for video production
- 3 theatre/dance studios, resourced as required (video cameras and sound recording equipment was used sometimes)
- a sound recording studio facility, used for recording movement of a dancer.
- at home, in the café and in other social and informal spaces where composers worked with laptops and headphones.

All recordings were catalogued by date, location, attendance, meeting purpose (i.e. to present to their tutor, record audio). Multimodal data was captured where possible: providing photographs of the documents created by the students as they worked on ideas together, as well as audio composition materials and the finished 10 minute film.

Data analysis

To examine the emergence of collaborative process a temporal micro- and macro analytic method was developed. Sawyer and DeZutter’s study of collaborative emergence in theatre improvisation (2009) observed recordings of 12 rehearsals and 5 performances of the same scene, providing clearly defined episodes for analysis. Maintaining this temporal sociocultural focus, the research presented here needed to

identify a significant focus of collaborative creative work that surfaced and resurfaced through the full length of the collaboration across multiple social and physical settings.

Recordings were imported to Caqdas NVivo where topics discussed could be coded. This included conversations about their creative ideas, module assessment, practical arrangements, and individual roles. The most persistent and sustained areas of creative work discussed by the students were identified as:

- discussions about using space in performance (movement through a space in dance and music);
- the aesthetic design of the piece (cultural influences, narrative, style);
- and the audiovisual relationship (the soundtrack, and composing in relationship with a visual structure).

These ‘conceptual creative themes’ were explored collaboratively and therefore identified to be the ‘collaborative conceptual creative themes’ (Dobson 2012 p95). Each moment that focused on the audiovisual relationship was identified as key episode for analysis. This meant that analysis focused episodes connected by one theme across the collaborative duration; where the students were making the soundtrack, discussing ideas relating to the soundtrack or audiovisual issues, discussing issues of process in relation to audiovisual issues, and exploring a specific idea connected to the soundtrack. This constituted 1 hour, 56 minutes and 20 seconds of recordings, data that spanned length and range of collaborative settings. The recordings were transcribed and prepared for sociocultural discourse analysis.

Sociocultural Discourse Analysis

Sociocultural discourse analysis [SCDA] affords an understanding of how ‘contextual resources’ can be utilised in the process of meaning making (Arvaja 2007, 2011). Two types of SCDA were used. The first was informed by Arvaja’s (2011) method of analyzing discourse to identify how meaning-making processes draw on local (the group), cultural and physical (situational) resources. Within the research reported here three types of contexts of meaning making in discourse were considered: immediate (perceptual) contexts, local contexts, and socio-cultural contexts (Arvaja 2008 p52) and how the composers harnessed these resources for meaning-making:

Local: their group and their group’s history, and anticipated future

Physical: references to locations and the tools used for creating work

Socio-cultural: references to knowledge about wider concepts, social settings, values and cultural knowledge.

Analysis considered the use of digital technologies, and how these were resourced in discourse analysis explored how common knowledge was developed - including which digital resources were being considered, the composers’ values in respect of their use of technology, and their emerging co-creative strategies involving different technologies.

The second type of analysis considered processes of interthinking and the development of common knowledge, with the three-part typology of exploratory, cumulative and disputational talk being used to explore this (Littleton and Mercer 2013; Dobson, Flewitt, Littleton and Miell 2011).

Findings

The findings offer four progressive contributions to our knowledge about the influence of digital technologies in undergraduate term-long collaborative music composition practices:

- digital music technologies are anticipatory, they do not need to be present to affect digitally resourced music composition practices;
- collaborative digital music practices foster little ‘c’ creativity, exhibited as ‘possibility thinking’ (Craft, 2011), as collaborators explore hypothetical future activities;
- where collaboration disrupts familiar digital music practices, composition becomes a complex *interactional* accomplishment;
- collaboration promotes opportunities for student to reflect on the choices they make themselves around the use of digital technologies in music composition.

Anticipated digital technologies and ‘possibility thinking’ in collaborative music composition.

While preparing their soundtrack, the composers began to develop a common knowledge about how they anticipated integrating different digital technologies for music composition. Through this process they drew on their knowledge about themselves, each other and their music technology preferences and in doing so, they imagined hypothetical scenarios involving digital technologies, and their anticipated and hypothetical uses of digital technology, since it is resourced in meaning-making for music composition.

Extract 1: hypothetical collaborative music composition process

John: We need to, I think take a piece of video, score it individually, just quick, ye know, just note down certain points, quick

Liam: But if we do that in the same room at the same time

John: We can bounce off each other

Liam: Yeh. And then that’s where all the decisions are going to be made quickly. I think it’s gonna be instant sound assignment in our own heads, in, on the score, does that make sense?

John: Yeh

Liam: So I might like this that one bit and I’ll say ‘ah!’ I like it, I could do that there. And you might say ‘well in that well in in that case then this’d work really well at that point’ and then we’ll then we’re gonna decide, quite quickly I think, then, you should do this sort of sound and maybe I’ll do this sound then try and make our stuff gel, and then work, and then come back and then say this is what we’ve done.

In this extract the composers are engaged in cumulative talk (Mercer and Littleton, 2007), developing common knowledge that is resourced by an imagined future hypothetical scenario. They anticipate a local co-creating that uses different technologies in the same physical setting and imagine that this will afford a desirable quality of process leading to socially developed work through further discourse. This process suggests an imagined process of distributed, and collaborative emergence; citing how they will bounce ideas off each other, make decisions quickly, and imagine sounds. The hypothetical conversation also suggests a cumulative quality to

their anticipated work around sound materials. Being imaginative in this way may be described as creative ‘possibility thinking’: ‘In its simplest form, possibility thinking involves posing in multiple ways the question ‘What if?’ and thus initiates the shift from the given to the possible’ (Craft 2011 p51). Craft considers this to be the engine for ‘little c’ creativity. Collaborative music practices stimulate possibility thinking for undergraduates who depend on different kinds of music software and concepts to create work. This imaginative work considered how they would handle digital technologies:

Extract 2: Imagining steps - how to work with different file types

John: so what I’m saying is that we a all of our sounds onto your computer, you format them to be ‘a’ format, give them to me, then I work on them

Liam: and then soon as you give them back to me I’ve

John: you put them in ‘b’ format. So they never stay in my domain completely.

Can I still do this like this multitrack composition

Liam: yeh you’ll be doing exactly the same thing it’s just that

John: but we know that when they come to me they’re already first stage of the processing, two’ll be finished, then I’ll put my effects on them, bounce ‘em down and give ‘em to you, and then you put the ‘b’ format on them

Liam: yeh. Just stick a plug-in on the output and it’s done.

The composers were engaged in considerable discourse about their creative process, developing common knowledge about an anticipated use of digital technologies that were neither present nor understood completely by both of the students. Preferring to use familiar technologies the composers needed to imagine collaborative processes that involved digital technologies in detail before commencing work. Continuing their process negotiation, here the composers explore how they anticipated handling different types of digital audio files, establishing that only one of them is able to work with surround-sound file types². Various physical tools are suggested in relationship with the creating choices that the students make: including their agreed use of Liam’s computer, ‘a’ and ‘b’ format files, multi-track composition, and ‘bouncing’ files before using ‘plug-ins’. They developed a local common knowledge of computer-mediated music concepts, resourcing further meaning-making in this negotiation. By imagining hypothetical futures the difficulties arising from their integration of different technologies stimulated possibility thinking.

How technically resourced collaborative music composition is a complex interactional accomplishment

The interviews indicated that, at the outset of the project, each of the composers had distinctive preferences regarding the uses of music software for music composition. Their collaborative project introduced a long-term process of developing common knowledge about each other’s preferences and their anticipated joint practices. This integration of technology, and its associated concepts and technique constituted complex *interactional* accomplishment, exemplified in the first full group meeting

² Here ‘a’ format refers to stereo audio while ‘b’ format refers to the ambisonic (multi-channel) format.

where Liam suggests the use of ambisonics³, to connect the movement of sound with the movement of dance. Liam explains the basic definition of this 3-D sound, using 16 speakers: ‘we’d get one microphone, stick it in the center of the performance space, that records everything, sort of how Jazz bands used to be recorded, and then, we take that recording, we will have already got all of the movement for the surround sound and then we could, set the speakers in that showing space that we were talking about so we get the full 3D sounds...’. These ideas are resourced by Liam’s knowledge about ambisonic processes and systems used to capture and recreate the sound of a dancer moving in space, and the use of a multi-speaker array. The suggestion leads a process of interthinking, then slight refinement of what is implied by the idea of ambisonics:

Extract 3: negotiating shared understanding of digital technology

John: Instead of having 4 speakers, you’re basically gonna have 16 set in the space

Liam: We could work with 4, if we can only get 4. But 16 is really nice.

John: But even there maybe get some upwards direction and downwards direction.

Liam: Yeh.

Building common knowledge of how this technology could be applied within the project, this brief episode begins to evidence the kind of exploratory talk (Mercer and Littleton 2013) that the composers engaged in. Students can bring different understandings about what technologies and technical process can offer; seen here as John modifies Liam’s suggestion (to use 16 speakers) Liam responds by explaining that the number of speakers is flexible (they could use 4), then John refines the idea further by suggesting that speakers could point in different directions. Resourcing knowledge about the equipment available the students build common knowledge about its anticipated use in their project.

In a subsequent meeting, the composers continued to consider surround-sound technology with respect to sound synthesis formats. Liam suggests that they create multi-channel sounds designed for quadraphonic performance from the start of their composition practice, rather than creating individual mono sounds to be placed in a final quadraphonic mix ‘I think our composing we shouldn’t do any spatialisation...we’re just making quad channel sounds at home’:

Extract 4: negotiating processes that involve different digital formats

Liam: For any big sounds⁴ if we use my laptop and do it in ambisonics. For smaller sounds that you wanna do you can do in stereo on your laptop and then we’ll bring them into quad, into ambisonic

John: But can we not take stereo normal files and place them within ambisonics?

Liam: we can but we lose so much

John: I know you lose that whole

Liam: Image

³ ‘Ambisonics is a powerful technique for sound spatialisation. It can allow recording, manipulation, and composition with naturally and artificially constructed three-dimensional *sound fields*.’ (Malham and Myatt 1995)

⁴ is a powerful ambisonic sounds for quadraphonic performance, while ‘smaller’ indicates mono or stereo sounds that need to be integrated into a mix.

John: Thing of what ambisonics is all about

Liam: Yeh

John: As long as we use that enough and a lot

Liam: Yeh

John: Then individually spaced things are gonna be just as important as the overall

Liam: Yeh. Things are still individually positioned

Here Liam and John anticipate using Liam's laptop and different types of digital file formats. In their interaction the composers are developing common knowledge about the resources, their anticipated collaborative creating, and about ambisonics; a surround sound method that is mediating both technical and compositional choices. Knowledge, and agreement about file formats has implications for their approach to software, composition and sound positioning. It becomes clear that the composers have different understandings about the use of ambisonics, creating particular challenges and opportunities for learning through practice as the preparation to work collaboratively under this circumstance requires significant negotiation; opportunities to learn through discussion. While John may develop a better understanding of ambisonics, the composers' interthinking in dialogue engages them further in the process of building a local knowledge for creative action; these episodes are reminiscent of a mutual intermental development zone (Mercer and Littleton 2007), where the composers are developing common knowledge about each other and their relationships with technology.

To address this difference in knowledge about ambisonics, Liam offers John various suggestions: that he can learn new techniques by observing Liam working, or that they could work together in the same room so John could present files for John to manage in the surround-sound software. Familiarity with the software, and comfort gained from the experience of 'flow' (Csikszentmihalyi 1992) as described by both composers in the supplementary information provided by their interviews, is disrupted by collaborative work. This is seen in the following extract where John rejects Liam's process suggestions.

Extract 5: seeking to maintain familiarity with composition technologies in collaborative music composition

John: Cuz I'm only saying because you know if you're not around and I'm sitting at my laptop and I we've been working on it for example and I've come up with an idea. I'm not gonna think oh Liam's not here I'm not gonna work on it. I'm just gonna try and come up with something and show you as soon as you get home you know, and like.

Liam: I mean that's just like, pretty much what I just said to you.

John: But then if I'm, if I, if that wasn't actually a quad file already for example, that say I get it to work on my (computer) it doesn't matter, it's the same thing. Cuz I mean to be honest, I mean if I were being completely honest, I don't really like just working and sitting on somebody else's computer and feeling like I don't know what's going on because I don't know what's going on you know? And it's not very fun that way.

Liam: Maybe it would be a good idea for us to go up for a session and for you to observe me working on my sonic arts piece. How I'm using the plugins I just need to show you.

John: Oh that sounds like my idea of hell.

Experienced composers can develop creating preferences and relationships with particular digital tools and conceptual processes. For John the idea of only composing when Liam is present is too restrictive; ‘I’m not gonna think oh Liam’s not here I’m not gonna work on it’ as he develops ideas when he uses his own laptop in his own time. John expresses value in independent work and a resistance to Liam’s suggestion for knowledge sharing where John is observing Liam’s working with ambisonic tools: ‘that sounds like my idea of hell’. Undergraduate musicians may be inclined to make compositional choices based on a kind of ‘emotion-based assessment’ (Vass 2004 p85); responding emotionally to ideas and software options (in this case) because they are more ‘appealing’; here John prefers to use his own tools and concepts for music composition, these are comfortable and familiar to him, offering freedom of composing in his own time with full understanding of what is happening.

Each of these extracts exemplify how collaborative music composition practices, that involve a range of digital technologies, resource a developing common knowledge about creative and technical process. Collaborative work is a complex interactional accomplishment; achieved through negotiation, meaning-making and ‘possibility thinking’ around compositional ideas, technical knowledge, anticipated actions and conversations, and individual computer-based composition preferences.

Digital technologies mediate the long-term ecology of creating

While engaged in this development of common knowledge about the use of digital technologies, while imagining their anticipated uses of equipment, the composers constituted their physical, social and technical situations for creating work. This negotiating, meaning-making and ‘possibility thinking’ informed an emerging ecology of practice. This comes together in extract 6 where negotiations informed choices about anticipated music composition settings:

Extract 6: negotiating process and setting in relation to digital technology

Liam: Maybe in that case we need to do all of our work in the research well not all of it coz that’s inflexible but the majority of our work in the research studio with two laptops, so, so that, I can work on a section. I can do it in Logic and then say when it’s ready to go into the big picture now.

John: And then I do the same thing?

Liam: And then you can sit away, so you’re not in the in the sound field

John: No, ok

Liam: Too much noise and you can sit and work with your headphones

John: no definitely

Liam: Away from it and work on something and bring it in because we both know Nuendo, well we both know Cubase

John: Definitely no that’s exactly as I imagined it happening but (in) the same thing is, what would happen, if our session here would be that, would be, me coming up with a sound you coming up with a sound and then going yeh that’s gonna work and then putting it to the side and then coming up with something else and then going over to the studios and the big sessions up there I think we don’t need our laptops we should just come up with our hard drive and spend all of the time with all the sounds we’ve worked on

Liam: I think we should take laptops, so one per, if one person gets stuck in a groove and really gets into it the other person can just get on with their own thing and not feel pressurised or feel useless

John: No but I think I think once we've made the sounds and we're just making, doing the spatialisation and the general ideas I wanna be involved in that

Liam: I think we need to involve, for your sake we need to involve the spatialisation as early as possible so you can start to understand what's possible

John: what no I, oh definitely yeh. Erm [but] that's what I mean, but we need to get the first session in, at home and make those first groups of sound first groups of er collaboration of different sounds. Then go up there and [sp]end a while you showing me the possibilities of what to do with those sounds.

Liam: I disagree a bit I think maybe for our first proper session we should go to uni, I should take my laptop, you shouldn't take a laptop, I'll sit you down in front of Nuendo with some source materials and you just do your own thing cuz you know what you're doing the only difference is you need to know where to place plugins in the signal chain.

In this meaning-making episode a range of anticipated physical settings are suggested: to use individual laptops, headphones, and hard drives to move digital files across locations. Suggestions are mediated by conceptual knowledge about the domain (sound fields spatialisation) and anticipations of joint and independent actions (phases of working jointly and independently in relationship with particular physical spaces and technologies). The composers imagine various solutions that implicate flexible modes of working, informed by values and personal preferences around being able to experience 'flow' (Csikszentmihaly 1992); 'if one person gets stuck in a groove and really gets into it the other person can just get on with their own thing and not feel pressurised or feel useless'. The desire to maintain familiar practices; without pressure to do unfamiliar work with digital resources that might disrupt this 'flow'. It also displays the students' metacognition for process, in relation to the digital resources, and also their future settings for working independently and jointly. The processes and situations agreed through dialogue were subsequently displayed, with the students working on their own equipment in the same room. Throughout the collaboration, the composers made choices that prioritised particular spaces, technologies and composition practices, disrupted by collaborative negotiation in a way that constituted an local and emerging ecology of practice. This raises implications for how learning, practices and musical accomplishments could differ if the composers challenged and revised these choices and assumptions as they form the very context through which subsequent work is undertaken.

Discussion

To date music education research has successfully provided evidence-based understandings of the processes of learning computer-mediated music composition, helping to foster more informed and diverse uses of digital resources for learning in early music education. With particular focus on learning in creative and collaborative situations these studies have focused on classroom-based tasks designed by teachers and researchers. However, music-making often has a broader social and temporal dimension, and the roles of digital technology in multi-situational, temporal and social situations of creating have been largely overlooked. Undergraduate musicians produce music in a much more diverse range of private and social settings, and computer-mediated music-making can traverse a range of physical, and social

settings over time, especially in collaborative projects. To understand the character of learning and creating under these circumstances this research asked: how undergraduates (re)negotiate common knowledge, shared meaning and collaborative understanding of their collaborative music composition over time, and how is this process of collaborative creating mediated by concrete tools and resources.

The methodology adopted an ethnographic perspective (Hammersley and Atkinson 1995), grounded in Vygotsky's theories of the mind (1978) with a focus on the meditational affect of social and cultural tools. Analysis focused on emergence around an audiovisual 'collaborative conceptual creative theme', when it surfaced and re-surfaced naturally through the life of a specific project.

The sociocultural discourse analysis evidenced how collaborators drew on various resources within a process of meaning-making, developing common knowledge (Littleton and Mercer 2013), and showing how digital resources impacted the composers' distributed collaboration (Sawyer and DeZutter 2009). Knowledge about digital technologies clearly resourced meaning-making, which helping to calibrate the composers' understanding about each other, their methods of working and anticipated music composition practices. This highlighted local values, concerns and preferences in respect of the digital resources, in particular, showing how undergraduate composers may seek to retain and use familiar processes in computer-based music making. The key point here is that their values inform the collaborative negotiations and the emerging composition practices, shaping their subsequent actions and a local ecology of collaborative practice.

The longitudinal perspective shows how this ecology of practice informs the emerging social and physical settings where music is composed independently and jointly over time. Idea generation and negotiation informed a movement from the theatre studios, to recording studios, to a shared computer, and then to personal laptops in shared and independent spaces. In these settings the digital audio workstation can draw individuals out of collaborative discourse, into individualized sound work, reflecting a broader challenge of single computer use in group work. Discourse analysis also showed that when the students began using the technology sound ideas fell out of consideration, and technological failures disrupted the 'flow' of composing. These observations are characterised in other research, whereas the original findings offered in this paper show how remembered and imagined uses of technology mediate and constitute creative accomplishments, and an emerging ecology of practice in collaborative music composition.

The four findings offered here present new insight into how digital technology affects learning and music composition practices within long-term, multi-situational trajectories; collaborative practices ecologies that exist beyond the classroom.

Firstly digital resources are anticipatory; they do not need to be present to mediate the development of common knowledge about music composition processes. Informed by knowledge about technologies that composers may be inclined to use, discourse provides a space for thinking together that informs meaning-making and the emerging creative possibilities. This finding signals the influence of remote technology, implicating that students might begin by considering a greater diversity of tools, particularly in the early stages of collaborative planning. Students might also develop greater self-awareness about the assumptions being made about which technologies and techniques are anticipated; opening other possibilities for consideration

Secondly the challenge of integrating different knowledges for music composition can resource ‘possibility thinking’ (Craft 2010); the engine of little ‘c’ creativity. Collaborative discourse showed a joint exploration of situations imagining: steps in the implementation of different types of audio files, conversations around idea generation and feedback, and hypothetical situations that the composers have no prior experience of. These imagined uses of technology resourced a detailed kind of meaning-making, indicating value in further research on how long-term collaborative music making fosters collaborative learning, distributed creativity, and also personal creativity, particularly within Higher Education.

Thirdly, long-term digitally resourced music composition is a complex *interactional* accomplishment; Creative ideas could ‘fall out’ of consideration in cumulative talk, whereas ideas that had been dropped also sometimes resurfaced and leading to exploratory talk at other times. The research showed that co-creating was a long-term process, where creative ideas were developed in phases of both independent and joint activity in multiple social contexts over time. Research collaborative learning research shows how computer technology and educational software supports learning dialogues; since children, and undergraduates show their capacity to think together through dialogue, further research might consider the pedagogical value of interaction within undergraduate music practices.

Finally, in respect of these findings, this research shows how collaboration promotes opportunities for student to reflect on the choices they make themselves around the use of digital technologies in music composition. The study also highlights how collaborations that rely on digital technologies for creating can generate new opportunities for learning through knowledge sharing, but more importantly, through interthinking (Littleton and Mercer 2013), and the creation of a continually developing dynamic common knowledge. Digital technology has a valuable role to play in education where it is remembered and imagined as well as when they are being used. Remote technologies resourced meaning-making and fostered exploratory work around hypothetical future work with technology. Most fundamentally this research demonstrates how digitally-mediated creative work, undertaken in long-term collaborative situations, is a complex interactional accomplishment. Digital technologies are increasingly present in the creative and performing arts disciplines, and the findings presented in this paper have implications for understanding how knowledge is developed through social and cultural inter-relationships in other collaborative situations.

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